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ENERGY SURVEY

Energy Audit for ICA Maxi in Sandviken

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Preface

This study was carried out as a thesis project in the Master of Energy Systems at the University of Gävle, Sweden.

First of all, I would like to thank my supervisor Ulf Larsson who gave me the possibility to work on this thesis and guided me when developing it. His help was really useful.

Secondly, I want to show my gratitude to my opponent Sébastien Daniere that helped me when doing the thesis and solved and explained me a lot of doubts I had. Without his advice, it will not have been the same. Thank you very much Seb.

I also cannot forget to thank Kent Nilsson (Triennium) and Staffan Ahlqvist (ICA Maxi Sandviken) that provided me with information about the building and its installations.

Finally, I would like to thank my classmates and friends that even being far away from my family, made amazing my stay in Sweden. It was really nice to meet you all.

Abstract

The store located in Sandviken is using 3061.184 kWh of electricity per year separated into support and production processes. The survey shows that 72% of this amount is used for support processes and the rest for production.

In support processes lighting and heating are the ones that use more electricity, 683 and 631 MWh/year respectively. Both are quite big for the size of the store, and they have to be reduced as much as possible.

Production processes consumption is based on cooling and freezing units since almost the 90% of the electricity used in production processes is consumed by the compressors. This is why the reduction is mainly focused on the compressors.

In order to decrease the energy use, some reduction measures have been applied to both, support and production processes. Now, it is being used 25 W/m^2 in lighting but this value should be around 15 W/m^2. This means that the electricity used in lighting should be reduced in 40%. For this aim, different measures such as reorganizing the schedule and new distribution of the lamps can be made.

The amount of electricity used in heating should be reduced since it is too high for this kind of building. Besides, it should be analyzed, but it is recommendable to change the heating from electrical heaters to district heating. The amount of heat needed will be the same but DH is more efficient and it will be possible to have some savings.

Cooling and freezing units should be analyzed in order to reduce the electricity use of the compressors and become them more efficient. At the same time, the refrigerant flow could be reduced by different ways like the use of glass doors in the freezers.

Finally, just say that some calculations of this study have been made based on assumptions. Hence, it is recommendable to take them as general values that give an idea of the electricity use in the store, not as real values of the electricity consumption of the building.

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1. Introduction

This section is a brief introduction to the thesis. It will start explaining the situation of the energy consumption in the world and why is so important to save energy. Later, it will go through the explanation of the location of the building and its main characteristics.

1.1. World energy use

It is not really difficult to see that energy plays a very important role in everyday life. In each field like transport, household, entertainment, services, production… energy is needed almost for everything. This dependence on it has become higher and higher during the history but people have used their gained experience to make the best of their energy resources and get the bests living conditions in a comfortable environment.

Nowadays, Europe only owns a very small part of the world energy resources; the biggest contribution comes from coal deposits belonging to Poland, Germany and United Kingdom. Main world coal resources are located in North America, China and Australia. Relating to oil and natural gas resources, West Asian countries and the former Soviet Union are the main exporters of these goods.

World energy consumption is mainly based in these energy resources. The problem is that most of the oil resources will come to an end by the year 2030 and if natural gas and coal are also taken into account, all fossil fuel resources will be over before the end of the 21^{th} century. Besides, according to the International Energy Outlook 2008 (IEO2008), the energy consumption is supposed to increase in 50% from 2005 to 2030, especially in nations outside the Organization for Economic Cooperation and Development (non-OECD countries like China and India) that are now rising and developing very fast. See Figure 1. and Figure 2.

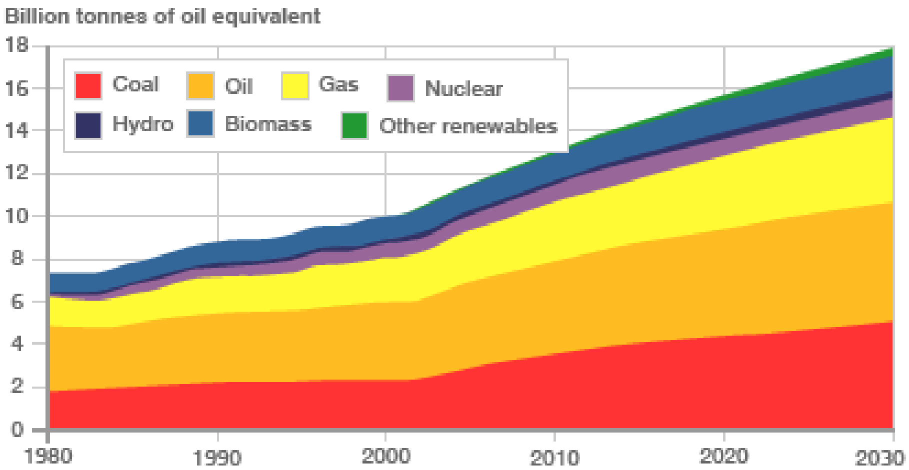

Figure 1. **Global Energy Demand**

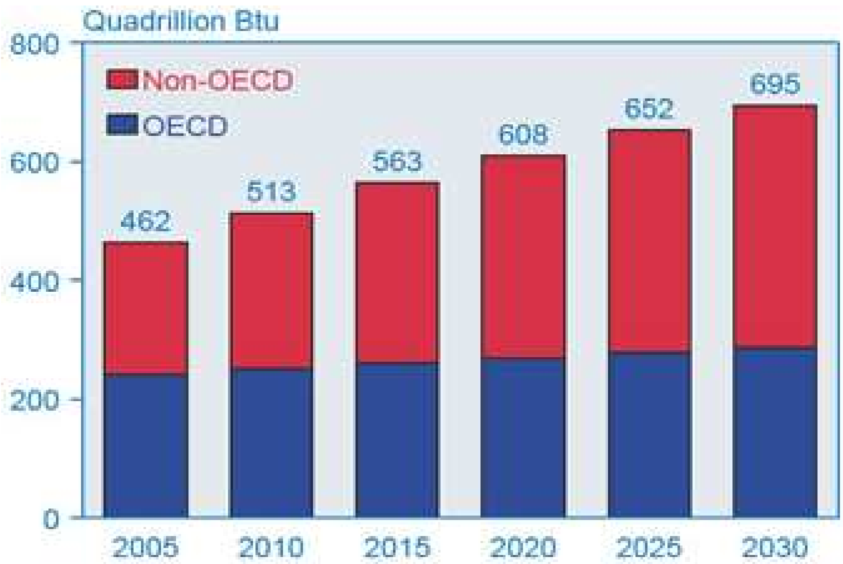

Figure 2. **World Marketed Energy Consumption, 2005-2030**

Apart from the fact that some energy sources will be vanished but their use will increase in the next years, it has also to be considered the effect the emissions of greenhouse gases to the atmosphere has caused in the global climate during the last years. Nowadays CO_2-equivalent concentration in the atmosphere is above 380 ppm and it should not be more than 400 ppm if it is wanted to be kept in its acceptable limits. This fact leads to the obligation of reducing the fossil fuel CO_2 emissions to zero by the year 2050, although in the last two decades it has been an increase in the emissions of 43% [3,4].

As said before, a lot of energy is taken from fossil fuels (hydrocarbons) whose combustion releases CO_2 to the atmosphere. Nowadays, this is the most important and urgently needed to solve environmental task. By the year 2030 (see Figure 3.) it will had happened an increase of 55% over today's level, reaching the amount of 42.3 billion metric tons of CO_2 emissions per year. As seen in the figure, non-OECD countries will especially increase. In fact, China, whose economy is expanding by almost the 10% every year, will overcome the United States and will be the biggest emitter of carbon dioxide to the atmosphere by 2010 [5].

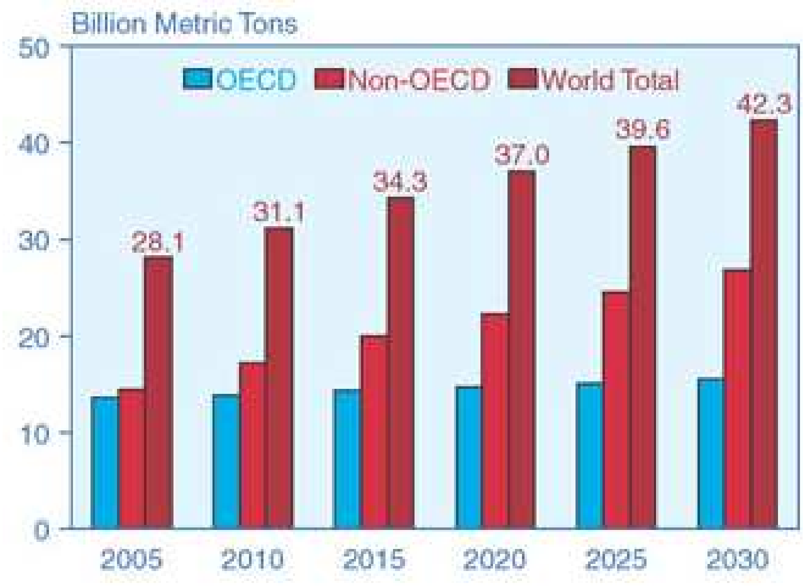

Figure 3. **World Carbon Dioxide Emissions, 2005-2030**

Due to all these facts new measures have to be implemented in order to reduce the energy consumption and CO_2 emissions. New energy sources, like renewable, have to be also developed and boosted if it is not wanted to face up to both main problems: global climate change and energy crisis due to lack of energy sources.

Apart from the fact that consumers will be run out of them in the near future, the use of fossil fuels has to be reduce by changing them for other sources such as biofuels. If this happens, it will help the environment and people will not be so dependent on them. At the same time, energy consumption should be reduce by applying to new efficiency measures and making people aware of the importance of saving energy.

New energy sources like renewable sources have to be enhanced and developed. These ones have to substitute other old ways of obtaining the energy and the amount of energy obtained from them has to increase constantly.

If new strong policies are applied and governments implement new measures, a substantial improvement can be achieved and the situation can change. Measures like green certificates, CO_2 allowances, the EU target of 20% of renewable energies by 2020, The Kyoto Protocol… are just some examples of the way different governments should follow towards a sustainable and clean environment. Whit this kind of agreements, there has been an important emphasis on reducing the energy use and they lead to the use of energy efficient systems such as combined heat and power systems, CHP, and combined cooling, heating and power systems, CCHP. These kinds of systems permit the use of environmentally friendly fuels like biofuels. After several studies, these systems have been proved to reduce emissions of pollutants, and due to this, these systems have the potential to become an important solution for the global warming [1,2].

