Energy Audit and Renovation Proposal for a joint Ventilation System of Five Commercial Premises

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Abstract

Energy saving is a highly concerned topic in the developing countries. To achieve a desirable living and working condition for inhabitants while consuming minimum amount of energy, more and more efforts, new technologies are developed and invested in the different industries by countries. It has been discussed that energy use in the building sectors is intensive and has the largest share in the total energy supply. Therefore, a growing number of companies and institutions are either required or voluntary to take energy efficiency measures once a year or more to identify current energy use, as well as the opportunities for energy efficiency improvement. One of the energy efficiency measures is energy audit. This report is aiming at pinpointing the current energy consumption for a joint ventilation system used by five premises in downtown Gävle, Sweden. The building company is planning a renovation for the ventilation system, including a cut down of energy supply while improving thermal comfort by providing adequate ventilation. The main object area is a restaurant, which consumes most energy supply. During the measurements, three sets of equipment (TSI VelociCalc plus, SWEMA FLOW 230 and TSI-AccuBALANCE) were used to collect air flow and temperature data. The results indicate that the current energy use for the joint ventilation system during a year is around 50438 kWh, using recommended ventilation rates; while it can be reduced to 34737 kWh. For the restaurant, the required ventilation rate is 1204 l/s to provide fresh air constantly if it is over 150 people and give ventilation according the standard: 7 l/s·p+0.35 l/s·m². The current ventilation rate is only 312 l/s, thus clearly failing to comply with the standard. One viable method for providing enough ventilation rate and at the same time without wasting energy is to install CO₂ detector, which regulates the ventilation rate according to the level of CO₂ concentration. The studied shops have instead very high ventilation rates in the current system; though this provides good air quality, the energy is wasted unnecessarily.
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1. Introduction

1.1 Background

1.1.1 Global Energy Consumption

The world-concerned problem today is energy problem. Increased energy consumption in different sectors has lead to decreased energy resources, insufficient energy supplies and most important is severe environmental impacts (global warming, land desertification, ozone diminution, etc.) The latest statistics as shown in figure 1 and figure 2 from International Energy Agency (IEA) indicate that from year 1971 to 2011, Total Primary Energy Supply (TPES) for the world by coal/peat is increased from 24.6% to 28.8%, though oil decreased from 46.0% to 31.5%. The total percentage of coal and oil consumption still takes around 60%, as compared to other primary energy supplies. Figure 1 and Figure 2 indicate how total primary energy supply is distributed from 1971 to 2011 by fuel consumption.

![Figure 1 World Total Primary Energy Supply from 1971 to 2011](image)

**Figure 1** World Total Primary Energy Supply from 1971 to 2011 [1]
1.1.2 Building Energy Consumption

There are three main sections that contribute the total annual energy consumption. These are energy consumed in industries, transportations and buildings. Among which, the energy consumption in buildings is confronted with dire challenges, for that energy used in buildings hold over 50% out of the total energy consumption. One of the reasons that lead to this consequence is the growth in population. Increased occupants will cause more time spent in the building, rose up building services and thermal comfort criteria. In order to meet the standard comfort levels, more energy input is required. In additional, the energy supply still depends mostly on coal and oil, which in turn causes more environmental problems. A study from Ratcliffe M and Dr Day T states, in UK and other developed countries, building energy consumption account for around 50% as compared to total energy use [3]. Figure 3 gives an example of final energy use in USA in 2006. The figure also represents how energy is consumed for both residential and commercial buildings.

Figure 2 1973 and 2011 fuel shares of TPES [2]

Mtoe: million tonnes of oil equivalent
Figure 3 Final Energy Consumption Distributions in U.S. in 2006 [4]

It can be concluded from figure 3 that in residential buildings, the largest energy end user is heating, others are water heat, lights, cooling, refrigeration etc. For commercial buildings, lights takes up most proportion, then heating, cooling, water heat, ventilation and office equipment.

In addition to population factor that causes more energy input to the building, buildings that are old, poor-insulated, more leaking envelope, with inefficient appliances requires more energy input than buildings that are well-insulated and with efficient appliances are also main reasons of increased energy consumption.

1.1.3 Energy Efficient Measures in Buildings

The European Energy Efficiency Plan (2011) has indicated that, “energy efficiency is the essential of EU’s Europe 2020 Strategy for smart, sustainable and inclusive growth and of the transition to a resource efficient economy and it also states that buildings are energy intensive, holding one of the greatest potentials for energy saving” [5]. Energy efficiency has been defined as the provision of energy to achieve acceptable environment conditions, while in the meantime minimizes the total energy supply [6].

In Europe, countries are putting more effort to reach the objective of “nearly zero-energy building” stated by European Union. Sweden is for instance one of the developed countries in the world aiming at minimize the supply of coal/peat and oil in primary energy use, while increasing the provision of renewable energy. Annunziata E et al has pointed out that to achieve the goal; one of the strategies is to taking energy efficient measures [7]. With the practices of energy efficiency measures, large portion of the energy consumption can be reduced. According to Gireesh et al., energy efficient measures are categorized into two kinds: non-investment measures and
investment measures. Non-investment measures are also known as habitual measures, e.g., switching off the light when leaving a place. Investment measures are financial based such as energy audit [8]. Another study also stated that energy-efficiency audits are effective methods for buildings to identify and implement opportunities for energy efficiency improvements. Such measures should be employed by enterprises, both large and small, to achieve the high energy efficiency performances [9]. With the help of investment measures, efficient energy reduction can be achieved. Energy audit is an investment measure that is an investigation, survey and analysis of the energy use distribution in a specific building. Energy audit of a building will identify where energy losses from the building envelope and ventilation systems, giving a clear understanding of the energy balance for the building.

