IS SPACE HEATING IN OFFICES REALLY NECESSARY

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Abstract

New office buildings in Sweden are very thoroughly insulated due to the Swedish building code. This code, however, does not consider the type of activity maintained in the building. This means that the heating equipment must be designed as if no activity at all is going on in the building. In modern offices there is a lot of equipment installed which uses electricity. This electricity is converted into heat which can be utilized for heating of the premises, mostly in a direct way but also by use of exhaust air heat pumps or heat exchangers. This paper deals with a modern office building located in Linköping, Sweden, about 200 km south of Stockholm. The building is used as an office hotel and the tenants deal with the design of hard and soft ware for computers. The lighting and computers in the building use electricity which converts into heat. In this paper it is shown that this electricity is all that is needed during normal conditions, i.e. when people work in the building. The building is also equipped with a district heating system which is designed as if no activity goes on in the building, and subsequently the heating equipment is larger than it has to be. In this special case it might have been better to install an electric heating device for hot water heating and very cold winter conditions, instead of using district heating at all. This is so even if district heat has about half the price compared to electricity. At the present, when district heating is used, no measures for saving heat can be profitable due to the low district heating price. The fact is that the tenants are complaining of too much heat instead of too little and the prevailing indoor temperature was about 24 degrees centigrade in January 1990 even if 20 degrees would be sufficient. There is subsequently a need for a properly working regulation system. The one that is present today is designed due to the most modern standard there is, but it is shown that it is not able to keep the temperatures at a modest level.

INTRODUCTION

In the beginning of 1990 the Swedish State Power Board financed an inquiry of many different industrial branches in order to find out how to reduce the need for electric power before the Swedish nuclear power plants will be out-phased in 2010. One of these examinations dealt with a modern office building where computers were used for research and design of both hard and software. Modern offices are also equipped with lot of lighting which consumes electricity, and a ventilation system using big fans for the transportation of clean and used air in and out of the building. A monitoring program was developed in order to find out how much, for what, and when electricity and heat are used in the building. The monitoring prevailed for about three weeks in January because there was a need for measures during winter conditions. Unfortunately the month of January was extremely mild and subsequently the result must be considered with this fact in mind.

THE BUILDING

The building contains about 5 200 m^2 where 4 800 m^2 are used by the tenants. The total transmission factor has been calculated to the values shown in Table 1.

	Area [m^2]	U-value [W/m^2K]	Area $\times$ U-value [W/K]
Attic floor	1 340	0.15	201.0
External walls	2 565	0.20	513.0
Floor	1 340	0.30	402.0
Windows	538	2.0	1 076.0
		Total	2 192.0

Table 1: Transmission Factors for Different Building Components

In Linköping the design outside temperature, according to the Swedish Building Code, is -19 °C, while the inside temperature is set to +20 °C. This means that the thermal load because of transmission is about 85 kW.

VENTILATION

The ventilation equipment is designed to distribute about 26 000 m^3/h and the thermal load, due to the code, has been calculated to 112 kW or 2 574 W/K. Then it has been assumed that the HVAC system is equipped with an air to air heat exchanger with an efficiency about 70 %. The values for the air flow and the efficiency, calculated as found in [1], have been confirmed by the measurements. There is also a system of regulation that is going to turn off the fans when nobody is working in the building. If the temperature is higher than a certain value the fans are turned on as long as this temperature prevails. This is so because the building is constructed using concrete floors with pipe formed cavities. The ventilation flow is transferred through these cavities and the concrete thus will take care of internal energy gains in the building. Using the fans will thus spread high temperatures in one part of the building to places with low ones.

CLIMATE CONDITIONS

In order to calculate an energy balance over one year for the building, it is necessary to use information about the mean outdoor temperature. The Swedish Meteorological and Hydrology Institute presents the following temperatures for 1989, and mean values for a 30 year period, for the site Malmslätt not far away from Linköping.

Month	1989	1931-1960	Month	1989	1931-1960
January	3.9	- 2.9	July	17.5	17.7
February	3.4	- 3.0	August	14.8	16.4
March	4.0	- 0.1	September	11.0	12.2
April	5.7	5.3	October	7.0	7.1
May	12.1	11.0	November	2.1	2.7
June	15.3	15.4	December	-1.3	0.0

Table 2: Outdoor Temperatures in the Neighborhood of Linköping, Sweden

The reason for choosing 1989 as the calculation year is that it is the most resent year where the actual consumption of district heat and electricity are known. The temperature values for 1989 will result in the number of degree hours shown in Table 3 if it is assumed that one degree hour is generated as long as the outdoor temperature is colder than the desired inside temperature.