From another point of view, if the energy consumption is divided in different sectors as it can be seen in Figure 4., it will show that transportation and industrial sectors use each one 30% of the total amount of energy consumed in the world. For the transportation is important to mention that the 95% of the energy comes from oil, which means that causes a huge amount of CO_2 emissions to the atmosphere. Besides, the amount of energy consumed by this sector has been almost doubled (80% of increase) in the last 30 years. However, for industry, the amount of energy has been maintained although the industrial production is considerably higher nowadays.

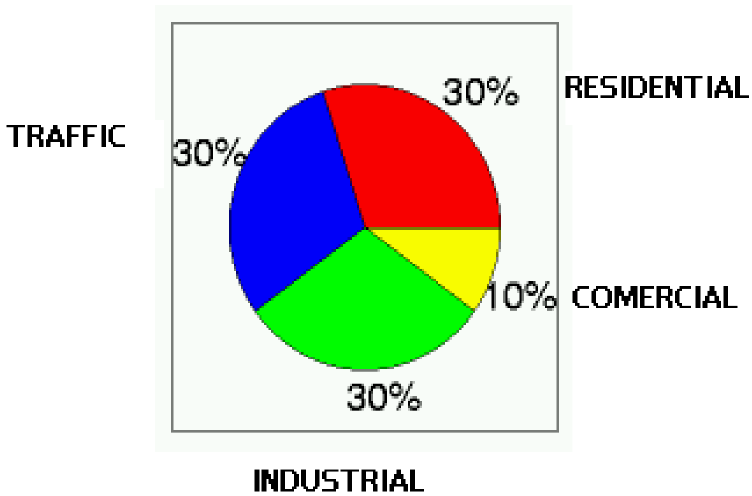

Figure 4. **Distribution of the energy demand**

The building sector (residential and commercial) occupies a big part of the total amount, exactly the 40% [3,4]. Instead of all the energy consumption in the world, if only electricity is taken into account, it uses the 50%. Therefore, reducing the energy demand and improving the energy efficiency in buildings is nowadays essential to achieve a sustainable built environment and at the same time to save energy in this sector that uses a big part of the total energy consumption in the world.

Clean alternatives like renewable energies or district heating (instead of electrical heaters) can be introduced in order to increase the energy efficiency of the building and reduce the environmental impact. This last alternative (DH) could be really interesting because it gives the chance to use heat sources such as waste heat (garbage burning).

Nowadays, a big effort is being made to design the buildings more "environmentally friendly" as possible (green buildings), with the lowest energy consumption and environmental impact, but of course, without forgetting the importance of the thermal comfort. Some of these buildings, especially in United States and Canada are developed by the program called LEED (Leadership in Energy and Environmental Design) [8]. This way towards a sustainable development leads to higher initial investments, but finally has advantages such as energy savings, less environmental impact and one of the most important for the owners of the building, economic savings due to the amount of energy saved.

Focusing on commercial buildings, since this is the kind of building that is going to be studied in this thesis, in the United States, by the year 2007 they were responsible of the 18% of both CO_2 emissions and energy use [9]. This kind of buildings is deeply studied and its design is very complex. Besides, processes like lighting use a big amount of the energy in commercial building and this is why some efficient measures like introducing efficient light bulbs are dominant [10].

1.2. Location

The building is located in Sandviken, a small town seat of Sandviken Municipality. It is located approximately 190 km north of Stockholm, in the county of Gävleborg (Province of Gästrikland, middle part of Sweden) and about 25 km west of Gävle, main city of the county. See Figure 5.

Figure 5. **Location of Sandviken in Sweden**

The municipality has a population of 37 000 inhabitants and a 1 165 km^2 area. It is also the main home of Sandvik, a well known steel and engineering company all over the world.

The store is located in the north part of the town (see Figure 6.) in the main shopping area next to many other shopping centres and stores.

Figure 6. Location of the store in Sandviken

1.3. The building

Maxi ICA Stormarknad Sandviken is a supermarket belonging to the ICA supermarkets chain. The ICA Group is one of the most important Nordic retail companies with more than 1 300 stores and 5 200 employees only in Sweden. It was established in Västerås in 1917 by a man called Hakon Swenson and since then, it has spread also in Norway and other Scandinavian countries.

The owner of the store in Sandviken is Claes-Göran Rydberg. However, although he is the owner of the supermarket, not all the profits got from selling products are for him. There is one little part in the supermarket that is owned by the big owner of the ICA chain. The benefits got from the products in that part are for him (the big boss), but the rest of the store belongs to Mr. Rydberg. In the following picture (Figure 7.) it can be seen in red which the part owned by the big ICA boss is.

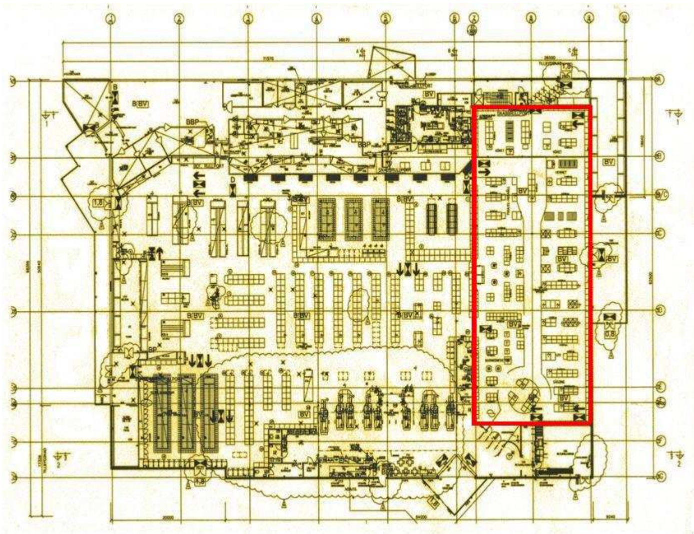

Figure 7. Map of the building

The fact is that there is only one unique electricity invoice for all the building. This means that all the electricity used by the little part (the one owned by the ICA chain) is together with the rest of the building consumption and they do not exactly know what is the exact amount of the invoice each owner should pay for their own electricity use.

The building was built in 2002 and five years later, at the end of 2007, it was rebuilt and it became a Maxi ICA. The area of the store was increased (also the offices) and new installation systems were installed to provide good working conditions in the bigger building. Nowadays it has a total area of 4200 m^2 and an average height of 5.5 m. The surface of the store is 3450 m^2. See a detailed plan in Appendix 6.

2. Objectives and Limitations

In this second part, it is going to be explained which the main aim of this thesis project is, as well as which were its limitations when carrying it out.

On one hand, what it is wanted to achieved with this thesis is to study the energy consumption of the Maxi ICA store in Sandviken, more exactly the electricity consumption and then, propose new energy efficiency measures in order to reduce the electricity use in the store. As it was said before, the building only uses electricity for everything, no district heating, oil…

For its study, it has been done an energy survey. Then, it is easier to study the electricity consumption in the building and get what is wanted: the electricity consumption for each individual processes, so that each one can be studied and analyzed separately.

The survey is done to understand the energy dynamics of the system in the store. It will provide possible savings for the electricity in different processes without decreasing their working efficiency.

The problem is that this energy survey is limited since it could not be possible to obtain all the information required. Some data taken from the measurements are not as accurate as they should be and this restricts in some way the final results. In order to reduce and simplify the data given some averages have also been done and in some cases that will be explained, some assumptions have been taken too.

Anyway, this little changes and assumptions slightly change the final results and conclusions. At the end, it will not be any problem to get a general overview of how the energy survey is and how the system works. It will be possible to get a really good general idea.

On the other hand, thanks to this project it will be possible for Mr. Rydberg, the owner of the supermarket, to know which the amount of the electricity used by the little part is. This way, he will know which the amount of the invoice he has to receive from the ICA chain' boss is.

This thesis is only focused on the electricity consumption and reduction, so this is why environmental issues or any other kind of studies are out of this thesis. However, it is a fact that a reduction in the energy consumption will be at the same time good for the environment.

But apart from helping the environment reducing the energy use, this reduction will carry profits and money savings that will be helpful to cover the initial investments costs that still probably could the owner have or for any other purposes.

3. Theory

The following section will be a short explanation of the methodology used for working on the thesis and doing the energy survey: the method used for differentiating the unit processes, the theoretical fundaments of the heat balance in the building, how to focus the energy survey…

3.1. Method

A unit process is a single component that uses energy and transforms it on goods. Depending on their objectives, unit processes are usually classified as production processes and support processes. The aim for the first ones is to create goods and services whereas support processes aim is to create good working conditions and maintain production processes. Thus, the reduction measures will be basically focused on support processes.

For analyzing the electricity use in the building, it has been used a top-down approach method that defines the entire energy consumption in the store. Top-down approach is a method which consists on breaking down a system to gain insight into its compositional sub-systems or unit processes. It means that the unit processes are studied by starting from the final energy consumption in its overall (the whole amount of energy the building needs) and finishing with the specific consumption each unit process has.

First it is analyzed and explained how the whole consumption of energy is and then it goes through a more specific point of view by analyzing each energy consumption unit. By this way, it is possible to get a well defined structure that facilitates a comparative analysis of each unit process, helps to identify concrete efficiency measures that will lead to reduce the energy use and gives a good general overview of the energy consumption in the building.

If the system is seen as a box and it is studied what goes in and out of it, it can be easier to understand it. It will be possible to see that the only kind of energy used is electricity. Then different unit processes must be defined and specified for each type of energy, in this case, all of them use electricity.

After this, the amount of electricity used by each process has to be found. To reach this value each unit process has to be studied separately. Some consumptions will be easily calculated just knowing the power demand of the devices and their working time. In other cases, it would be necessary to make measurements as well as some assumptions that will give an average power value.

Thanks to all this data calculated, each unit process will be clearly defined and then, it will be possible to compare the amount of electricity used for production and support processes.

3.2. Energy Balance

The aim of an energy survey of a building is to provide a general understanding of the units and processes that happen inside it and determine their energy use. This way, it is possible to compare the energy used by each process and decide if it is the right amount or if reduction measures have to apply in order to reduce unit processes energy use.

Once the amount of energy used by each processes is specified, an energy balance has to be done. The total amount of energy used by the units (in this case only electricity) has to meet the electricity consumption specified by the annual invoice. This way it will be easy to know if the energy survey is done properly.

The electricity consumption in the building can be analyzed in different ways. It is important first to make a balance between support and production processes in order to see the amount of electricity used by each group and this way determine if this amount is the correct one. Thanks to this it is possible to know where reduction measures should be focused.

It is also possible to specify the energy balance with all the unit processes in the store. It will help to know which the most important processes are and on the other way, which are the ones that use less amount of energy. Obviously, the reduction measures will be focused on those processes that use larger amount of energy.

After applying the reduction measures, if the balance is done again, it will be easy to know the amount of energy saved in each unit.