1.2 Aim of this Project

1.2.1 Location of Gävle

Gävle is a city located in the east coast of Sweden, by the Baltic Sea near the mouth of the river Dalälven. According to data achieved in Statistics Sweden, it has a population of 97558 in March 2014, which makes it the 13th most populated city in Sweden [10]. The yearly average temperature is around 5°C. The following figure shows the location of Gävle, which is indicated in red spot.

![Figure 4 Location of Gävle in Sweden](image)
1.2.2 Building Information and Object Areas

The object area is a restaurant called Helt Enkelt, situated in the downtown of Gävle. The company is opting for renovation of the ventilation system. The purpose of this study is to review the mechanical ventilation system that the restaurant is using. In the current condition, it shares a common ventilation system with four other shops, which are Hemmakväll, Smart Eyes, Ohlssons Tyger and Life, respectively. All five premises are in the ground floor by the side of Main Street. **Figure 5** is taken when I was collecting data information, is a photo of the building with the five premises. According to the data provided by the building manager, the running time for the ventilation system is 133 hours in total for one week from Monday to Sunday. Given that the opening time is divergent between the restaurant and the other shops, causing the ventilation system to operate almost twenty hours per day. Besides, the staffs and customers in the restaurant are often complaining about the poor air quality and thermal comfort during their stay. This suggests that the supply ventilation rate is insufficient to provide $7 \text{ l/s}\cdot\text{p}+0.35 \text{ l/s}\cdot\text{m}^2$, standard value of maintaining good air quality. Therefore, it is important to make an energy audit about the ventilation system. Find out how much ventilation is for the five premises, and if it is too high or too low; how much energy in total is consumed during one year before for the current system; and how much energy will be consumed to provide enough ventilation rates in order to maintain acceptable air quality. Finally is to compare the results, and suggest recommendations for the renovation of the ventilation system.

**Figure 5** The Location of the Five Premises
1.3 Literature Review

Books are reviewed during the writing of this thesis. The book Handbook of Energy Audits (Albert Thumann, William J. Younger and Terry Niehus), Eighth Edition and Energy Audit of Building Systems: An Engineering Approach (Moncef Krarti), Second Edition provides basic understanding and theories for energy audit. What is energy audit, how to carry out a comprehensive audit for commercial buildings.

The book Sustainable Energy Utilization written by Hans Havitun, Paulina Bohdanowicz discusses energy utilization in ventilation systems and the energy needed for achieving desirable indoor climate. In the content of the book, ventilation requirements are defined with respect to meet thermal comfort standards, and different ventilation systems are presented including the driving mechanisms and designing criteria and relative merits are also compared.

The book Buildings and Energy – a systematic approach by Enno Abel and Arne Elmroth presents a systematic and holistic methodology to both reducing energy usage and maintain acceptable air quality, ensuring good thermal comfort.
2. Theory and Method

2.1 Energy Audit

2.1.1 Benefits from Energy Audit

In general, energy audit refers to the investigation and analyzation of the energy flows for energy conservation in a building, system or process over a period of time. Study from Ray E. et al., has defined energy audit as,

“The energy audit is used to identify energy savings projects and prioritize the potential projects in order of their profitability. The projects have to fit the budget for future capital expenditures and be constructible, and the required shutdown tie-ins normally need to fit the turnaround schedule” [12].

A thorough audit of a building consists of the inspection of the building envelop, HVAC system, hot-tap water, internal heat generated by people and equipments, examining voices and meters, as well as interviewing with relevant stuffs to get more comprehensive information. The purpose is to reduce the amount of input energy to the system without negatively affect the output. There are generally three types of energy audit according to Thumann A and Younger William J: Preliminary Audit, Standard Audit and Computer Simulation based Audit [13]. In the following section, basic descriptions are given in terms of the three levels of energy audit.

2.1.2 Types of Energy Audit

- Preliminary Audit

Preliminary audit is the basic level of an energy audit. Auditors take an on-site visit, visually inspect the individual energy systems and make an evaluation of the energy consumption data. After which, potential energy saving opportunities can be formed. For example, fix of broken windows, exposed water pipes. It is the least costly audit and an opportunity to collect information for detailed audit.

- Standard Audit

Based on preliminary audit, standard audit requires auditors to takes more detailed energy analysis, reviews of the equipment, system and operational characteristics of the object area. In order to get more accurate results, simplified tools are introduced like degree-day method and linear regression models [14].
• **Computer Simulation based Audit**

Computer simulation based audit is most comprehensive but also time-consuming. Auditors use computer simulation software to collect energy data of the facility through the year. For a long-term measurement, sensors are needed to be placed inside the system to measure the dynamic data. It considers the weather and other variables, accordingly forms a dynamic model of the energy consumption of the facility as well as energy use distribution by load types, for instance, energy use of lighting, fans, coolers, and ventilators [15].

**2.2 Indoor Climate and Ventilation**

**2.2.1 Indoor Climate**

The energy efficiency measures are not just to make energy savings for the facility. It is also of great significance to have a good indoor climate for the residents, workers to living and working with. In Sweden, winter is extremely cold, the temperature can be lower than -20°C. Hence a good thermal comfort is very important.

