Energy Saving Activities in the City of Helsinki

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Synopsis

There is potential to save energy economically and also improve the function of ventilation. Energy auditing is an efficient tool for clarifying the potential

Abstract

In 1993 the City of Helsinki made an agreement with the Ministry of Trade and Industry on objectives and measures for energy saving in the building stock owned by the City of Helsinki. For that target the City of Helsinki has carried out studies concerning energy use in multi-storey residential buildings and offices. These studies indicate that there is potential to improve the energy economy and the function of ventilation in individual buildings.

Energy auditing is an efficient tool for clarifying the energy balance and energy-saving potential and in some cases identifying buildings with inadequate ventilation. So far the City of Helsinki has carried out the energy audits in 98 buildings. The types of these buildings were, for example, schools, day nurseries, hospitals and offices. The results show that the potential savings for buildings would be, on average, 17 % in heating energy, 9 % in electricity and 7 % in water consumption.

The required investment would be paid back in 1,5 years. The pay-back period is rather short because most of these measures do not require any investment, e.g. changing the operation time of the air-handling unit or set points is only required. Improving the operation of the air-handling unit is most effective because only a one hour reduction in the daily operation time of fans means about 5 % energy saving in a typical office building. Energy-saving investments which were found to be economical were, e.g. heat recovery of exhaust air, control system and water tap.

1 Background for Energy Saving Activities

1.1 Energy Consumption in the City of Helsinki

The results of this presentation are based on studies which were carried out in the City of Helsinki. The City of Helsinki as the owner of buildings of over 27 million cubic metres is ranked as the biggest real-estate owner in Finland. The property includes a large variety of buildings, such as (1) blocks of flats, (2) office buildings, (3) schools, (4) day nurseries, (5) libraries, (6) theatres, (7) hospitals, (8) sports halls, (9) industrial buildings, and (10) civil defence shelters. Figure 1 summarizes the buildings owned by the City of Helsinki.

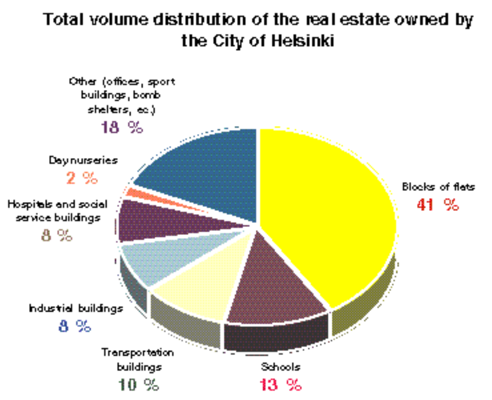

Figure 1-1. Buildings Owned by the City of Helsinki Based on Their Volumes in Cubic Metres

A lot of energy is consumed in heating and lighting and in cleaning these buildings, as well as in providing many of the City's other public services, such as local transport, street and parking lighting, and technical operation and maintenance. Due to the large amount of real estate, savings in Helsinki's energy consumption are also of national importance.

Helsinki is a northern capital with 523 000 inhabitants. It is located on the southern coast of Finland, very close to 60^{o} North Latitude, which makes it one of the northernmost capitals in the world. But the warm Gulf Stream, as well as the Baltic sea, influence its climate, which is often moderate but may also show more extreme temperatures varying from +30,8 ^{o}C in July to -34,3 ^{o}C in January (actual recorded minimum and maximum values 1961 - 1990). The average temperature in Helsinki in July has been +17,0 ^{o}C and -5,7 ^{o}C in January (1961 - 1990). Obviously the weather conditions place special requirements on the construction of houses and energy consumption. Many special solutions have been developed for winter conditions, such as the use of triple-glazed windows and the heat recovery from exhaust air, which are more or less standard nowadays. The dimensioning outside air temperature is set at -26 ^{o}C.

In 1995, about 12,2 TWh of energy was consumed in Helsinki, which is about 5 % of Finland's total consumption. The buildings owned by the City used about 11 % of this total. The consumption was about 45,5 kWh per cubic metre.