3.3. Heat Balance

The idea of the energy balance is going to be used in this study to calculate the heating loads in the building. With the help of the energy survey, that will calculate the amount of heat bought, and thanks to the heat balance, it will be possible to know the amount of heat that is recovered from the compressors heat exchanger. This is the main aim of the heat balance, which apart from this, will also show the different heat losses in the building.

The first step when doing a heat balance is to establish all the ways that heat enters (heat gains) and leaves (heat losses) the building. The heat gains must always be equal to the heat losses.

For this building, they have been considered as heat losses the following processes:

- ***Mechanical ventilation losses (Q_{vent}).*** Ventilation in the building is very important to keep good air quality by removing inside air and introducing new outdoor air. When removing this hot air from the inside, a big heat load is lost. This has to be taken into account when doing the heat balance.

$$Q_{vent} = \rho \cdot c_p \cdot q_v \cdot d_h$$

ρ = density of the air [kg/m^3]
c_p = specific heat under constant pressure [J/kg·°C]
q_v = ventilation flow [m^3/s]
d_h = degree-hours [h·°C]

- ***Natural ventilation losses (Q_{inf}).*** Also known as infiltration losses, they happen when indoor air leaves the building through doors, windows or other gaps. They depend on the type of building, but generally it can be assumed that they are the 15% of the transmission losses:

$$Q_{inf} = 0.15 \cdot Q_{tr}$$

- ***Transmission losses (Q_{tr}).*** When there is a difference between indoor and outdoor temperatures, a heat flow is established through the walls and this way, hot air leaves the building. This has to be taken into account when doing the heat balance.

$$Q_{tr} = \Sigma (U \cdot A) \cdot d_h$$

A = surface [m²]
U = heat transfer coefficient [W/m²·°C]
d_h = degree-hours [h·°C]

Heat in the building is introduced by three different ways. These heat gains are the followings:

- ***Heat recovery from rotator heat exchanger (Q_{rot}).*** When introducing air from the outside, it exchanges heat with the air taken from the inside. This way, it is possible to recover the 70% of the heat from the air that is being removed:

$$Q_{rot} = 0.7 \cdot Q_{vent}$$

- ***Heat recovery from compressors (Q_{comp}).*** Heat can be recovered from the compressors cycle. When condensing the refrigerant after its compression, the compression cycle losses heat and this heat can be used for other purposes. This amount of heat is not known, but it will be calculated by the heat balance.

- ***Heat from electrical heaters (Q_{bought}).*** When even more heat is needed, there are some electric heaters that heat the inlet air. This amount is calculated by the energy survey since it is heat produced by the electricity bought.

Once heat losses and gains are specified the equation of the heat balance is expressed like this:

$$Q_{in} = Q_{out}$$

$$Q_{gain} = Q_{losses}$$

$$Q_{rot} + Q_{comp} + Q_{bought} = Q_{vent} + Q_{inf} + Q_{tr}$$

Knowing all of them instead of one, it is possible to calculate the one missing. In this case, thanks to the heat balance it will be possible to know the amount of heat recovered from the compressors.

4. Processes and Calculations

This fourth section will be separated in two parts. All the unit processes in the store are going to be explained separating them in support and production processes. The corresponding calculations for each process will be also specified.

4.1. Production processes

As it was explained before, production processes are those ones whose aim is to produce some goods or products from a raw material that is introduced in them, electricity in this case.

In this study, three production units have been differentiated: bakery ovens, grill ovens and cooling + freezing. Two of them are related to heating and the other one is used for running all the fridges and freezers in the store.

Production processes in the store use annually 847.85 MWh of electricity, which means around 30% of the total electricity consumption. In the following subsections it is explained how this value is calculated.

4.1.1. Bakery ovens

For the production of bread and some other products, three different ovens are used in the bakery: oven nº1, oven nº2 (same characteristics as oven nº1) and the stone oven. The bakery works from 5.30 to 19.00 every day. As it can be seen in the graphs (see Appendix 3), all of them work between these hours. Some of them work non-stop but they can be switched off for some time.

During five days, the electricity consumed by these ovens was measured in order to get a detailed idea of how do they work. After that, some data was collected and the average power of each oven was calculated.

Oven nº1. This oven consumed 615.3 kWh of electricity during the five days the measurements lasted, which means a power consumption of 4.67 kW. So, it is:

$$4.67 \cdot 24 \cdot 365 \cdot 10^{-3} = 40.91\ \frac{MWh}{year}$$

Oven nº2. In this case, 612.66 kWh of electricity were used, with an average power consumption of 4.65 kW. With this, is got the annual energy consumption:

$$4.65 \cdot 24 \cdot 365 \cdot 10^{-3} = 40.73\ \frac{MWh}{year}$$

Stone oven. The average power is 1.28 kW, with an energy consumption of 167.99 kWh in the five days. With this, is got:

$$1.28 \cdot 24 \cdot 365 \cdot 10^{-3} = 11.21\ \frac{MWh}{year}$$

If all the annual consumptions are added now, it is possible to get the total amount of electricity consumed by the bakery:

$$40.91 + 40.73 + 11.21 = \mathbf{92.85}\ \frac{\mathbf{MWh}}{\mathbf{year}}$$

As all the ovens work the same hours every day of the year, it can be assumed that the used averages are quite similar for the whole year, so this number is quite exact to the real electricity consumption of the bakery.

4.1.2. Grill ovens

There are two grill ovens in the store that are used to cook grilled chickens or other products. Both are used for similar purposes but they have different sizes. As it can be seen in the graphs (see Appendix 3), the small grill only works the working days. However, the big one works from Monday to Saturday. None of them work on Sundays.

The same way as it has been done for the bakery, the electricity consumption for each one is going to be calculated.

Small grill. With an electricity use of 23.34 kWh and an average power consumption of 0.18 kW, the annual consumption of the small oven is:

$$0.18 \cdot 24 \cdot 365 \cdot 10^{-3} = 1.58\ \frac{MWh}{year}$$

Big grill. This grill consumed 149.18 kWh of electricity during the five days the measurements lasted. This means an average power of 1.13 kW, so:

$$1.13 \cdot 24 \cdot 365 \cdot 10^{-3} = 9.90\ \frac{MWh}{year}$$

As it will happen with most of the values got from the measurements, as they were made from Thursday to Monday, the averages will be lower than what they really are because they are done with two non-working days each three working days. In some cases when the device works all the days of the year, this will not have any importance, but in this case, two more working days should be taken in account. This way the average will be higher.

Anyway, it can be assumed that the averages are quite real because they are so low that they slightly will change the final value. With all this, the total amount of electricity consumption for the grills is:

$$1.58 + 9.90 = \mathbf{11.48}\ \boldsymbol{\frac{MWh}{year}}$$

4.1.3. Cooling + freezing

There is a cooling installation in the store that provides cold refrigerant to the coolers and freezers and make them work in order to preserve the food and different kind of products in the store. Most of the freezers and coolers in the store work this way although there are very few ones that are plugged.

There exist seven compressors in the installation, four for positive cooling and three for negative cooling (freezing). Thanks to the refrigeration cycle cold is produced in the compressors room and then it is transported to the coolers and freezers. In the positive loop, cold is transported in a water-glycol mix whereas in the negative one, CO_2 is used for the transportation.

Some counters are responsible of counting the working hours for each compressor. Once, the values are taken, the total amount of working hours per year is calculated. With this value and the power of the compressors, it is possible to get the electricity consumed by the cooling and freezing units:

$$29.7 \cdot 23\,981.75 \cdot 10^{-3} = 712.26\ \frac{MWh}{year} \qquad \textbf{(Positive cooling)}$$

$$15.64 \cdot 1998.48 \cdot 10^{-3} = 31.26\ \frac{MWh}{year} \qquad \textbf{(Negative cooling)}$$

The final amount of electricity used for cooling + freezing is:

$$712.26 + 31.26 = \mathbf{743.52}\ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

4.2. Support processes

Support processes are those ones whose aim is to provide good working conditions. In this study, six support processes have been differentiated: lighting, ventilation, hot tap water, pumping, heating and air cooling.

Support processes in the store use annually 2213.33 MWh of electricity, the 72% of the total electricity consumption. Thereupon it is explained how this value is calculated.

4.2.1. Lighting

A big part of the electricity consumed in the building is used for lighting. Good working conditions must be supplied for the employees and also for the customers in the store, so that the amount of lights has to be the exact one in order to have the ideal lighting.

The working hours for the lamps are divided in two main steps. One half of the lights are switched on every day at 5.30 and the rest 50% two hours later (7.30), just 30 minutes before the store opens its doors. They work all the day till 22.30, when all of them are switched off.

With this, it is known that one half of the lights work 17 hours per day and the other half 15 hours. In order to simplify the calculations, as the amount of lights switched on in the first step is the 50%, instead of thinking that this 50% works for 2 hours, it can be supposed that all the lights work for 1 hour. This way it can be simplified and said that all the lights work 16 hours per day, which means 5840 hours in one year.

Once this is clear, the only thing missing is to know all the kind of lamps in the store and the power they use. After counting them, it is possible to calculate the amount of electricity used for lighting.

If all the powers of the lamps are summed (see Appendix 2 for more details), it is got a power consumption in lighting of 116886.3 W (around 117 kW), which means an annual electricity use of:

$$116\,886.3 \cdot 16 \cdot 365 \cdot 10^{-6} = \mathbf{682.62}\ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

As it has been explained before, one part of the store is owned by the owner of the Ica supermarkets chain (the big owner of all the Icas in Sweden). This part is using 31604.4 W with an annual electricity use of 184.57 MWh. The rest of the store uses 498.05 MWh of electricity per year. With all these values, it can be seen that the other part, the one owned by the ICA chain, uses almost one third of the electricity that is used for lighting (see Figure 8.).

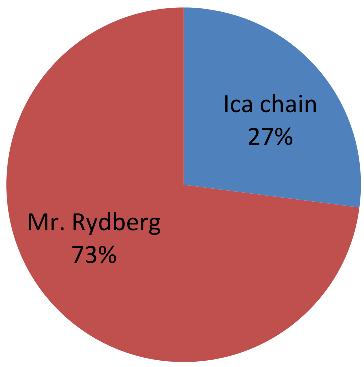

Figure 8. Electricity use for lighting

4.2.2. Ventilation

The ventilation system in the store changes the indoor air continuously in order to have a good indoor air quality. In this case, it is also used for heating, since the air is heated and then introduced in the rooms.

In this section it will mainly be taken into account the electricity used by the fans that put air into and out of the building. When the warm indoor air is taken out, it exchanges the heat with the air taken from the outside that is going to be introduced. This way a big amount of heat is recovered. This recovery is done thanks to a rotator heat exchanger (similar to a roulette) that warms up the inlet air with the heat taken from the outlet air. The small amount of electricity used by these roulettes is also taken into account in this section.