As Thumann A and Younger William J stated in the book that there are five factors influencing indoor climate [16], which are:

- Heating systems
- Ventilation in building
- Structure of building
- Activities inside
- Outdoor climate

**2.2.2 Ventilation**

Ventilation is one of the most important influencing factors to a high indoor air quality. It is a process to provide fresh air into a space while at the same time extract the odorous, unpleasant air and excessive moisture from the space. Ventilation in a space is generally through two ways: natural ventilation and mechanical ventilation/forced ventilation. The definition of each ventilation process is defined in the following [17]:

- **Natural ventilation** is the ventilation of the inside air without the use of fans or other mechanical equipments. Outdoor air is introduced inside the space by the cause of wind and thermal pressures through intentional openings in the building’s envelope. To name but a few, intentional openings contain windows, doors, louvers, roof ventilators and passive stacks connecting to registers.
- **Mechanical/forced ventilation** ventilates the air in a space through an air handling unit or by simply placing a fan in the space. Mechanical ventilation will increase the input energy for heating or cooling while it ventilates a space; however, heat recovery ventilation is applied to compensate the input energy. A heat recovery ventilation is composed of heat recovery unit, also known as a heat exchanger, together with supply and exhaust fans. Heat recovery unit is used to recover heat from return air, and re-circulate and mix it with the fresh outside air. By the information provided by the building manager, the mechanical ventilation system applied in the building is using rotary heat exchanger as heat recovery unit. **Figure 6** is the air handling unit with rotary heat exchanger.

**Figure 6** Example of Rotary Heat Exchanger in Mechanical Ventilation System [18]

### 2.3 Mechanisms of Rotary Heat Exchanger

#### 2.3.1 Rotary Heat Exchanger

As can be seen in the Figure 5, the rotary heat exchanger, also known as thermal wheel, is placed in between income air stream and return air stream. **Figure 7** shows the diagrammatic operation of the rotary heat exchanger. A honeycomb matrix of heat-absorbing material is rotating slowly and constantly as indicated in figure 7. It absorbs heat energy from the returned air stream at one half of the honeycomb matrix and as it rotates upwards, giving up the heat energy to the incoming fresh air. Thus, the energy is recovered from the return air and transferred to the supply air, rising the supply air temperature by an amount proportional to the temperature difference between the two air streams. Besides, the device efficiency is also an influencing factor to which how much energy can be recovered from the return air. The overall efficiency for the rotary heat exchanger in this case is assumed to be 70%.
2.3.2 Maximum Power for heating the New Air

The new air will be preheated. Therefore, an extra energy is required to operate. Thus the energy consumed in this case is calculated as:

\[ P = V_{\text{supply}} \cdot \rho_{\text{air}} \cdot C_P \cdot \Delta T \cdot (1 - \eta) \]

Where,

- \( P \) = maximum power required for heating the supply air in the time period of one second (kW)
- \( V_{\text{supply}} \): Total ventilation rate supplied into the space [l/s],
- \( \rho_{\text{air}} \): Density of the air (1.237kg/m\(^3\)) at the standard atmospheric pressure and at the temperature of 20\(^\circ\)C,
- \( C_P \): Specific heat capacity of the air (1.012J/kg\(^\circ\)C) at the standard atmospheric pressure and at the temperature of 20\(^\circ\)C,
- \( \Delta T \): Temperature difference between indoor temperature and lowest outdoor temperature in Gävle for light buildings during a year [\(^\circ\)C], which can be found in the Appendix II,
- \( \eta \): Efficiency of the rotary heat exchanger, which is assumed 70% for the rotary heat exchanger.

2.3.3 Mechanical Ventilation Loss

Mechanical ventilation loss calculated here is the total energy required to provide ventilation to the five object areas in the period of one year. It is calculated as:

\[ Q_{\text{MVL}} = V_{\text{supply}} \cdot \rho_{\text{air}} \cdot C_P \cdot q_{\text{degree}} \cdot \frac{H}{8760} \cdot (1 - \eta) \]

Where,

- \( V_{\text{supply}} \): Total ventilation rate supplied into the space [l/s],
\( \rho_{\text{air}} \): Density of the air (1.237kg/m\(^3\)) at the standard atmospheric pressure and at the temperature of 20\( ^\circ \text{C} \),

\( C_p \): Specific heat capacity of the air (1.012J/kg\(^\circ \text{C} \)) at the standard atmospheric pressure and at the temperature of 20\( ^\circ \text{C} \),

\( q_{\text{degree}} \): Degree hours for a year [\( ^\circ \text{Ch/year} \)], which we can get from the \( q_{\text{degree}} \) table in Appendix IV,

\( H \): Hours for ventilation in use in one year,

\( \eta \): Efficiency of the rotary heat exchanger, which is assumed 70\% for the rotary heat exchanger.

### 2.4 Data Collection Methods

The data was collected April in 2013. Three sets of equipments were used to measure the airflows for all the inlet air ducts and exhaust air ducts for the five premises, namely TSI VelociCalc plus, SWEMA FLOW 230 and TSI-AccuBALANCE. After the data collection, the total ventilation rate is calculated, as well as the energy losses.

**TSI VelociCalc plus** (TSI Inc. Shoreview MN USA) is a convenient and adaptable instrument capable of measuring air velocity, pressure, room temperature, relative humidity and volume flow rate, along with the functionality that it can store readings and calculate the average value. The sensor is placed in the tip of a telescoping probe. When measuring air velocity, it is placed perpendicular to the direction of the flow. It was used to measure the supply air velocity in the aggregate rooms when other measuring equipments were inapplicable due to the irregular geometry of the grills and air-vents.

![Figure 8 TSI VelociCalc plus [20]](image)
SWEMA FLOW 230 (©Swema AB) can be applied for both supply and exhaust airflow measurement. It has a range from 0 l/s to 60 l/s. It can only measure the airflow for exhaust air-vent without the prolonging hood on. By adding the hood, it can measure both supply and exhaust air. Calibration has to be done every time before starting a measurement to make sure it works more accurately.