1.2 Energy and Environment

Energy production is always harmful to the environment, because all conventional energy sources are problematic to some extent. The worst threat is the greenhouse effect, which is caused by the increasing amounts of carbon dioxide, methane and nitric oxide in the atmosphere. All of these result from the production and consumption of energy. The greenhouse effect is especially enhanced by the combustion of fossil fuels that contain a large amount of carbon, on which Helsinki's energy production is also based.

In 1995 about 82 % of Helsinki's carbon dioxide emissions came from energy production, 13 % from traffic, 3 % from individually heated residences and offices and 2 % from individually heated factories. At the same time, about 90 % of sulphur dioxide and particle emission is due to energy production.

Combined heat and power production in the City's own power stations and a district heating network are characteristic of Helsinki. As many as 91 % of all buildings and 95 % of office buildings are heated in this way. As a result, the fuel consumption efficiency rate in the power stations is as high as 89 %. Despite the frequent cold winters, the outdoor air quality is pretty good, mainly thanks to modern centralized district-heating systems.
The City of Helsinki has developed the energy efficiency of power plants over several years. One proof of that is the UN Environmental Award for environmentally aware combined heat and power production which Helsinki Energy received in 1990.

In the future there are several ways to diminish the greenhouse effect. It may be reduced by choosing methods of energy production that lead in the desired direction, such as combining and centralizing the production of heating energy and electricity. Also the choice of fuels plays an important role. Helsinki has decided to increase heat and power production with natural gas. The first natural gas combined power plant was started up in 1991 and the next one will brought into operation line in 1997.

1.3 Targets for Heat and Electricity Consumption

In 1993, the City of Helsinki made for the first time an agreement with the Ministry of Trade and Industry on objectives and measures for energy saving in the City's own consumption of energy. The agreement presumed that the City would save, by 1996, 3,5 % of the heat consumption and 5 % of the electricity consumption of its own buildings. The objectives for 2005 are 10 % and 15 %, respectively. The base year is 1990. Financially, in the City of Helsinki the expected savings are FIM 12 million and FIM 30 million for the years in question (USD equals FIM 4,64 based on the exchange rate of December 20, 1996).

The City of Helsinki has agreed to examine and put into practice new savings goals, to improve their follow up, and to develop new economical technologies together with the Ministry. The Ministry has agreed to participate in the financing of research and the implementation of the energy conservation projects.

A special Energy Saving Board was established by the City of Helsinki to monitor its energy consumption and to co-ordinate the implementation of the energy-saving work. The members of the board represent various departments of the City, such as real estate, public transport, schools, social services and health care, as well as energy production and distribution. The required information and instructions are passed through a network of contact persons to various departments of the City.

2 Efficient Use of Energy is a Strategic Target

Energy-saving measures play a very important role in the City of Helsinki. The strategic plan is first to cut energy costs by reducing energy consumption and also to maintain a constantly lower consumption level in order to ensure savings in the future as well. Also, the saving has a positive impact for the environment: when consumption decreases the amount of emissions is reduced.

A lot of co-operation is required from the City's personnel at all levels in order to achieve the set objectives. The City aims at a unified campaign to ensure that appropriate information reaches the right people.

At the same time, continuous research and development work is needed. At present, in the ongoing project, new technical tools and methods for solving non-technical problems have been developed. Also the energy audit program is carried out. The audits will be carried out on altogether 150 buildings by the end of 1996.

In order to ensure the latest methods and best possible quality, co-operation is required between the City and its partners. Besides the City´s own development project the City of Helsinki is co-operating with several organizations. For example, with Austrian (Graz), Belgian (Geel) and Dutch (Schiedam) partners an international EU-funded project has started which objective is to build energy agencies in these towns. The City of Helsinki is also participating together with VTT and Finnish Real-Estate Federation to develop and implement an energy certificate for buildings based on the EU-SAVE directive.