Nowadays there are four ventilation systems in the store. Two are old (nº 1 and nº 2), installed when the first Ica was built, and the other two, the one in the roof (nº 3) and the little one for the offices (nº 4), were installed when the building was rebuilt and made bigger. All of them work from 8.00 to 22.00 (14 hours/day) instead the small one for the offices that works from 8.00 to 21.00 (13 hours/day). Each system has one rotator heat exchanger and two similar fans, for inlet and outlet air respectively. See next table (Table 1.).

Ventilation system	Power of the fans (kW)	Power of the roulette (W)	Total power (kW)
1	11	160	22.16
2	1.1	40	2.24
3	7.5	100	15.1
4	2.2	80	4.48

Table 1. Ventilation systems

Knowing all this data, it is possible to calculate the electricity used by each system:

$$22.16 \cdot 14 \cdot 365 \cdot 10^{-3} = 113.24 \ \frac{MWh}{year}$$ (**System nº 1**)

$$2.24 \cdot 14 \cdot 365 \cdot 10^{-3} = 11.45 \ \frac{MWh}{year}$$ (**System nº 2**)

$$15.1 \cdot 14 \cdot 365 \cdot 10^{-3} = 77.16 \ \frac{MWh}{year}$$ (**System nº 3**)

$$4.48 \cdot 13 \cdot 365 \cdot 10^{-3} = 21.26 \ \frac{MWh}{year}$$ (**System nº 4**)

Once all of them are calculated, the only thing needed to calculate the total electricity used in ventilation is to sum them:

$$113.24 + 11.45 + 77.16 + 21.26 = \mathbf{223.11}\ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

4.2.3. Hot tap water

The store needs water for all the toilets and taps in the rooms. They need hot water in the little kitchens, bakery, toilets, staff room… and in any other tap in the building, so, it has to be a device that provides it. The taps are supplied with water heated by an electrical water heater located in the main machinery room.

As it can be seen in the diagram for the tap water (Appendix 3.), the electric heater ES23-500 works every day during the whole year, although the amount of working hours decreases during the weekend, specially on Sundays. It can be appreciated that the heater works only in three steps: switched off (0 kW), medium (3.1 kW) and maximum power (6.21 kW).

Thanks to the measurement tools, it is known that the average power consumption for the water heater is 4.97 kW and that it used 654.3 kWh during the measurement days. With all this, it is known that the annual consumption of electricity is:

$$4.97 \cdot 24 \cdot 365 \cdot 10^{-3} = \mathbf{43.54}\ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

The same way as happens with the grill ovens, the real average of power consumption should be higher since two working days are not taking in account and the consumption of water is higher during those ones. Anyway, it can be assumed that the average is good because finally, the annual value does not differ so much.

4.2.4. Pumping

For the distribution of all the hot water and refrigerant flows through the pipes some pumps are used. This way the refrigerant can be driven to the freezers and coolers and the same way, the hot stream from the heat exchanger to the ventilation systems.

These pumps have their own device that measures their power, working hours and electricity used in kWh. So, with this data taken from these devices, it is easy to get the annual electricity use.

If all the values are summed, the electricity consumption for the total pumping is:

$$17.70 + 15.21 + 57.18 + 28.11 + 6.71 \ = \mathbf{124.91} \ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

4.2.5. Air curtains

There are some air curtains at the entrance of the store that avoid indoor air losses and help keeping the warm air inside. They are mainly used during winter time (around 6 months) and they have a power consumption of around 16 kW each. Of course, they only work 14 hours/day, when the doors of the store are opened. They have an approximate electricity consumption of:

$$16 \cdot 4 \cdot 14 \cdot \frac{1}{2} \cdot 365 \cdot 10^{-3} = \mathbf{163.52} \ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

4.2.6. Air cooling

Air cooling in the store is used to cool down the temperature inside the store those days when the temperature outside the store is too high. Normally cold is produced thanks to the compressors, but usually more cold is needed, so in those cases, the device that provides the cold air is a Thermocold EASY 255 C. This air is introduced into the store by the ventilation system.

Air cooling is less used than heating, but it still consumes a big amount of electricity. Every year it uses **344.46 MWh** of electricity, as seen in Table 2. in the next page. It could not be measured, so for its calculation some assumptions were taken like it is going to be explained in the following section 4.2.7. The real value could be slightly different but it can be a good approximation.

4.2.7. Heating

As it was explained before, the heating in the building works by air heating. The air introduced for ventilation is heated, which means that there are not radiators in the building. When the air is taken from the outside, it is first cleaned (filtered) and then heated before introducing it into the building.

There is also one platform in the store that it is used when the trucks arrive to the store and unload their goods and products. This platform must be heated some days during the year in order to avoid its freezing. It is heated electrically only during working hours and the days that temperature is below 0°C. Later on, in this section, it will be specified the electricity used by this platform.

Going back to the space heating, the first step when heating the air is to warm it up with the heat recovered from the outlet air that is being removed out from the store. This is possible thanks to a rotator heat exchanger. After this, the air is heated with the heat recovered from the compressors heat exchanger.

In the coldest days of the year, it can happen that even more heat is needed, so in those cases, an electric heater is the responsible to provide it. As can be seen, in this last case is in the only one where electricity is used for heating. The other two ways are very good ways of recovering the heat that is not needed and this way save a big amount of energy.

For calculating the amount of electricity used in heating, it has been studied together with the air cooling. They are not measured so it has been taken some assumptions to get an approximation to the real values.

It is already known the consumption of the other units (ventilation, hot tap water, bakery, lighting…), so, if the sum of these amounts is subtracted to the total annual electricity consumption that is got from the invoice, it is easy to get the amount of MWh corresponding to heating and air cooling, both together.

Once this value is calculated, it can be assumed that for winter months all the electricity is used for heating, for summer months everything is for air cooling and for autumn and spring months both units, heating and air cooling, use the same amount of electricity. This way, it is supposed that from October to March all the electricity is for heating, from June to July all is for air cooling and in April, May and September this amount of electricity is used for both (50% each one). All this calculations are summarize in the Table 2.:

Period	Total electricity use (MWh)	The other units (MWh)	Heating (MWh)	Air cooling (MWh)
Winter	1566.19	1042.77 + 32.50	490.91	0
Autumn/Spring	736.90	521.39	107.76	107.76
Summer	758.09	521.39	0	236.70
Year	3061.18	2118.05	598.67	344.46

Table 2. **Heating and air cooling**

The energy consumption for each period has been separated first. Then, to these values, the amount of electricity used by the rest of the units is subtracted. These values are the sum of all other production and support units. They annual amount sums up to 2118.05 MWh where 32.5 MWh (it is going to be explained later on in this section) are for heating the unload platform only in winter. It is suppose that the rest of the units work the same every period of the year, so this way, dividing 2085.55 MWh in three periods (in winter period it is the 50% because there are six months and in the other two only the 25% of the hours in the year), the amount of electricity used by the rest of the units is got. The result of the subtraction will give the amount of MWh used for the space heating and air cooling.

To finish with the heating part only the electricity used by the heated platform is missing. This platform helps to the unloading of the goods carried by the trucks. It has a surface around 100 m^2. In these kinds of constructions 250 W/m^2 are used for heating them in order to avoid their freezing. This electrical heating only works during working hours and when outdoor temperature is below 0°C. So, it has been found the number of hours per year between 8.00 and 22.00 that the outside temperature in Sandviken is below 0°C. This value is 1300 hours/year, so with all this data, the electricity used by the platform will be:

$$250 \cdot 100 \cdot 1300 \cdot 10^{-6} = \mathbf{32.5} \ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

So, to sum up, this is the total amount of electricity for heating used by the store:

$$598.67 \ + 32.5 = \mathbf{631.17} \ \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

5. Results

After all the different processes in the store have been explained and theirs consumptions have been specified, in this section, all of them will be put together in an energy balance that will show which are the most important units and where should the reduction measures be applied.

Apart from this, the heat balance of the building will be calculated. It will be possible to know the amount of heat recovered from the cooling and freezing processes.

5.1. Energy Balance

With all the values calculated in the section before, it will be made a comparison between different units and this way see the amount of electricity used by each one comparing with the rest. The following table (Table 3.) summarizes the results obtained before:

Unit process	Electricity (MWh)	%
Bakery	92.85	3.0
Grills	11.48	0.4
Cooling/freezing	743.52	24.3
Lighting	682.62	22.3
Ventilation	223.11	7.3
Tap water	43.54	1.4
Circulation pumps	124.91	4.1
Air curtains	163.52	5.3
Air cooling	344.46	11.3
Heating	631.17	20.6
Total	**3061.18**	**100**

Table 3. Unit processes and their electricity consumption

If the units are separated in production and support processes, the use of electricity is divided like in the following graph (Figure 9.):

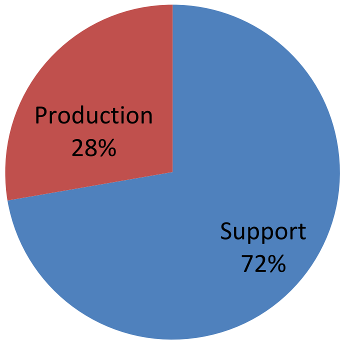

Figure 9. Electricity consumption divided in support and production processes

Production processes are using 847.85 MWh/year from the total electricity consumption. A big part of this electricity use is utilized for cooling and freezing, as it can be seen in the next figure (Figure 10.). The electricity used by the ovens and the grills is less significant, only the 12%.

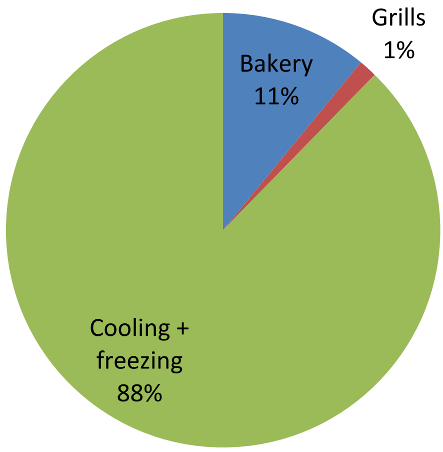

Figure 10. Electricity consumption in production processes

On the other hand, support processes are using much more electricity than support processes, exactly, 2213.33 MWh/year. Heating and lighting are the most important processes, while hot tap water only uses a small part of this amount. See the following graph (Figure 11.).