Figure 9 SWEMA FLOW 230 [21]

TSI-AccuBALANCE (TSI Inc. Shoreview MN USA) has the capability of measure big airflows and at large air-vents that usually are installed in the ceiling. It has a range from 15 l/s to 1000 l/s and can be used to measure both supply and exhaust air. It is very easy to operate; the hood has a big opening which can completely enclose grills and air-vents. Readings can be directly obtained from a digital display.

Figure 10 TSI-AccuBALANCE [22]
3. Calculation Results

The ventilation rate through every single grill in the space was measured, then both the total supply ventilation rate and exhaust ventilation rate was calculated for the five premises: Smart Eyes, Ohlssons Tyger, Life, Hemmakväll and the restaurant Helt Enkelt.

Below is a list of tables showing the measurement results for the five premises:

**Table 3.1** Measured total airflows in the shop Smart Eyes

<table>
<thead>
<tr>
<th>Room</th>
<th>Supply Air (l/s)</th>
<th>Exhaust air (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop</td>
<td>269</td>
<td>38</td>
</tr>
<tr>
<td>Storage</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Toilet</td>
<td>no</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>285</td>
<td>86</td>
</tr>
</tbody>
</table>

**Table 3.2** Measured total airflows in the shop Ohlssons Tyger

<table>
<thead>
<tr>
<th>Room</th>
<th>Supply Air (l/s)</th>
<th>Exhaust air (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop</td>
<td>290</td>
<td>290</td>
</tr>
<tr>
<td>Storage</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>Toilet</td>
<td>no</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>306</td>
<td>304</td>
</tr>
</tbody>
</table>

**Table 3.3** Measured total airflows in the shop Life

<table>
<thead>
<tr>
<th>Room</th>
<th>Supply Air (l/s)</th>
<th>Exhaust air (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop</td>
<td>251</td>
<td>46</td>
</tr>
<tr>
<td>Toilet</td>
<td>no</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>251</td>
<td>73</td>
</tr>
</tbody>
</table>

**Table 3.4** Measured total airflows in the shop Hemmakväll

<table>
<thead>
<tr>
<th>Room</th>
<th>Supply Air (l/s)</th>
<th>Exhaust air (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shop</td>
<td>257</td>
<td>256</td>
</tr>
<tr>
<td>Storage</td>
<td>48</td>
<td>47</td>
</tr>
<tr>
<td>Toilet</td>
<td>no</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>309</td>
<td>321</td>
</tr>
</tbody>
</table>
### Table 3.5 Measured total airflows in the shop Helt Enkelt

<table>
<thead>
<tr>
<th>Room</th>
<th>Supply Air (l/s)</th>
<th>Exhaust air (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dining Room and Kitchen</td>
<td>312</td>
<td>184</td>
</tr>
<tr>
<td>Refrigerating Chamber</td>
<td>no</td>
<td>3</td>
</tr>
<tr>
<td>Wine Room</td>
<td>no</td>
<td>15</td>
</tr>
<tr>
<td>Toilet</td>
<td>no</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>312</td>
<td>266</td>
</tr>
</tbody>
</table>

In this study, the calculations are divided into two parts.

- First is to calculate the maximum power required for heating the new air and then to calculate the yearly energy loss in the current ventilation system.
- Second, assume that the restaurant is using one separate ventilation system while the other four shops share one system, then calculate the new yearly energy loss for the new system.

### 3.1 Maximum power for heating supply air in the current ventilation system:

In the first part, the power for heating the new air in the system for the five object areas is calculated as the following:

1) **The heating power for the shop Smart Eyes:**
   \[
   P_1 = q_{\text{supply}} \times \rho_{\text{air}} \times c_p \times \Delta T \times (1 - \eta)
   \]
   \[
   P_1 = 0.285 \times 1.2 \times 1 \times 42 \times (1 - 0.7)
   \]
   \[
   P_1 = 4.3 \text{ kW}
   \]

2) **The heating power for the shop Ohlssons Tyger:**
   \[
   P_2 = q_{\text{supply}} \times \rho_{\text{air}} \times c_p \times \Delta T \times (1 - \eta)
   \]
   \[
   P_2 = 0.306 \times 1.2 \times 1 \times 42 \times (1 - 0.7)
   \]
   \[
   P_2 = 4.6 \text{ kW}
   \]

3) **The heating power for the shop Life:**
   \[
   P_3 = q_{\text{supply}} \times \rho_{\text{air}} \times c_p \times \Delta T \times (1 - \eta)
   \]
   \[
   P_3 = 0.251 \times 1.2 \times 1 \times 42 \times (1 - 0.7)
   \]
   \[
   P_3 = 3.8 \text{ kW}
   \]

4) **The heating power for the shop Hemmakväll:**
   \[
   P_4 = q_{\text{supply}} \times \rho_{\text{air}} \times c_p \times \Delta T \times (1 - \eta)
   \]
   \[
   P_4 = 0.309 \times 1.2 \times 1 \times 42 \times (1 - 0.7)
   \]
   \[
   P_4 = 4.7 \text{ kW}
   \]
5) The heating power for the restaurant Helt Enkelt:

\[ P_5 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_5 = 0.312 \times 1.2 \times 1 \times 42 \times (1 - 0.7) \]

\[ P_5 = 4.7 \text{ kW} \]

➢ The total heating power in every second for the current system is calculated as:

\[ P_{\text{TOTAL}} = P_1 + P_2 + P_3 + P_4 + P_5 \]

\[ P_{\text{TOTAL}} = 4.3 + 4.6 + 3.8 + 4.7 + 4.7 \]

\[ P_{\text{TOTAL}} = 22.1 \text{ kW} \]

3.2 Energy loss through current ventilation system for the five shops:

The average yearly temperature for Gävle is 5°C, and the average room temperature is 20°C. Usually the temperature is one or two degrees higher than 20°C, the extra temperature is generated by the activities taken indoor, customers and working personnel, which is not counted in the calculation for simplification. So, 20°C is assumed in this case. Therefore, the degree hours \( q_{\text{degree}} \) can be obtained from degree-hour table in Appendix IV which is 121300°Ch.