3 Energy Audit Tool for Fault Diagnosis

The general target of the energy audit is to analyse the heating and electrical energy consumption, determine the targets of energy use and present economical energy-saving measures. Also during the energy audit, all noticed faults and defects are written down. The energy audit requires measurements and inspections in the building and energy-saving calculations for the basis of recommendations.

Normally the energy audit consists of three phases: (1) office, (2) field and (3) analysis phase. In the office phase, background information on the building and systems is collected. This is essential for planing the concrete measurement programme. In the field phase, measurements are carried out and the actual use and also set points of HVAC systems are checked. Also in the field phase, the system faults and indoor problems are recorded. In the analysis phase the measures which improve the energy economy and indoor conditions are studied. It should be noticed that these measures could not deteriorate the indoor climate.

3.1 Significance of Ventilation for Heating Energy Consumption

Figure 3-1 shows the energy balances of typical buildings ((1) office, (2) multi-storey residential building and (3) detached house). The balances are calculated based on the current Finnish National Building Code. In this code there is no requirement for exhaust air heat recovery for the residential building. In offices and public buildings heat recovery is recommended if the air flow rate is over 1 m^3/s. The effect of heat recovery can also been seen in Figure 3-1 as a low, consumption bar of ventilation in the office case.

Ventilation typically accounts for about 50 % of the total heating energy consumption in buildings. Therefore it is the key factor in the energy use of buildings and the cost effects of changing the operation hours of fans are significant.

Typically, when the fans are operating 10 h/d in the offices, a 1-hour reduction of the operation time means 5 % in heating energy use. In the Finnish climate a 1 hour reduction in operation time means annually about 2 kWh/cubic metre of building and 4 kWh/air flow, m^3/s, when there is no exhaust air heat recovery. When there is heat recovery unit values are about 1 kWh/cubic metres of building m^3 and 1,6 kWh/air flow, m^3/s.

3.2 Energy Target as a Indicator of System Performance

The calculated target value of heating energy consumption plays a key role when buildings are chosen for the energy audit. The difference between calculated and measured values always indicates that there is something exceptional in the studied building. Logical reasons for abnormal consumption are:

- inappropriate use of systems (operation times or set points),
- faults in systems. (e.g. heat recovery and controls),
- high heat gains (solar or equipment),
- abnormal use of domestic hot water or
- wrong input data in target calculation (e.g. operation time of building has changed or technical data of systems or structures is wrong).

In some cases the calculation method itself could be the reason for this difference when, for example, the thermal mass of the building is significance because of intermittent heating or very high heat gains. But typically the simple steady-state calculation method without modelling the dynamic behaviour gives reasonably good results. The philosophy of this target value is more or less intented to be a reference value by which all parameters are known. If there are the differences the reason should be checked more carefully. The reason for the potential difference is (1) wrong input data, (2) faults or (3) misuse of systems.

Because the thermal behaviour of the building envelope is normally rather static, it means that typically the systems cause the abnormal consumption. Because ventilation is the biggest component fault diagnosis should be started there. Ventilation faults could include:

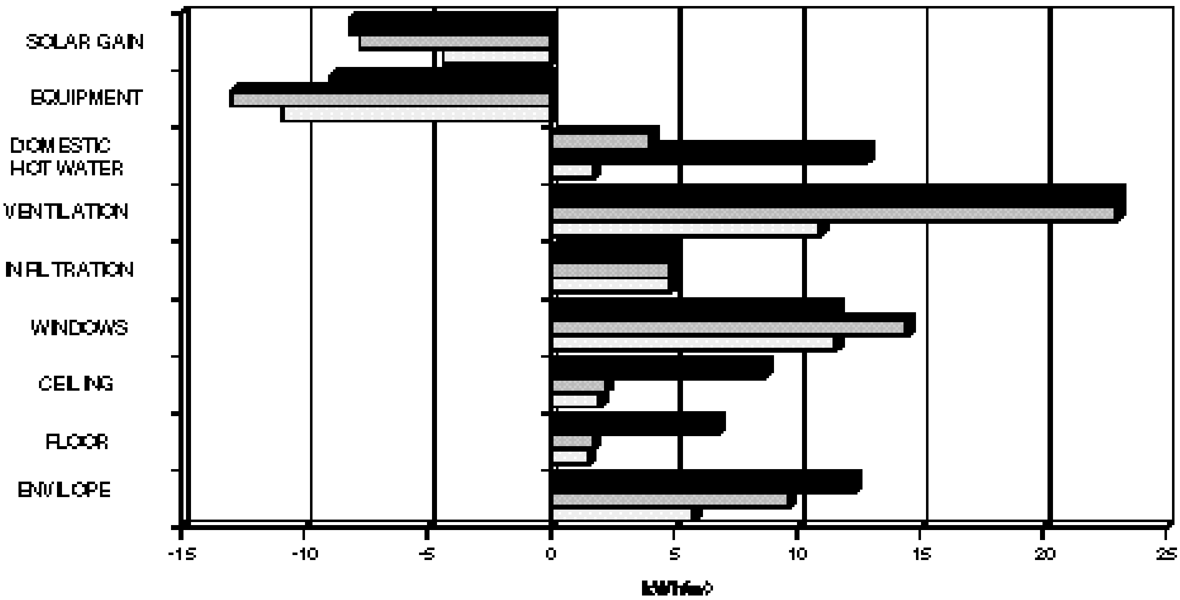

Figure 3-1. The Energy Balances in Office, Multi-storey Residential Building and Detached House.

• faults in heat recovery or use of return air,
• wrong set points of supply air,
• abnormal operation times of fans or
• wrong supply or exhaust air flow rates.

The last two faults could mean problems in indoor climate. In this approach the ventilation fault should be noticed as an abnormally low energy consumption.

4 Situation in the Building Stock

In the City of Helsinki an energy audit programme of public buildings and an assessment of the ventilation rate of multi-storey residential building have been carried out. In the audit programme the main point is to improve the energy efficiency of buildings and at the same time maintain the desired indoor climate.

4.1 Energy Saving Potential in Public Buildings

Energy audits have been carried out in 98 buildings owned by the City. The results showed that the potential savings for these buildings would be, on average, 17 % in heating energy, 9 % in electricity, and 7 % in water consumption. In one year, the savings would amount to FIM 3 million, and the required investment would be paid back in 1,5 years. The pay-back period is rather short because most of these measures do not require any investment, e.g. changing the operation time of the air-handling unit or set points is only required. Typical energy saving investment which were implemented (pay-back period under 7 years) were, e.g. heat recovery of exhaust air, control system and water tap. The audits are continuing and will have been carried out altogether on 150 buildings by the end of 1996.

The specific consumption of the heating energy and electricity, and the permitted maximum for 1996 was reached in 1994. If this trend continues, the respective objective for 2005 will be achieved.

In the project, a statistical method for choosing the individual buildings for auditing has been developed. In the method, the target energy consumption values were calculated and compared with the measured values (figure 4-1). The reasons for differences were analysed by auditing (Kosonen and Hoving 1995).

The results of 9 audited buildings show that ventilation is the main or significant reason for the difference in 7 buildings. The reasons for these differences were analysed more carefully and the following reasons were found:
Case 1: operation time of fans 1,5 h/day too long. Exhaust fans work for an unnecessarily long time (24 h/d).
Case 2: operation time of fan about 1 h/day too long. Indoor temperature about 1 ^{o}C higher than in the target energy consumption calculation.

• Case 3: supply air flow too high (expected not measured).
• Case 4: operation time of exhaust fans smaller than in the target energy consumption calculation.
• Case 5: the supply air flow rate too high (expected not measured).
• Case 6: the target and measured values about the same.
• Case 7: the target and measured values about the same.
• Case 8: ventilation rate lower than in the calculation (natural ventilation).
• Case 9: indoor air temperature lower than used in the calculation but also the heat recovery efficiency lower than in the calculation. In this case the target and measured values were about the same: the faults were not discovered before auditing.