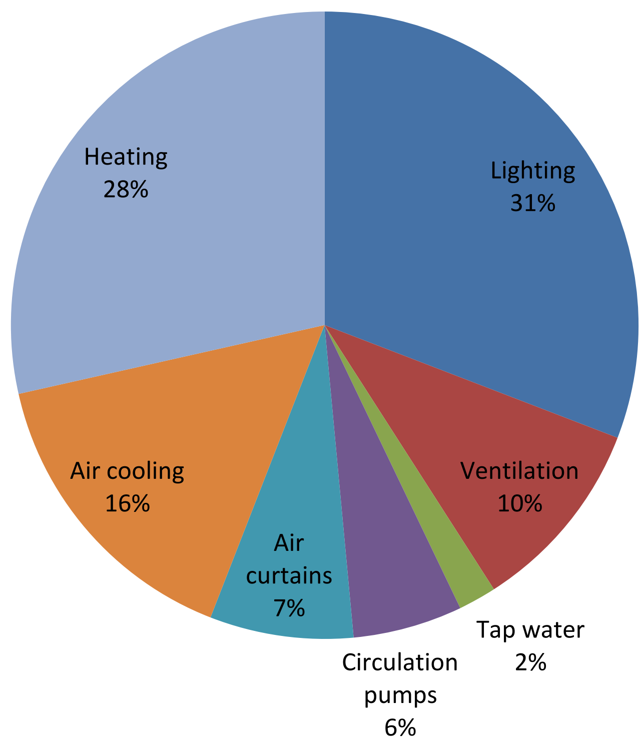

Figure 11. Electricity consumption in support processes

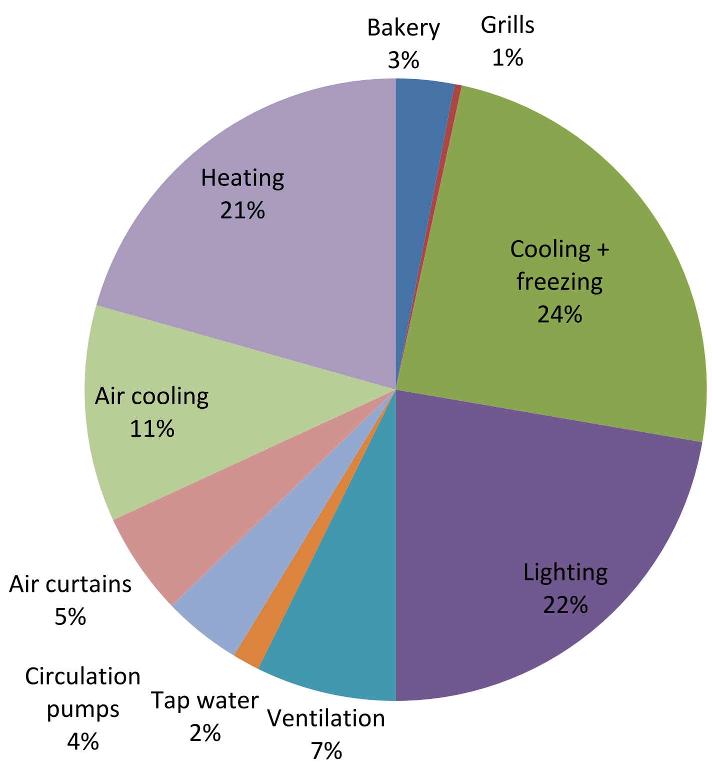

Figure 12. Total electricity consumption

To have a better overview, in the graph before (Figure 12.) it is possible to see all the unit processes together. This makes easier to see the amount of energy from the total consumption used by each one and can give an idea of which are the processes that waste more energy and thus, where the reduction measures have to be applied.

5.2. Heat Balance

As it has been explained in the theory part, the heat balance of the building is summarized in the following equation:

$$Q_{rot} + Q_{comp} + Q_{bought} = Q_{vent} + Q_{inf} + Q_{tr}$$

If Q_{rot} is substituted, it is possible to get:

$$0.7 \cdot Q_{vent} + Q_{comp} + Q_{bought} = Q_{vent} + Q_{inf} + Q_{tr}$$

$$Q_{comp} = Q_{tr} + Q_{inf} + 0.3 \cdot Q_{vent} - Q_{bought}$$

In order to be able to calculate the heat recovered from the compressors, first, all the other heat loads must be specified (see Appendix 1. for calculations):

- $\mathbf{Q_{vent}} = \rho \cdot c_p \cdot q_v \cdot dh =$ **1 740.77 MWh**
- $\mathbf{Q_{tr}} = \Sigma\,(U \cdot A) \cdot d_h =$ **307.97 MWh**
- $\mathbf{Q_{inf}} = 0.15 \cdot Q_{tr} =$ **46.20 MWh**
- $\mathbf{Q_{bought}} =$ **598.67 MWh** (see Table 2.)

If all these values are introduced in the equation of the heat balance, it is got that **277.73 MWh** of heat are recovered from the cooling and freezing processes. Normally in this kind of installations, the amount of heat than can be recovered is the

15-30% of the superheating, in this case 150-300 MWh. These means that the heat recovery from compressors is quite good since more than 85% of the heat that can be recovered is got. For more detailed calculations see Appendix 5.

6. Saving measures

Once the energy survey is done and it is exactly known which the amount of energy used by each process is, saving measures can be proposed in order to reduce the electricity consumption in some processes.

The store is using now more than 700 kWh/m^2 of electricity and this value is too high for this kind of building.

These measures will be mainly focused in support processes such as lighting and heating that consume a big amount of the electricity used in the building. Cooling and freezing unit process will be also analyzed to see in which way its electricity use can be reduced.

6.1 Savings in lighting

At this moment, only for lighting the store is using more than 600 MWh per year of electricity and an amount of power of almost 117 kW.

As it was said before, all the lamps work non-stop from 7.30 to 22.30. Apart from this, one half of them work 2 hours more per day, from 5.30 to 7.30, when all together start working. These lights are needed for employees in the bakery, cleaning staff…

The first efficiency measured suggested is related to the working hours of the lamps, tight their working schedule. The store is open from 8.00 to 22.00, so it would be better if all the lamps work exactly in that period of time. The 30 minutes before and after are not really necessary, it would be enough if one half of them are working. This way, it could be possible to save one hour (with the half of the lamps working) of lighting per day, which means, as it can be seen in the following calculation, a saving of 21.33 MWh per year:

$$116\,886.3 \cdot \frac{1}{2} \cdot 1 \cdot 365 \cdot 10^{-6} = 21.33\ \frac{MWh}{year}$$

This is just the 3% of the electricity consumption in lighting, but it gives an annual profit of 20 000 SEK.

Apart from this, just add that the number of lights working from 5.30 to 7.30 is too high. It could be reduced to the 25%. The same can be applied to the lights working from 22.00 to 22.30.

The second and most important measure consists on reducing the amount of lamps in the store. Now the store has a power consumption of 105 kW with an area of 3450 m^2. The recommended value of power per m^2 for shops and stores is 15 W/m^2 and in this case it is being used more than 25 W/m^2. This means that the electricity consumption in the store can be reduced in 40% with good planning.

The majority of the lamps in the store are T5 lamps, very efficient ones so there is no need to change them. But with a good distribution of them the number of lamps can be reduced. Besides, instead of being installed in the roof, they should be located in lower heights, closer to the customers so that a smaller number of lamps would be needed.

With all these measures, it would easily be possible to reduce the amount of electricity used in lighting to the half. This will give an annual saving of 300 000 SEK.

6.2. Savings on heating

It would be really difficult and at the same time very important to decrease the amount of heat needed to heat the building, but there is a better way of obtaining this heat, instead of producing it with electric heaters. Non electricity specific processes, such as space heating, can be substituted by district heating (DH) if they are driven by electricity. A big amount of energy is saved this way because there is no need of conversion the electricity to heat. Besides, the kWh of energy is cheaper in DH than in electricity.

This measure should be studied by the DH supplier in Sandviken. Depending on the initial investment and its pay-back, it could be a very interesting option of saving money.

6.3. Savings on cooling + freezing

Different kind of measures can be applied in order to get a reduction of the electricity production in this unit process.

The first one is related to the losses of cold in the freezers and coolers. During night or non working days there are some curtains that cover the freezers and avoid massive cold losses. This is a very good way of saving energy, but it would be better if instead of curtains, some glass doors were installed. The amount of electricity saved in this case would be bigger and there would not be any problem for customers. They would just need to open the doors.

There are also some other measures applied to the compressors such as the installation of a floating high pressure. This device decreases the temperature of condensation of the refrigerant and it is perfect for working in summer when the heat from the compressors is not needed and it is released to the outside. During winter, this heat is necessary, but when it is not, thanks to the floating high pressure electricity can be saved since compressors work less.

Another suggestion is to install sub-coolers in the positive coolers in order to improve their cooling capacity.

If an inverter is installed in each compressor, it will vary the speed of the compressor instead of working in two steps as it is doing now (on and off). This way allows the compressor to work with variable flow and to be able to adapt the cooling capacity to the cooling demand of the freezers.

6.4. Savings in tap water

The only way of saving in tap water is to reduce the amount of water that needs to be heated, and this is only got by reducing the consumption of water in the store. The electricity use in hot tap water is very small comparing with other processes, so the savings will slightly change the final electricity consumption, but at least, it will give a profit that could be used for other purposes.

There are some devices that help to reduce the water flow through the tap. They are known as aerators (see Figure 13.) and they use the Venturi effect to mix air with the water. They are inexpensive, but really effective since the water flow can be reduced in 50%. They are excellent for rinsing and washing dishes and some of them are variable in the case more flow is needed.

Figure 13. Aerators

With these devices it would be possible to save more than 20 MWh per year of electricity, which means a profit of around 20 000 SEK.

7. Conclusion

The results got in this study can give an idea of how different unit processes work. In some cases, the obtained value is not the real one although is good enough to have an idea of how do they work. Especially in air cooling and heating, some assumptions had to be taken to get an approximation to the real value. These units should be analyzed deeply.

Thanks to the energy survey it has been possible to know the amount of electricity used by each unit process in the building. The study has shown that there is a big amount of electricity used by support processes. These processes do not affect the functioning of the store and their consumption seems to be easier to decrease than the one of the production processes. That is why the measures should be mainly focused in these processes.

The building is new, it was rebuilt two years ago, and most of the systems and installations too: majority of the lamps are very efficient (T5 lamps), ventilation systems recover a big amount of heat… This is why the reduction of the electricity use is not so easy.

A big reduction can be achieved in lighting if the suitable measures are applied, almost the 50%. With good distribution and lower height of the lamps and tighter working schedule this saving can be achieved. The possibility of heating the building by district heating could also be feasible, so it would be a good idea to study it and see if it is worth or not. The amount of electricity for heating is too big even though the amount of heat recovered from compressors is quite good, so it would be good apart from changing to DH, to find a solution and decrease the electricity used by the electric boilers.

Other processes consumption would be difficult to decrease because they already are quite efficient. In ventilation for example, the only way of saving would be reducing the ventilation flow so that the power of the fans would decrease too.