Month	Hours	Temp. diff.	Ventilation	Envelope
January	744	20.1	10 050	14 954
February	672	20.6	10 382	13 843
March	744	20.0	10 080	14 880
April	720	18.3	9 223	13 176
May	744	11.9	5 997	8 853
June	720	8.7	4 384	6 264
July	744	6.5	3 276	4 836
August	744	9.2	4 636	6 845
September	720	11.7	5 897	8 242
October	744	16.3	8 215	12 127
November	720	21.9	11 037	15 768
December	744	25.3	12 751	18 823

Table 3: Degree Hours for the Ventilation System and the Climate Envelope

The desired inside temperature is set to 24 °C because the measurements showed that that was the actual mean temperature during the monitoring period. The monitoring program showed that the ventilation system was used far more than expected. This may depend on the fact that the system was subject for a change and a new computerized system was to be installed. However, it is expected that the system during 1989 was used in the same magnitude as it was used during the first weeks of 1990 and this means that the equipment is running from 8 am to 12 PM during workdays and from 2 PM to 12 PM during Saturdays and Sundays. Other times it is turned off. This means that the ventilation system operates about 504 hours each month. Using these values result in Table 3.

HOT WATER HEATING

There is also a need for hot water heating in the building. No special monitoring of this heat has been made but the magnitude of heating for this purpose can be found by examining the district heating measurements during summertime, when no space heating at all is supposed to be necessary. In this way it can be found that about 5 kW is applicable as a mean value for a whole month.

FREE HEAT

There is also a lot of free heat in the building, from solar radiation, heat from persons and from appliances. The solar radiation has been calculated for the four different orientations of the windows by use of a computer program, described in detail in [2]. The values are presented in Table 4.

Month	North	East	South	West
January	1.1	3.9	21.3	3.9
February	2.6	10.3	34.5	10.3
March	6.9	26.6	54.7	26.6
April	10.8	39.1	51.5	39.1
May	16.2	55.9	58.3	55.9
June	17.3	57.2	56.8	57.2
July	17.1	57.2	57.7	57.2
August	13.4	47.0	54.8	47.0
September	8.6	32.0	53.6	32.0
October	4.2	16.1	43.5	16.1
November	1.3	4.9	22.2	4.9
December	0.6	2.1	14.7	2.1

Table 4: Solar Radiation Through Triple Glazed Windows in kWh/m^2 for Different Orientations in Linköping, Sweden. Latitude 58.3 degrees.

These values are to be multiplied with the area of the windows in the different orientations, see the result in Table 5.

The free heat from persons visiting and working in the building is assumed to be of the magnitude of 100 W for each person. It is also assumed that there is about 75 persons in the premises. Free heat from appliances and lighting is the overwhelming part of the free gains in the building. The electricity meters in the building have been read about each four months and the bills have been sent to the tenants. Using these billing statistics, show what amount of free energy that is at hand. These values are also presented in Table 5.

	Losses			Supplies			
Month	Transm.	Vent.	Hot water	Solar	Persons	Appl.	Distr.h
January	32 779	25 868	3 720	3 476	5 580	50 478	3 720
February	30 343	26 723	3 360	6 730	5 040	45 565	3 360
March	32 617	25 945	3 720	13 632	5 580	50 478	3 720
April	28 881	23 740	3 600	16 983	5 400	50 708	3 600
May	19 406	15 436	3 720	22 739	5 580	54 350	3 720
June	13 731	11 284	3 600	23 091	5 400	52 597	3 600
July	10 600	8 432	3 720	23 152	5 580	54 350	3 720
August	15 004	11 933	3 720	19 647	5 580	54 350	3 720
September	18 066	15 178	3 600	15 114	5 400	52 597	3 600
October	26 582	21 145	3 720	9 398	5 580	54 713	3 720
November	34 563	28 409	3 600	3 850	5 400	53 300	4 022
December	41 260	32 821	3 720	2 115	5 580	55 077	15 029
Total	303 832	246 914	43 800	159 927	65 700	628 563	55 531

Table 5: Energy Balance in kWh for Office Hotel in Linköping, Sweden

ENERGY BALANCE

The discussion above shows the base for how much heat that is supposed to be necessary to supply to the building. The values are shown in Table 5 and the technique is presented in more detail in [2]. From the table it is obvious that only a very small amount of space heating is necessary to supply by use of the district heating system. In November and December a total of 11 731 kWh is assumed to be used for this purpose. Throughout the whole year, a total of 55 531 kWh has been calculated to be supplied and this is about 11 kWh/m^2. The billing statistics show that in fact 220 400 kWh were delivered, or about three times more than needed. Note also that an indoor temperature of 24 °C was used in the calculations while 20 degrees is a more common temperature to use.