The efficiency of the rotary heat exchanger is around 70%.

The ventilation running time is 133h every week, and it runs whole year, which means 52 weeks in total, giving in total 6916 h.

As all the information is specified, the energy loss is then calculated for the five object areas as following:

1) The energy loss for the shop Smart Eyes:

\[ Q_{\text{MVL1}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL1}} = 0.285 \times 1.2 \times 1 \times 121300 \times \frac{5916}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL1}} = 9826 \text{ kWh} \]

2) The energy loss for the shop of Ohlssons Tyger:

\[ Q_{\text{MVL2}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL2}} = 0.306 \times 1.2 \times 1 \times 121300 \times \frac{5916}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL2}} = 10550 \text{ kWh} \]

3) The energy loss for the shop of Life:

\[ Q_{\text{MVL3}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL3}} = 0.251 \times 1.2 \times 1000 \times 121300 \times \frac{5916}{8760} \times (1 - 0.7) \]
Q_{MVL3} = 8653 \text{kWh}

4) The energy loss for the shop of Hemmakväll:

\[ Q_{MVL4} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{MVL4} = 0.309 \times 1.2 \times 1 \times 121300 \times \frac{6916}{8760} \times (1 - 0.7) \]

\[ Q_{MVL4} = 10653 \text{kWh} \]

5) The energy loss for the restaurant of Helt Enkelt:

\[ Q_{MVL5} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{MVL5} = 0.312 \times 1.2 \times 1 \times 121300 \times \frac{6916}{8760} \times (1 - 0.7) \]

\[ Q_{MVL5} = 10756 \text{kWh} \]

\[ \text{The total energy loss through the current mechanical ventilation system is then:} \]

\[ Q_{\text{TOTAL}} = Q_{MVL1} + Q_{MVL2} + Q_{MVL3} + Q_{MVL4} + Q_{MVL5} \]

\[ Q_{\text{TOTAL}} = 9826 + 10550 + 8653 + 10653 + 10756 \]

\[ Q_{\text{TOTAL}} = 50438 \text{kWh} \]

3.3 Energy loss through new ventilation system for the five shops:

The new running time for ventilation system for the restaurant is calculated as 3640h per year. The running time for the four shops is 4992h per year. The detailed ventilation run-time can be checked in Appendix I Table 7 and Table 8.

The new supply ventilation rate needs to provide 7 l/s·p+0.35 l/s·m² for an occupied space in order to provide enough ventilation and maintain good air quality. Here the number of people p, is referring to the number of working staffs and customers in a very busy day. The information about the number of customers and floor area of each shop is obtained with the help of the owners of each shop and building managers. It is shown in Table 3.6.
Table 3.6 General information for the five premises

<table>
<thead>
<tr>
<th></th>
<th>Number of Customers</th>
<th>Number of Employees</th>
<th>Opening Hours (h)</th>
<th>Floor Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Eyes</td>
<td>320</td>
<td>2</td>
<td>9</td>
<td>180</td>
</tr>
<tr>
<td>Ohlssons</td>
<td>380</td>
<td>2</td>
<td>8</td>
<td>180</td>
</tr>
<tr>
<td>Life</td>
<td>300</td>
<td>4</td>
<td>8</td>
<td>180</td>
</tr>
<tr>
<td>Hemmakväll</td>
<td>350</td>
<td>2</td>
<td>11</td>
<td>200</td>
</tr>
<tr>
<td>Helt Enkelt</td>
<td>150</td>
<td>10</td>
<td>---</td>
<td>240</td>
</tr>
</tbody>
</table>

The number of customers in Table 3.6 is the total number of customers visited each shop in a very busy day. For the four shops, time period is set as 10 minutes, approximate visiting time of a customer. For example, for shop Smart Eyes, the customers are around 320 in a very busy working day, the working hour is 9 hours. So, it is around 6 customers in the shop every 10 minutes, plus 2 working staffs, became 8 people in total.

1) The energy loss for the shop Smart Eyes:

Thus, the new ventilation rate is calculated as:

\[ V_{\text{supply}} = (7 \text{ l/s·p}) \times 8\text{p} + (0.35 \text{ l/s·m}^2) \times 180\text{m}^2 \]

\[ V_{\text{supply}} = 119 \text{ l/s} \]

So, the new supply ventilation rate has to be 119 l/s to give good air quality and thermal comfort. The ventilation loss for Smart Eyes during a year is calculated as:

\[ Q_{\text{MVL1}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL1}} = 0.119 \times 1.2 \times 121300 \times \frac{4992}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL1}} = 2961 \text{ kWh} \]

2) The energy loss for the shop of Ohlssons Tyger:

The ventilation rate is:

\[ V_{\text{supply}} = (7 \text{ l/s·p}) \times 10\text{p} + (0.35 \text{ l/s·m}^2) \times 180\text{m}^2 \]

\[ V_{\text{supply}} = 133 \text{ l/s} \]