In production processes cooling + freezing is the most important one. There have been explained some measures that will help to decrease the consumption, but a better and deeper study should be done by experts in cooling. Other processes consumption, such as bakery, cannot be reduced so easily. As seen in the Appendix 3. there are big losses of heat when the ovens are opened and this forces the oven to work harder after it. This time the door is opened should be as short as possible, but anyway, the little savings got like this are insignificant to the total electricity consumption of the building.

Regarding to the electricity used by the little part of the building owned by the ICA chain, it was said that this part uses the 27% of the electricity used for lighting, 184.57 MWh. As seen in the next graph (Figure 14.), this amount of MWh is the 6% of the total electricity consumed in the store. It means that the owner of the ICA chain should pay to Mr. Rydberg the 6% of the annual electricity invoice, in general terms, about 180 000 SEK.

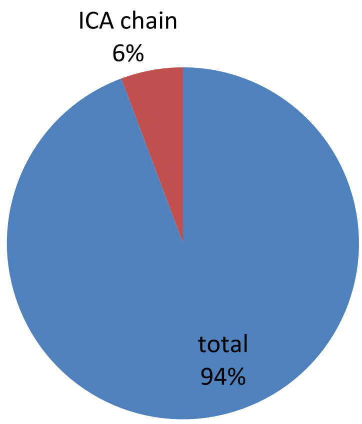

Figure 14. Electricity used by both parts

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Appendix 1. Heat Balance

In this short appendix, they will be specified the calculations done to know the mechanical ventilation losses and the transmission losses, that later are used for the heat balance of the building.

* Mechanical ventilation losses:

$\mathbf{Q_{vent} = \rho \cdot c_p \cdot q_v \cdot d_h}$

$\rho = 1.2\ kg/m^3$
$c_p = 1000\ J/kg \cdot °C$

- q_v = *ventilation flow [m^3/s]*: the total ventilation flow is the sum of the flows of the four ventilation systems. For the office, where the system works from 8.00 to 21.00, the flow is 0.4 m^3/s. In the rest of the store, where the systems (nº 1, 2 and 3) work 14 hours per day, they totally sum up to 20.13 m^3/s of air flow.

- d_h = *degree-hours [h·°C]*: this value will be the same for the three systems that work for the store, but not for the fourth system, the one for the office, because it works one hour less per day. 121 300 h·°C is the value for Sandviken for the whole year, but in this case, the systems are only working 13 or 14 hours per day. So:

$$121\,300 \cdot \frac{14}{24} = 70\,758\ h \cdot °C$$ **(Systems nº 1, 2 and 3)**

$$121\,300 \cdot \frac{13}{24} = 65\,704\ h \cdot °C$$ **(System nº 4)**

$\mathbf{Q_{vent}} = 1.2 \cdot 1000 \cdot [0.4 \cdot 65\,704 + 20.13 \cdot 70\,758] \cdot 10^{-6} = \mathbf{1\,740.77\ MWh}$

* Transmission losses:

$\mathbf{Q_{tr} = \Sigma\ (U \cdot A) \cdot d_h}$

- *U = heat transfer coefficient [W/m²·°C]*: for this kind of building the U value for the roof and for the floor is 0.25 $W/m^2 \cdot °C$. For the walls, this value is higher: 0.3 $W/m^2 \cdot °C$.

- *A = surface [m²]*: the area for the roof and for the floor is 4200 m^2. The total area for the walls is 1463 m^2.

- *d_h = degree-hours [h·°C]*: transmission losses happen not only during working hours, in this case, this value is 121 300 h·°C.

$$\mathbf{Q_{tr}} = [2 \cdot 0.25 \cdot 4200 + 0.3 \cdot 1463] \cdot 121\ 300 \cdot 10^{-6} = \mathbf{307.97\ MWh}$$

Appendix 2. Lighting

This is a short explanation of the different types of lamps that are placed in the store. Multiplying the number of bulbs, with the power or each one and the nº of these lamps that there is in the store, finally, the total amount of electricity in lighting is got.

Type of lamp	Nº of bulbs	Power of each bulb	Nº of lamps
Doubled tubular	2	53.9 (*)	618
Single tubular	1	53.9 (*)	267
Spot lights	1	85	240
Round	1	42	87
Big round lamps	1	55	12
Doubled protected tubular	2	30.8 (*)	61
Tubular (inside freezers)	1	39.6 (*)	96
Tubular (above freezers)	2	38.5 (*)	37

Table 4. Different types of lamps in the store

In the case when the lamp is a neon tube, marked like this (*) in the table before (Table 4.) the power of the lamp has been multiplied by 1.1 to get the real electricity consumption of these tubular lamps.

Appendix 3. Measurements

This appendix is dedicated to the measurements done in the store in order to analyze the electricity consumption of some devices. Thanks to them, it is possible to know how do the ovens and the heater work and how much electricity do they need.

Measurements were done between five days, more exactly five and a half. The technician installed some tools (see Figure 15.) that are able to measure the amount of electricity going through the wire. They were installed the 1st of April 2009 (Thursday) in the afternoon and they were removed early in the morning the next Tuesday, 7th of April 2009.

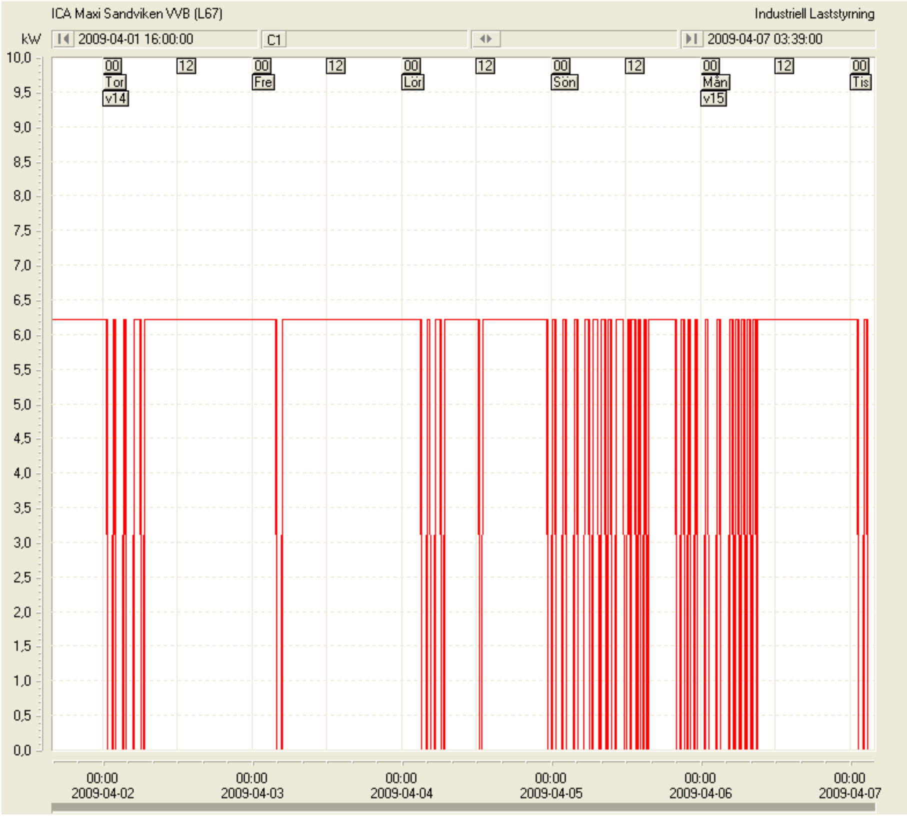
Figure 15. Measurement tools

After recovering all the data some graphs were given and the average values were calculated from them.

Hot tap water

For heating the water of the tap an electrical water heater ES23-500 is used (see Figure 16.). After it, it can be seen Figure 17. with all the data gathered by the tools.