In eight cases out of nine the method works fine. Only in one case (case 9) the problem in ventilation was not detected, because two faults compensated for each other (the low indoor temperature and the low efficiency of the heat recovery unit).

4.2 Inadequate Ventilation in Residential Buildings

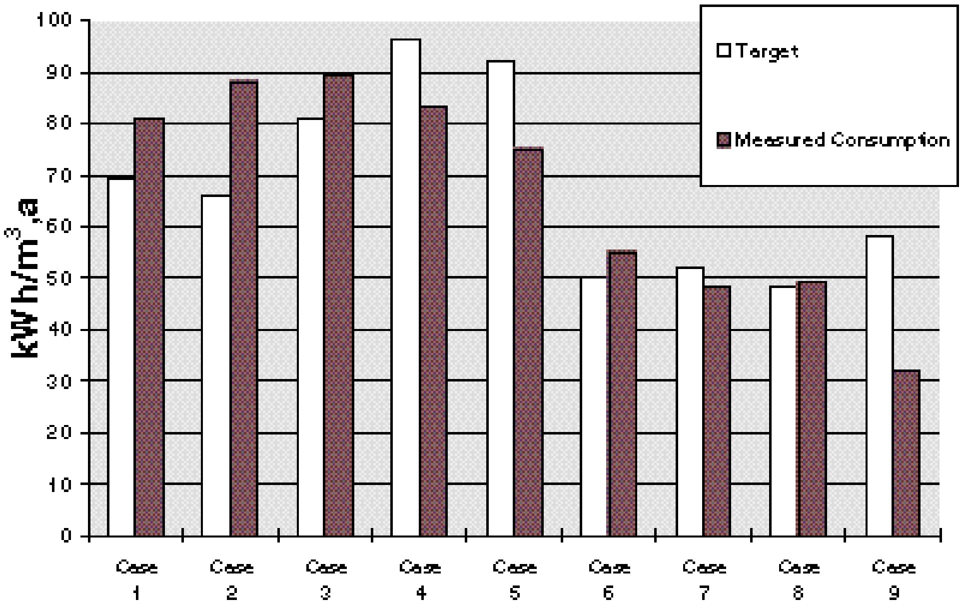

Figure 4-1. The Calculated and Measured Heating Energy Consumptions of nine Audit Buildings.

The ventilation rates which were measured by the City of Helsinki in the multi-storey residential buildings built in the 1960s and 1970s were too low. The minimum requirements for the air change rate (0,5 1/h) are met in only one fifth of the flats. One third of the exhaust air flows is only 50-60 % of the required and in one tenth respectively the exhaust air flow is practically zero (Dyhr 1995). The reasons for that are, e.g. technical faults and poor maintenance. Figure 4-2 is shows the ventilation rates and their distribution.

Table 4-1 presents the calculated specific heating energy consumption (including domestic hot water) with ventilation rate as a parameter.

The sensitivity study indicates that when 10 % difference between the target and measured consumption is used as a boundary value for abnormal operation, only ventilation rates deviating from the target by less than 25 % (see table 4-1). Therefore the normal energy monitoring will prevent worse indoor air problems caused by low ventilation rates.

Table 4-1. The Specific Heating Energy Consumption in 60's Multistorey Residential Building (Helsinki) with the Different Ventilation Rates.