ANALYSIS

Above it is shown that it should have been possible to heat the office hotel in Linköping with solely free heat from appliances, solar radiation and persons, at least if a desirable indoor temperature of 20 degrees C was used. How come it is such a big discrepancy between the calculated and the monitored values? Some possible explanations will be discussed below.

- Errors in the suggestions of the thermal envelope of the building
- Errors in the suggestions of the capacity of the ventilation flow
- Too few degree hours
- Too small assumed hot water consumption
- Too high assumptions of the free gains from the appliances, persons and solar radiation

The thermal status of the building has been calculated by use of the construction schemes and the area of the envelope assets. Two different calculations have been made, by the designer of the HVAC system and by the authors of this paper. Both calculations show the same magnitude of thermal losses. There is also a risk for bad workmanship when the building was built. The owner of the office hotel, however, has competent personal who have inspected the building now and then under the building process. The capacity of the ventilation equipment has been measured with a Pitot tube and the air flow was found to be very close to the designed. The heat exchanger could be bad but temperature measurements on each side of the exchanger showed that the values seemed to be better than the ones assumed. There is also a possibility that the ventilation system is used far more than expected, but again, measurements were base for the calculations. The number of degree hours used in this investigation comes from calculations on official statistic from the Swedish Meteorological and Hydrology Institute. The site Malmslätt where the measurements actually are done is only about 10 km from the location of the office hotel. The hot water use might be underestimated. The value used comes from a mean value for six months during the summer and it seems not possible that this can be the solution to all the encountered differences. Instead, it seems that the building cannot use all of the free energy available in the premises even if the it is specially designed for doing so. The free energy comes to a major part from the electricity used for all the lighting and running the computers. The value is metered using the ordinary electrical meters which is a base for the billing from the utility. There is thus not a severe risk for errors in the electrical metering. Further it might be supposed that a lot of the equipment is in fact located outside the building and subsequently the free gains will not be available. Such equipment exist e.g. some cooling devices and the outside lighting. Two of the ventilation fan motors are also located in away that most of the free heat from them will disappear in the ambient outside air. The facts above made it interesting to calculate the energy balance for the building once again but with the assumption that about 10 kW, which was found to be applicable, of free power never is available in the building. These calculations show that the use of district heating is supposed to be doubled, to about 120 000 kWh each year, or about half the real consumption. However, the monitoring in the building makes it possible to investigate if free energy is utilized the way it is supposed to be. This will be discussed in the next section of the paper.

UTILIZATION OF FREE ENERGY

In Figure 1 the electricity and district heating use are shown for two weeks in January 1990.

It is obvious that the district heating use goes down when the electricity use increases. The district heating, however, does not decrease as much as could be expected. Looking at the second peak in the figure, at about hour no. 97 it is shown that the electricity peak is about 50 kW while the decrease in district heating is only about 20 kW. The minimum use of district heat is about 20 - 30 kW no matter how much electricity that is utilized. The decrease in district heat use during daytime could also depend on the outdoor temperature that often is increased during the day. In Figures 2 and 3 the outdoor temperature

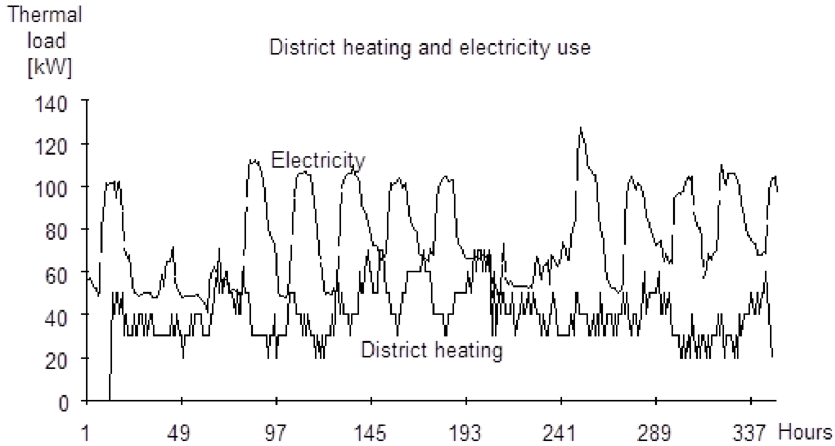

Figure 1: District Heating and Electricity Use in an Office Hotel in Linköping, Sweden

and the district heating load are depicted.