The mechanical ventilation loss is:

\[ Q_{\text{MVL2}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL2}} = 0.133 \times 1.2 \times 121300 \times \frac{4992}{8760} \times (1 - 0.7) \]
The energy loss for the shop of Life:

The new ventilation rate is then calculated as:

\[ V_{\text{supply}} = (7 \text{ l/s·p}) \times 11 \text{p} + (0.35 \text{ l/s·m}^2) \times 180 \text{m}^2 \]

\[ V_{\text{supply}} = 140 \text{ l/s} \]

The mechanical ventilation loss is:

\[ Q_{\text{MVL3}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL3}} = 0.14 \times 1.2 \times 1 \times 121300 \times \frac{4992}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL3}} = 3484 \text{ kWh} \]

The energy loss for the shop of Hemmakväll:

It is around 8 people in the shop every 10 minutes. The new ventilation rate is then calculated as:

\[ V_{\text{supply}} = (7 \text{ l/s·p}) \times 8 \text{p} + (0.35 \text{ l/s·m}^2) \times 200 \text{m}^2 \]

\[ V_{\text{supply}} = 126 \text{ l/s} \]

The mechanical ventilation loss is:

\[ Q_{\text{MVL4}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL4}} = 0.126 \times 1.2 \times 1 \times 121300 \times \frac{4992}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL4}} = 3135 \text{ kWh} \]

The energy loss for the restaurant of Helt Enkelt:

The new ventilation rate is:

\[ V_{\text{supply}} = (7 \text{ l/s·p}) \times 160 \text{p} + (0.35 \text{ l/s·m}^2) \times 240 \text{m}^2 \]

\[ V_{\text{supply}} = 1204 \text{ l/s} \]

The mechanical ventilation loss is:

\[ Q_{\text{MVL5}} = V_{\text{supply}} \times \rho_{\text{air}} \times C_p \times q_{\text{degree}} \times \frac{H}{8760} \times (1 - \eta) \]

\[ Q_{\text{MVL5}} = 1.204 \times 1.2 \times 1 \times 121300 \times \frac{3640}{8760} \times (1 - 0.7) \]

\[ Q_{\text{MVL5}} = 21847 \text{ kWh} \]
The total energy loss through the new mechanical ventilation system is then:

\[ Q_{\text{TOTAL}} = Q_{\text{MVL1}} + Q_{\text{MVL2}} + Q_{\text{MVL3}} + Q_{\text{MVL4}} + Q_{\text{MVL5}} \]

\[ Q_{\text{TOTAL}} = 2961 + 3310 + 3484 + 3135 + 21847 \]

\[ Q_{\text{TOTAL}} = 34737 \text{ kWh} \]

### 3.4 Maximum power for heating supply air in the new ventilation system:

The power for heating the new air in the system for the five object areas is calculated as the following:

1) The heating power for the shop Smart Eyes:

\[ P_1 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_1 = 0.119 \times 1.2 \times 1 \times 42 \times (1-0.7) \]

\[ P_1 = 1.8 \text{ kW} \]

2) The heating power for the shop Ohlssons Tyger:

\[ P_2 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_2 = 0.133 \times 1.2 \times 1 \times 42 \times (1-0.7) \]

\[ P_2 = 2.01 \text{ kW} \]

3) The heating power for the shop Life:

\[ P_3 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_3 = 0.14 \times 1.2 \times 1 \times 42 \times (1-0.7) \]

\[ P_3 = 2.12 \text{ kW} \]

4) The heating power for the shop Hemmakväll:

\[ P_4 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_4 = 0.126 \times 1.2 \times 1 \times 42 \times (1-0.7) \]

\[ P_4 = 1.9 \text{ kW} \]

5) The heating power for the restaurant Helt Enkelt:

\[ P_5 = q_{\text{supply}} \times \rho_{\text{air}} \times C_p \times \Delta T \times (1 - \eta) \]

\[ P_5 = 1.204 \times 1.2 \times 1 \times 42 \times (1-0.7) \]

\[ P_5 = 18.2 \text{ kW} \]
The total heating power for the system is then calculated as:

\[ P_{\text{TOTAL}} = P_1 + P_2 + P_3 + P_4 + P_5 \]

\[ P_{\text{TOTAL}} = 1.8 + 2.01 + 2.12 + 1.9 + 18.2 \]

\[ P_{\text{TOTAL}} = 26.03 \text{ kW} \]

According to the results, Table 3.8, Table 3.9 and Table 3.10 below are to make comparisons between the calculation results for current ventilation system and new ventilation system.

**Table 3.8** The ventilation rate for both current and new system

<table>
<thead>
<tr>
<th></th>
<th>Current airflow rate (l/s)</th>
<th>New airflow rate (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Eyes</td>
<td>285</td>
<td>119</td>
</tr>
<tr>
<td>Ohlssons</td>
<td>306</td>
<td>133</td>
</tr>
<tr>
<td>Life</td>
<td>251</td>
<td>140</td>
</tr>
<tr>
<td>Hemmakväll</td>
<td>309</td>
<td>126</td>
</tr>
<tr>
<td>Helt Enkelt</td>
<td>312</td>
<td>1204</td>
</tr>
</tbody>
</table>

**Table 3.9** The energy loss for both current and new system

<table>
<thead>
<tr>
<th></th>
<th>Current energy loss (kWh)</th>
<th>New energy loss (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Eyes</td>
<td>9826</td>
<td>2961</td>
</tr>
<tr>
<td>Ohlssons</td>
<td>10550</td>
<td>3310</td>
</tr>
<tr>
<td>Life</td>
<td>8653</td>
<td>3484</td>
</tr>
<tr>
<td>Hemmakväll</td>
<td>10653</td>
<td>3135</td>
</tr>
<tr>
<td>Helt Enkelt</td>
<td>10756</td>
<td>21847</td>
</tr>
<tr>
<td>Total</td>
<td>50438</td>
<td>34737</td>
</tr>
</tbody>
</table>