Figure 16. Water heater

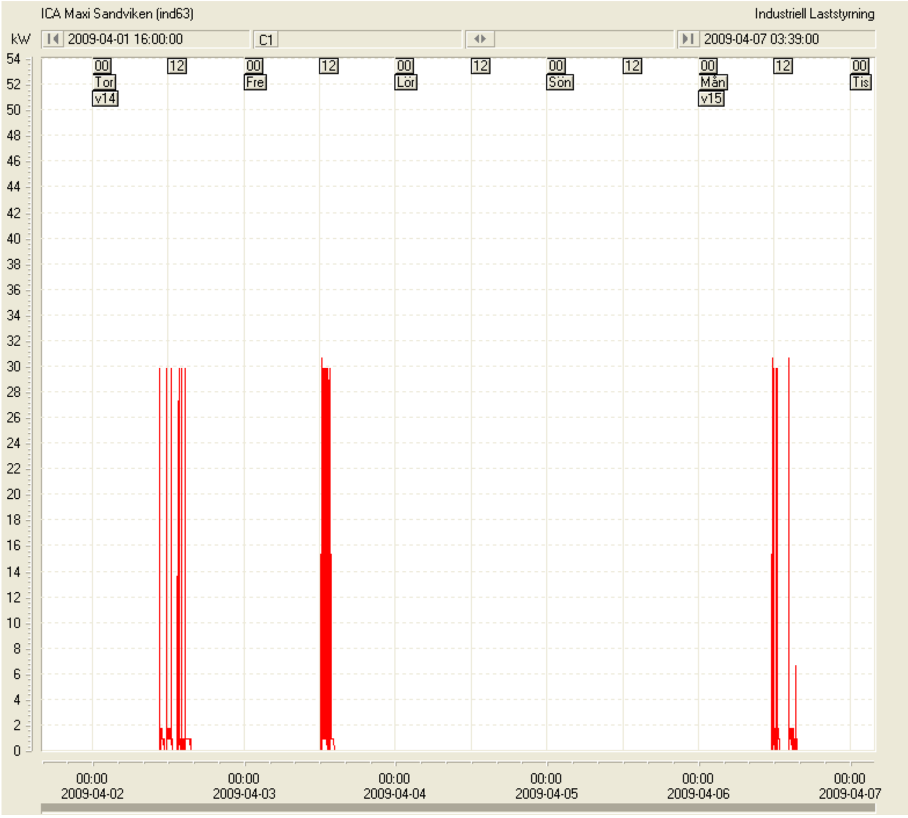


Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	4,97	0,00	6,21	654,3

Figure 17. Hot tap water

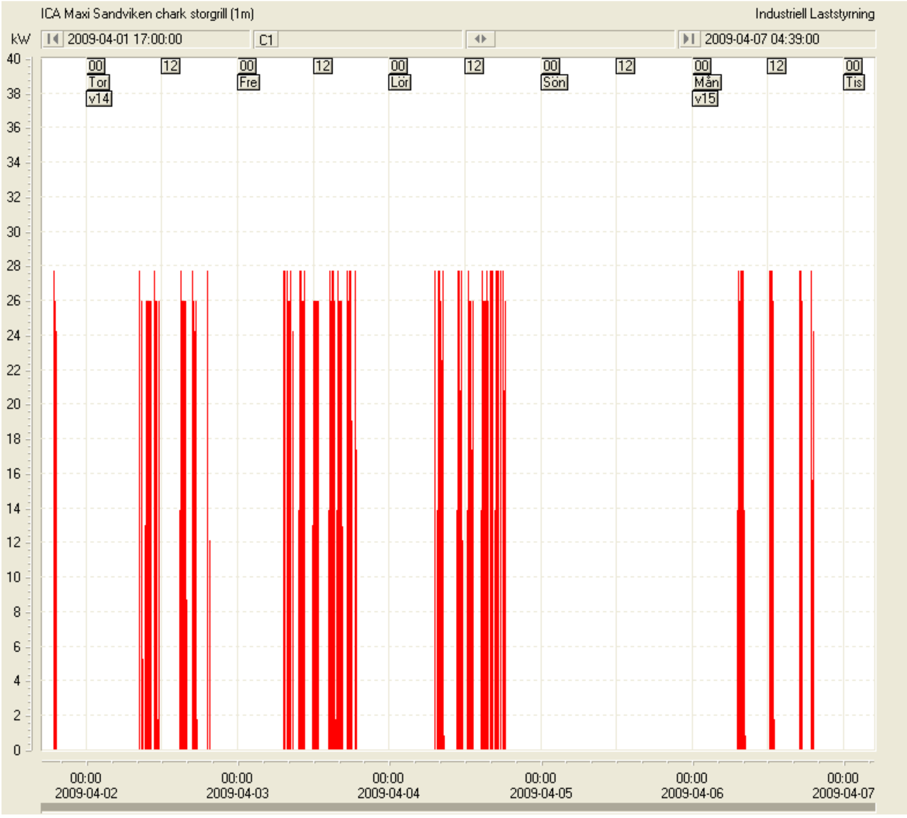
Grill ovens

As it was explained in the report, there are two grill ovens in the store that are used for cooking grilled chicken and other products. In the diagrams below (Diagram 2. and 3.) we have their detailed consumption.



Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	0,18	0,00	30,54	23,34

Figure 18. Small grill

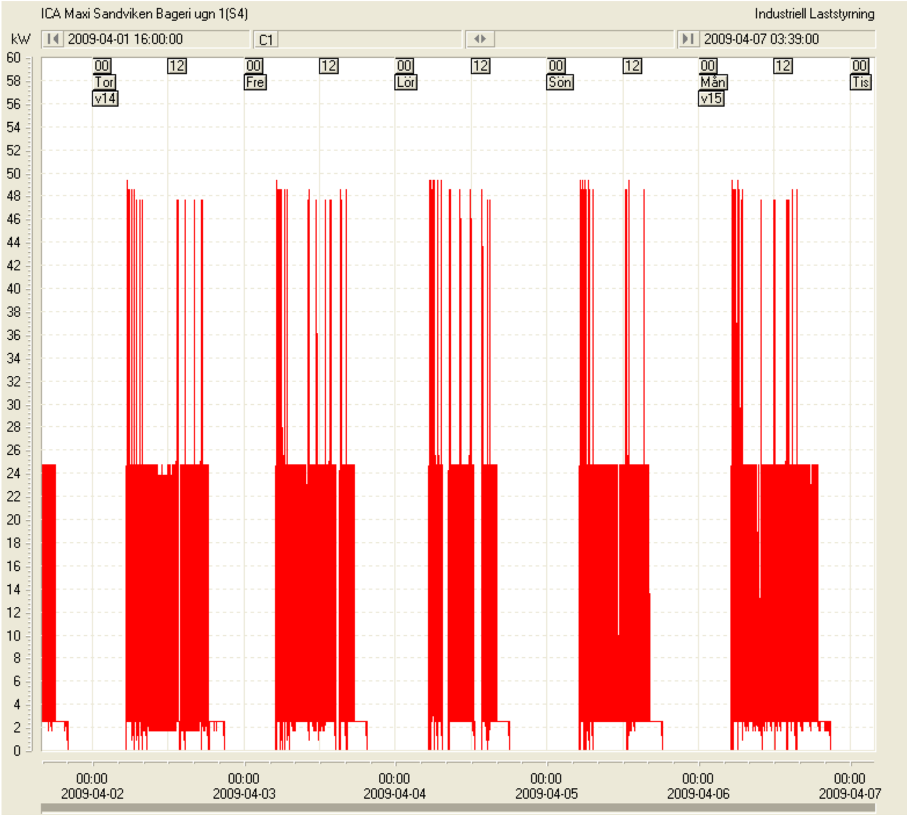


Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	1,13	0,00	27,60	149,18

Figure 19. Big grill

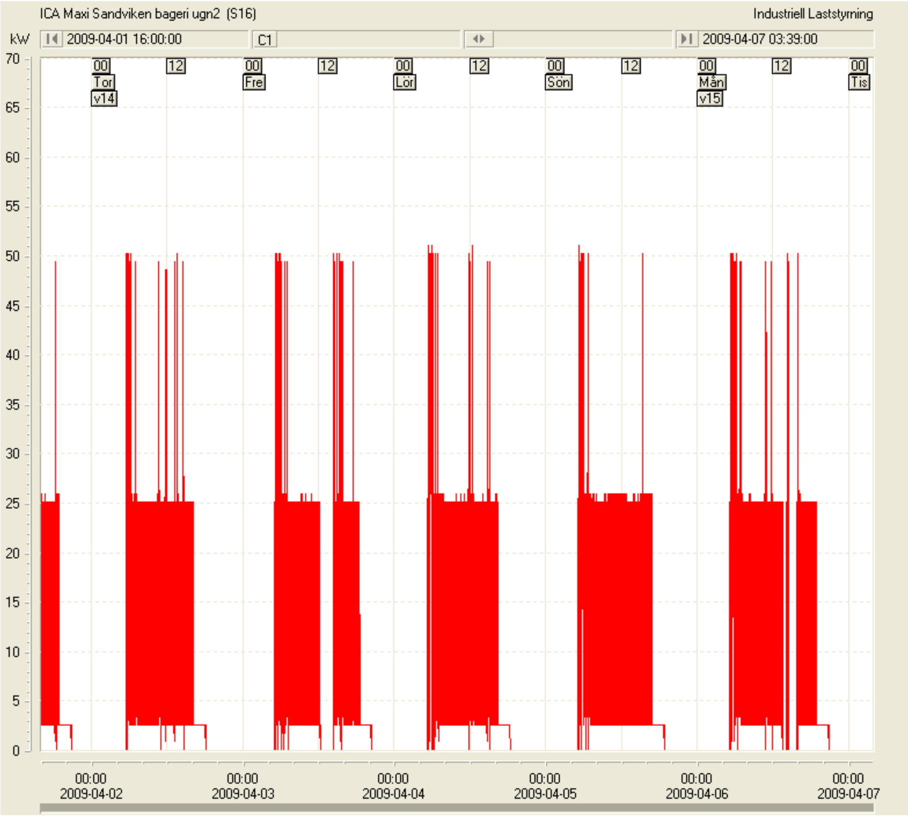
Bakery ovens

For the production of bread in the bakery there are three ovens in the store: oven nº 1, oven nº 2 and the stone oven. See their electricity consumption in the diagrams below (Diagram 4., 5. and 6.).



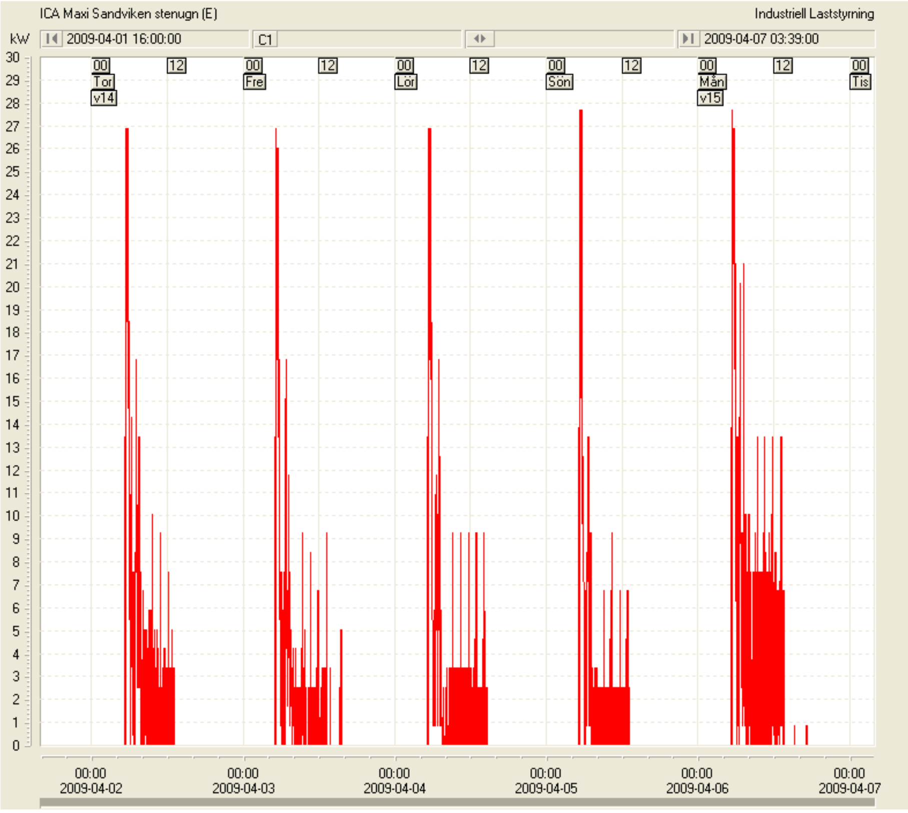
Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	4,67	0,00	49,27	615,30

Figure 20. Oven nº 1



Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	4,65	0,00	51,00	612,66

Figure 21. Oven nº 2



Enhet	Benämning	Average	Min	Max	'Energy kWh'
kW	Effekt	1,28	0,00	27,68	167,99

Figure 22. Stone oven

Appendix 4. Invoice

This appendix will be a short summary of the invoice received by the company responsible for the electricity supply, Sandviken Energi. The total amount of electricity used by the store is 3061.184 MWh for the whole last year, 2008. In the following table, the electricity consumption for each month is specified:

Period	Electricity (kWh)
January	274639
February	258689
March	268390
April	256382
May	244285
June	244855
July	261984
August	251252
September	236236
October	253056
November	248216
December	263200
Year	**3061184**

Table 5. Electricity consumption by months

If all this data is put into a diagram it will be easier to see which are the months with more electricity use:

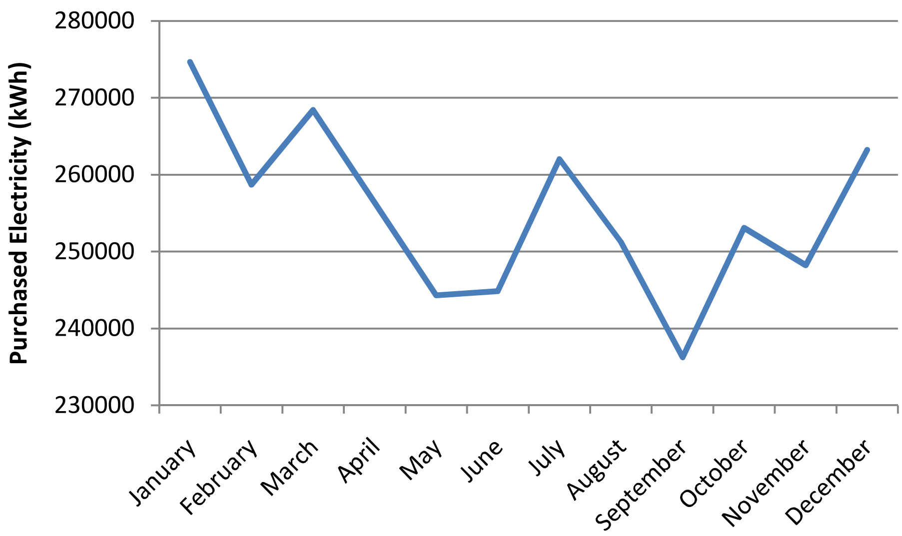


Figure 23. Electricity consumption by months

Analyzing the daily consumption during the year, it is known that an average daily consumption of the year is about 8360 kWh. The next diagram (Figure 24.) will show the consumption for each day in the year:

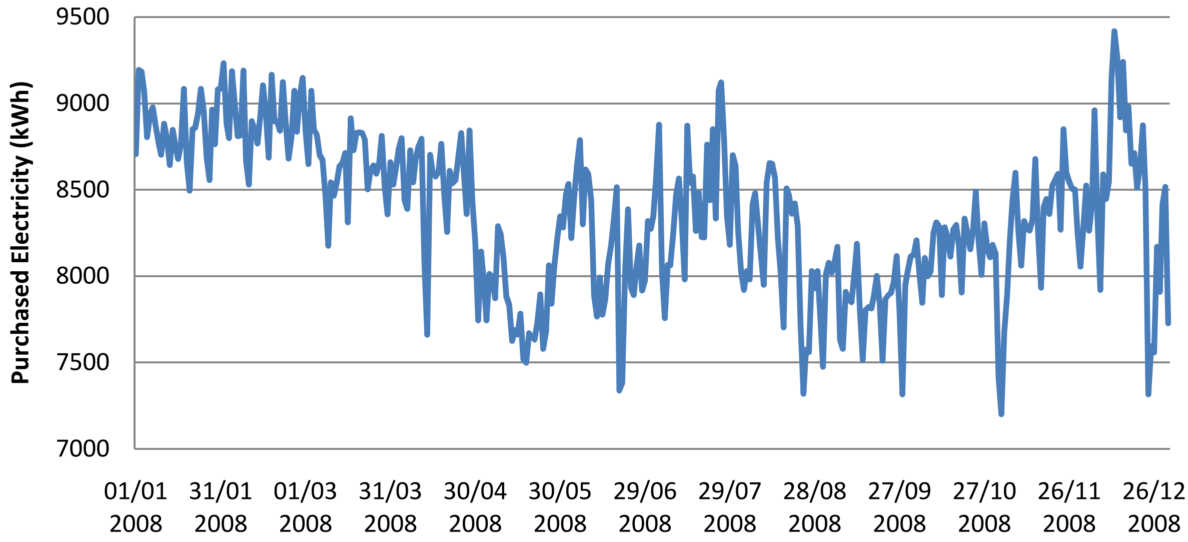


Figure 24. Daily consumption

To get a better idea, the following table and diagram (Table 6. and Figure 25.) will show the daily average consumption for each month. The red line in the graph represents the daily average consumption for the year. This way, it is easier to see in which period the daily consumption is higher:

Period	Electricity (kWh)
January	8859.3
February	8920.3
March	8657.7
April	8546.1
May	7880.2
June	8161.8
July	8451.1
August	8104.9
September	7874.5
October	8163.1
November	8273.9
December	8490.3

Table 6. Daily average consumption for each month

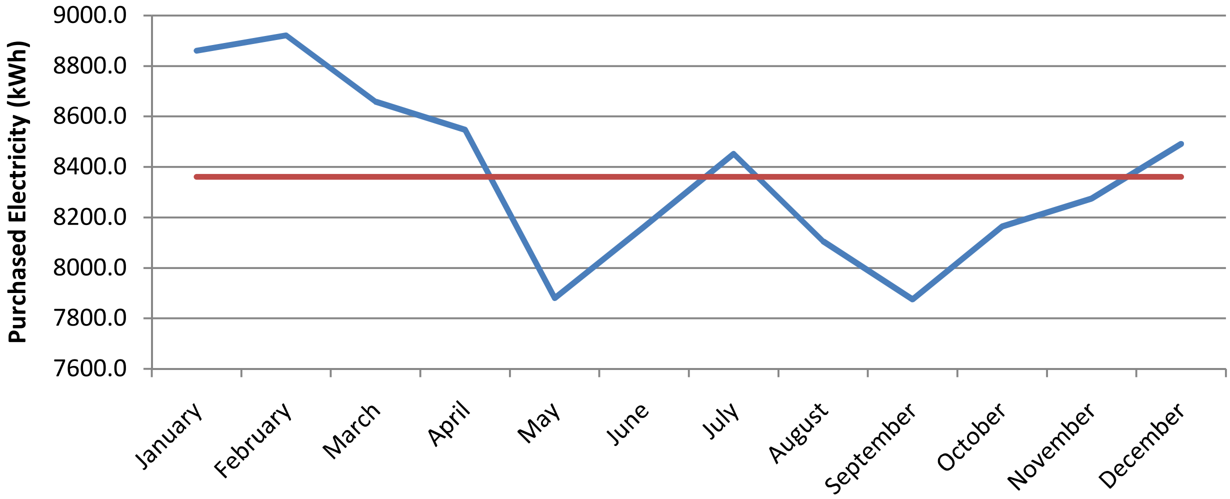


Figure 25. Daily average consumption for each month

Appendix 5. Heat recovery from compressors

This appendix is a short explanation of the calculations done to know which the amount of heat that can be recovered from compressors is. Normally, as it was said before, the amount of heat than can be recovered is the 15-30% of the superheating, in this case between 150-300 MWh as it will be seen in the following calculations.

For the positive compressors the condensing capacity (see Figure 26.) is exactly 101.3 kW and for the negative ones 30.8 kW (see Figure 27.). The 15-30% of these values is the amount of kW that it is possible to recover, so, if they are multiplied then by the working hours, the recovery heat is got. Remember that the heat recovery is only needed during winter, so this value is multiplied by 0.4 because it is assumed that the 40% of the working hours are in winter and the rest, the 60%, in summer. Compressors work more in summer because of the cooling needed.

$$101.3 \cdot 10^{-3} \cdot 0.15 \cdot 23\,981.75 \cdot 0.4 = 145.76 \; \frac{MWh}{year}$$ (**Positive cooling**)

$$30.8 \cdot 10^{-3} \cdot 0.15 \cdot 1998.48 \cdot 0.4 = 3.69 \; \frac{MWh}{year}$$ (**Negative cooling**)

$$145.76 + 3.69 = \mathbf{149.45} \; \frac{\boldsymbol{MWh}}{\boldsymbol{year}}$$

149.45 MWh is the 15%, so the 30% will be 298.9 MWh per year of heat that can maximally be recovered from the compressors.

Version 5.1.1

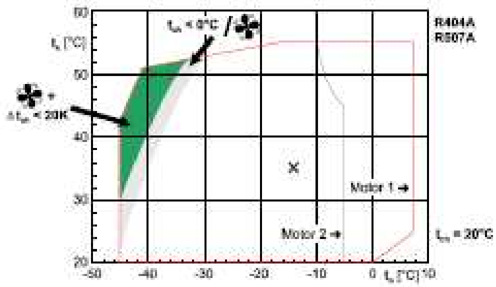
27/05/2009 / All data subject to change.

Compressor Selection: Semi-hermetic Reciprocating Compressors

Input Values

Compressor model	**6F-40.2Y**
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-14°C
Condensing SDT	35°C
Liquid subcooling	0K
Suction gas temperature	-2°C
Power supply	400V-3-50Hz
Useful superheat	100%
Capacity Control	100%

Application Limits (100%)



Output

Compressor model	**6F-40.2Y-40P**
Cooling capacity	71.6 kW
Cooling capacity *	77.0 kW
Evaporator capacity	71.6 kW
Power input	29.7 kW
Current (400V)	52.6 A
Voltage range	380-420V
Condensing capacity	101.3 kW
COP/EER	2.41
COP/EER *	2.59
Mass flow	2191 kg/h
Operating mode	Standard
Discharge gas temp. w/o cooling	66.6 °C

*Compressor-Performance data certified by ASERCOM (see T.Data/ Notes)

*According to EN12900 (20°C suction gas temp., 0K liquid subcooling)

Figure 26. Positive Cooling

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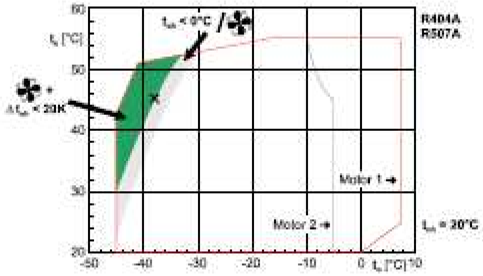
Compressor Selection: Semi-hermetic Reciprocating Compressors

Input Values

Compressor model	**6F-40.2Y**
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-38°C
Condensing SDT	45°C
Liquid subcooling	0K
Suction gas temperature	-10°C
Power supply	400V-3-50Hz
Useful superheat	100%
Capacity Control	100%

Application Limits (100%)



Output

Compressor model	**6F-40.2Y-40P**
Cooling capacity	15.13 kW
Cooling capacity *	17.72 kW
Evaporator capacity	15.13 kW
Power input	15.64 kW
Current (400V)	35.8 A
Voltage range	380-420V
Condensing capacity	30.8 kW
COP/EER	0.97
COP/EER *	1.13
Mass flow	549 kg/h
Operating mode	Standard
Discharge gas temp. w/o cooling	116.9 °C

*Compressor-Performance data certified by ASERCOM (see T.Data/ Notes)
Additional cooling/ Limitations (see Limits + T. Data)!
*According to EN12900 (20°C suction gas temp., 0K liquid subcooling)

Figure 27. Negative Cooling

Appendix 6. Detailed plan of the building