It can be found that after the first peak in the temperature curve, at about hour no 10, the temperature falls from 5.5 degrees to about 1.5 degrees centigrade. At the same time the district heating load increases from about 30 kW to 70 kW.

It is obvious that there is an influence between the outdoor temperature and the district heating load but it also seems that a temperature fall of about 4 degrees results in a very high increase of the district heating load, about 20 kW would be expected. Another means for examining if the free heat in the building has any significance is to examine if the building has a long time constant. If the outside temperature falls there should be a certain time gap before the district heating load will increase. As can be found from the curves no such gap can be observed. The district heating load will increase at the same time as the outdoor temperature decreases.

CONCLUSIONS

This investigation of an office building in Linköping, Sweden, implies that it should be possible to utilize the free energy from persons, solar radiation and appliances to such a degree that no space heating at all would be necessary. The investigation also showed that the building at the present could not take care of the free energy in the way that could be expected. This is so even if the building is specially designed in order to do so. The building is thoroughly insulated and a very heavy concrete construction is used for the floors and further the ventilation flow is led through cavities in these floors, but this does not seem to influence the energy use at all. The investigation also shows the importance of having possibilities to check the energy use in a building in a simple way. Otherwise it is very hard to reveal if any inadequacies is present in

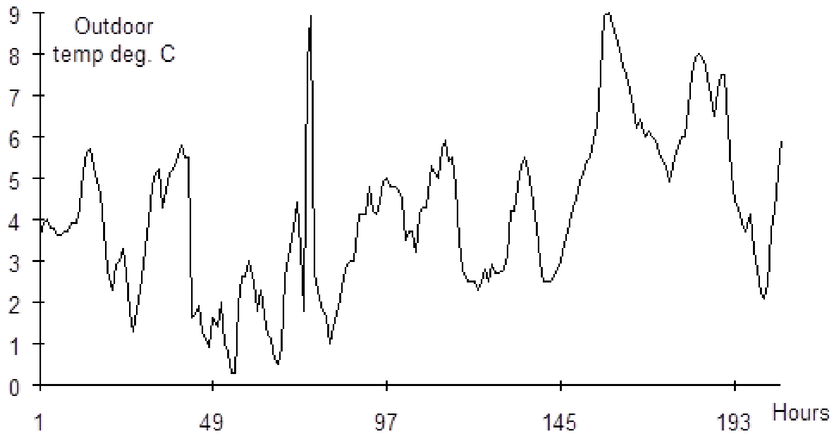

Figure 2: Outdoor Temperature in Linköping Two Weeks in January, 1990

the building or its system for energy regulation.

References

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[2] Gustafsson Stig-Inge and Karlsson Björn G. Life-Cycle Cost Minimization Considering Retrofits in Multi-Family Residences. *Energy and Buildings*, 14(1):9–17, 1989.

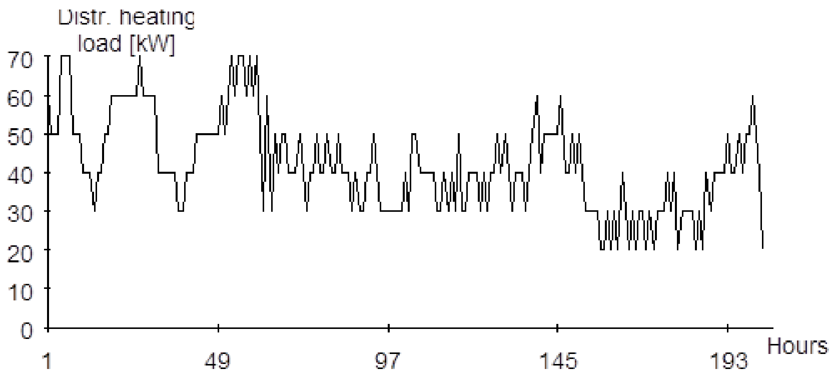

Figure 3: District Heating Load in Office hotel, Linköping, Sweden, During Two Weeks in January, 1990