**Table 3.10** The power for heating supply for both current and new system

<table>
<thead>
<tr>
<th></th>
<th>Current power (kW)</th>
<th>New power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Eyes</td>
<td>4.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Ohlssons</td>
<td>4.6</td>
<td>2.01</td>
</tr>
<tr>
<td>Life</td>
<td>3.8</td>
<td>2.12</td>
</tr>
<tr>
<td>Hemmakväll</td>
<td>4.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Helt Enkelt</td>
<td>4.7</td>
<td>18.2</td>
</tr>
<tr>
<td>Total</td>
<td>22.1</td>
<td>26.03</td>
</tr>
</tbody>
</table>
4. Discussions

It can be noticed from the tables in the calculation results part that only for shop Ohlssons Tyger the total supply airflow and the total exhaust airflow are in balance. Supply is 306 l/s and the exhaust is 304 l/s, very small difference. For shop Hemmakväll, the supply airflow is 309 l/s and the exhaust airflow is 321 l/s, showing not too big difference, which may due to the inaccuracy of the measuring devices.

For shops Smart Eyes, Life and Helt Enkelt, the results are on the contrary. Among which, the total supply airflow is much larger than the total exhaust airflow for both Life and Ohlssons Tyger. The reason for why the supply and exhaust airflow were not in balance is unknown. The front doors are opened all the time for the shop Smart Eyes and Life, and for the restaurant Helt Enkelt, the back door is opened most of the times during the working hours, which may caused the imbalance. Inaccuracy of the measuring devices and air-tightness of the building envelope are also reasons, the air leaks out from the building envelope because of the small openings, cracks.

As mentioned before, the lowest acceptable ventilation rate should meet the standard value 7 l/s·p+0.35 l/s·m² for normal commercial buildings. By looking at Table 3.8 in the calculation results, the total supply ventilation rate measured in the current system for the four shops (Smart Eyes, Ohlssons Tyger, Life and Hemmakväll) are much higher than the new ventilation rate. For instance, for Smart Eyes, the new ventilation is 119 l/s, which is adequate to give 7 l/s·p+0.35 l/s·m² while it is a very busy day in the shop. The old value is 285 l/s, much higher, though it provides very good ventilation but it also wastes more energy.

In the contrast, for the restaurant the situation is not positive. Considering that costumers are staying usually longer than half hour in the restaurant, and it is possible that the restaurant will be fully occupied with around 150 customers, it requires high ventilation. The calculation result shows that the supply ventilation rate should be 1204 l/s to give 7 l/s·p+0.35 l/s·m², while the old value is only 312 l/s. This could be the major reason of the discontent that the customers and working staffs has informed.

Yet, the discontent may also caused by the contamination in the supply air, most likely due to leakage from the extract air to the supply air in the rotary heat exchanger. Another reason is perhaps the filters, which have been in dust for very long period and hasn’t been cleaned, thus the efficiency is relatively low. When the polluted air enters the room, people felt discomfort inhaling it.
The total energy consumed during one year in the current ventilation system is 50438 kWh, if the renovation of the system set new ventilation rates, energy use could be saved to 34737 kWh. However, there’s another measure which the company can adopt to further more reduce the energy supply. The method here is to install CO₂ detector to measure the CO₂ concentration in the restaurant. It is automated installation, which the ventilation rate can be adjusted automatically according to the level of CO₂ concentration [23]. The limit value for CO₂ concentration is 1000 ppm. If CO₂ concentration in a room is less than the limit value, it represents acceptable air quality, thus there’s no need to have ventilation rate as 1204 l/s, and the value will be automatically set as 30% percent of the highest value 1204 l/s. As the CO₂ concentration increasing with the increasing of customers, the device connected to the ventilation system will regulates the ventilation rate, and therefore increases the ventilation rate.
5. Conclusion

This section concludes the study and highlights the recommendations that the restaurant could take to minimize the energy supply. The main purpose is to improve the thermal comfort in the restaurant and provide sufficient ventilation. Apart from this, it is also important to look at how the other four shops are consuming energy through ventilation system and what improvements or recommendations can be made.

Due to the inaccuracy of the equipments, the results may not be perfectly accurate.

For the restaurant, the working staffs and customers are complaining about the air quality and thermal comfort. As discussed in previous section that the current supply ventilation for the restaurant is 312 l/s, which is too small to provide airflow rate 7 l/s·p+0.35 l/s·m². Thus, the ventilation rate needs to be set higher. The new ventilation rate can be regulated through an installation of CO₂ detector as discussed in the previous section. In addition, filters in the ventilation duct have to be checked and cleaned regularly, to sustain cleanliness and freshness of the incoming air.