Ventilation Rate	Specific Energy Consumption	Difference with Reference Case
0,5 1/h (100 %)	53, 6 kWh/m^3	Reference Case
0,375 1/h (75 %)	48,4	~ - 10 %
0,25 1/h (50 %)	43,2	~ - 20 %
0,125 1/h (25 %)	38,3	~ - 30 %

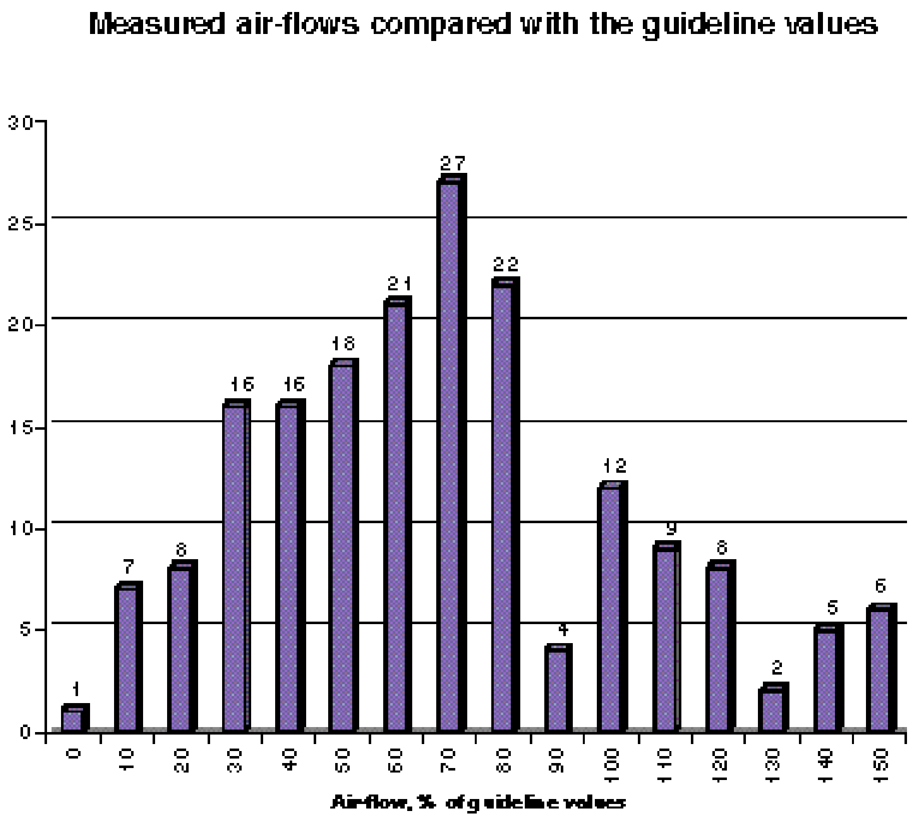

Figure 4-2. The Ventilation Rates and Their Distribution in Multi-storey Residential Buildings.

5 Conclusions

The studues carried out indicate that there is potential for improving the energy economy and the function of ventilation in individual buildings. Energy auditing is an efficient tool for clarifying the energy balance and energy-saving potential, and in the some cases for identifying buildings with inadequate ventilation. The results show that the potential savings for buildings would be, on average, 17 % in heating energy, 9 % in electricity and 7 % in water consumption. The required investments would be paid back in 1,5 years.

The pay-back period is rather short because many of these measures do not require any investments, e.g. changing the operation time of the air-handling unit or set points is only required. Improving the operation of the air-handling unit is most effective because only a one- hour reduction in the daily operation time of fans means about 5 % energy saving in a typical office building. Energy-saving investments which were found to be economical were, e.g. heat recovery of exhaust air, control system and water taps.

The ventilation rates which were measured by the City of Helsinki in the multi-storey residential buildings built in the 60´s and 70´s were too low. Only in one fifth of the flats are the minimum requirements for the air change rate (0,5 1/h) met. One third of the exhaust air flows are only 50-60 % of the required and in one tenth respectively the exhaust air flow is practically zero. The sensitivity study indicates that when 10 % difference between the target and measured consumption is used as a boundary value for abnormal operation, only ventilation rates deviating from the target by less than 25 %. Therefore normal energy monitoring will prevent worse indoor air problems caused by low ventilation rates.

References

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