For other four shops, it is not necessary to have such high airflow rate as in the current system. If renovation takes place, the company can set the airflow rate to the new value calculated in the result part. For further improvements it is suggested to make more in-depth of the building envelope for the shops Life and Ohlssons Tyger.
References


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Appendixes

Appendix I: Running time for the ventilation system and opening time for the restaurant and other four shops

Table 1 Running time for current ventilation system

<table>
<thead>
<tr>
<th>Running Time</th>
<th>Total Running Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Thursday 06:00 – 01:00</td>
<td>6916</td>
</tr>
<tr>
<td>Friday 06:00 – 03:00</td>
<td></td>
</tr>
<tr>
<td>Saturday – Sunday 09:00 – 03:00</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 Opening hours for the shop Smart Eyes

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Friday 09:00 – 18:00</td>
<td>2600</td>
</tr>
<tr>
<td>Saturday 10:00 – 15:00</td>
<td></td>
</tr>
<tr>
<td>Sunday closed</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Opening hours for the shop Olssons tiger

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Friday 10:00 – 18:00</td>
<td>2340</td>
</tr>
<tr>
<td>Saturday 10:00 – 15:00</td>
<td></td>
</tr>
<tr>
<td>Sunday closed</td>
<td></td>
</tr>
</tbody>
</table>

Table 4 Opening hours the for shop Life

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Friday 10:00 – 18:00</td>
<td>2340</td>
</tr>
<tr>
<td>Saturday 10:00 – 15:00</td>
<td></td>
</tr>
<tr>
<td>Sunday closed</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 Opening hours for the shop Hemmakväll

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Thursday 12:00 – 22:00</td>
<td>3692</td>
</tr>
<tr>
<td>Friday – Saturday 12:00 – 23:00</td>
<td></td>
</tr>
<tr>
<td>Sunday 13:00 – 22:00</td>
<td></td>
</tr>
</tbody>
</table>
Table 6 Opening hours for the restaurant Helt Enkelt

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Thursday 16:00 – 00:00</td>
<td></td>
</tr>
<tr>
<td>Friday 16:00 – 02:00</td>
<td>3276</td>
</tr>
<tr>
<td>Saturday 12:00 – 02:00</td>
<td></td>
</tr>
<tr>
<td>Sunday 15:00 – 22:00</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 Running time for new ventilation system for Helt Enkelt

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Thursday 15:30 – 00:30</td>
<td></td>
</tr>
<tr>
<td>Friday 15:30 – 02:30</td>
<td>3640</td>
</tr>
<tr>
<td>Saturday 11:30 – 02:30</td>
<td></td>
</tr>
<tr>
<td>Sunday 14:30 – 22:30</td>
<td></td>
</tr>
</tbody>
</table>

Table 8 Running time for new ventilation system for other four shops

<table>
<thead>
<tr>
<th>Opening Time</th>
<th>Total Opening Time in One Year (Hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday – Thursday 08:30 – 22:30</td>
<td></td>
</tr>
<tr>
<td>Friday – Saturday 08:30 – 23:30</td>
<td>4992</td>
</tr>
<tr>
<td>Sunday 12:30 – 22:30</td>
<td></td>
</tr>
</tbody>
</table>
Appendix II: The lowest outdoor temperature for light buildings of Gävle

Meteorologi och klimatologi
Dim temperaturer vintertid

Dimensionerande utetemperatur för värmeanläggning, DUT 1 ©
Källa: SÖN 73 (publ 1977) s. Förebyggsverkan 1977-10-23

Lowest temp. of Gävle

Vid beräkning av maximal erforderlig värmeelast när används den dimensionerande utetemperaturen, som erhålls ur 7:22 – 1 eller 7:23 – 1 enligt följande:

- för byggnad med lätt väggkonstruktion (ylik 100 kg/m²) fastställs den dimensionerande temperaturen (DUT 1) med ledning av 7:22 – 1.
- för byggnad med tung väggkonstruktion (ylik 100 kg/m²) fastställs den dimensionerande temperaturen (DUT 1) med ledning av 7:23 – 1.

Avstående DUT-värden enligt ovan korrigeras om tidigare dimensionerande byggnad ligger på en plats, som bedöms vara käll- re än trakten i genomsnitt.

7:22 – 1 är upprätt för byggnad med täckkonstantan R = 24 h, 7:23 – 1 för byggnad med täckkonstantan R = 80 h.

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

För byggnad med extremt lätt väggkonstruktion (med mot 50 kg/m²) används lämpligen utetemperad DUT 1 minskat med 2 h 4°C beroende på R-värdeets störlek.

I nuvarande byggverkens plerus är täckkonstantan av storleksordningen 160 h hos innerrum och 100 h hos hörmrum (hornrum har större avloppsfaktorer och därmed mindre värmeförmågan än innerrum). Vid minimallokaliserade regelverk med täcklag är R av storleksordningen 69 h, om intäckningens och värmeläggningens inflytande förrum.
Appendix III: The annual average temperature of Gävle
Appendix IV: The Degree-hour table

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

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

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>80750</td>
<td>73800</td>
<td>65800</td>
<td>55700</td>
<td>50200</td>
<td>47700</td>
<td>41900</td>
<td>35200</td>
<td>29700</td>
<td>24600</td>
<td>19600</td>
</tr>
<tr>
<td>6</td>
<td>87000</td>
<td>79500</td>
<td>72300</td>
<td>65300</td>
<td>58600</td>
<td>52200</td>
<td>46800</td>
<td>39700</td>
<td>33000</td>
<td>28400</td>
<td>23000</td>
</tr>
<tr>
<td>7</td>
<td>93500</td>
<td>85800</td>
<td>78000</td>
<td>71100</td>
<td>64100</td>
<td>57400</td>
<td>50800</td>
<td>44600</td>
<td>38000</td>
<td>32300</td>
<td>26900</td>
</tr>
<tr>
<td>8</td>
<td>100200</td>
<td>92200</td>
<td>84600</td>
<td>77200</td>
<td>69600</td>
<td>62900</td>
<td>55300</td>
<td>48600</td>
<td>42200</td>
<td>37100</td>
<td>31000</td>
</tr>
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Drifttid i hår för värmeanläggning, som funktion av ärts normaltemperatur, vid uppvärmning när minst 11°C.