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How Can Energy Be Saved in Offices, Schools, Hospitals, etc?

by Prof. E. Abel, Chalmers University of Technology, Sweden

In many respects, development in energy technology within the building sector since the middle of the 1970s has been impressive. As a result of energy conservation, the annual energy demand for heating purposes in the country's existing building stock has been reduced by over 20 TWh.
As far as the design and construction of new buildings is concerned, we possess knowledge and technology today that allows us to build with high energy efficiency. Not least important is the fact that there is now a solid fund of knowledge concerning the methods and technologies that should be used, as well as those that should be avoided.
But there is still, unfortunately, much that can be criticised in this largely favourable development. If any technological development is to be thoroughly successful in the long term its results must be constantly monitored.
The critical analysis must include physical systems, components and apparatus, as well as the interaction between them. It is important that any shortcomings in the physical designs in which development has resulted should be identified, that any tendencies to apply uncritical sub-optimisations should be recognised and that lines of development, methods of thinking and physical designs that can be suspected of giving rise to problems in future should be indicated.
Energy conservation and management in existing buildings, and energy-efficient construction of new buildings, represent such a wide and complex area of technology that they cannot be analysed in a single context.
The critical review sketched above must therefore be divided in practice, into a number of sub-aspects. In this article we consider some of these aspects as related to building services systems. We therefore consider primarily buildings containing a considerable quantity of such equipment, which means that they are more advanced in terms of building services systems than residential buildings.

The demand for electrical energy

It is very important to distinguish between thermal energy and electrical energy. If we look more closely at developments in heat demand and electricity demand since the mid 1970s we can see that they have followed completely different paths.
Figure 1 is a simplified diagram showing the country's fuel consumption and electricity consumption in residential buildings and non-industrial, non-residential premises. Fuel consumption is expressed in terms of the amount of heat released on combustion.
The diagram is too schematic to allow any in-depth analyses, but it does show very clearly that the consumption of fuel has fallen drastically while the use of electrical energy has increased considerably. This increase is mainly due to a significant increase in the use of electric heating.
If we subtract the quantity of electricity used for heating, we are left with the amount used as domestic electricity and for operation of household appliances, lighting, etc. Again, we can see that there is a rising trend.

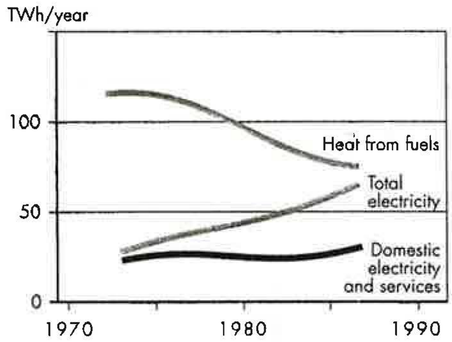

Figure 1: Fuel consumption and use of electricity in residential and non-industrial non-residential premises

In other words, there is no reduction in the use of electricity to match the successful reduction in oil consumption and total heat demand in the country's building stock. There are several reasons for this, these are considered in more detail below.
A review of the many Swedish energy conservation projects reveal that, the work has in practice been concerned almost exclusively with the conservation of heat as opposed to energy conservation. There have, until recently, been hardly any conscious attempts to reduce that portion of energy use met by electrical energy.
There has, indirectly, been a certain conservation effect as a result of improvements in the design and insulation standards of electrically-heated detached houses, but this has had little more than a marginal effect on the total use of electricity in the country as a whole.
The reason for this is due partly to the fact that high priority was given to reduction of all forms of oil consumption, and partly to the fact that electrical energy was cheap in relation to oil.
We cannot, however, disregard the fact that it is relatively easy to reduce the demand for heat, while

being technically and economically more difficult to reduce the demand for electricity once it has been created. Another explanation for the increased level of use of electricity can be that certain energy conservation measures result directly in a greater use of electrical energy. This may be done consciously and deliberately, e.g. through installation of a heat pump. In this case, a balance has to be struck between reduced fuel consumption - normally in the form of oil consumption - capital cost and running cost for electrical energy.
Or consumption of electricity may have been increased more or less in passing, as when, for example, installing equipment for heat recovery from ventilation exhaust air in offices, hospitals or industrial premises. The resulting heat savings are often so considerable that there is no question of the installation not being economically viable. However, it does involve increased energy demand for fans to compensate the pressure drop across the heat exchanger and the filters that are often needed in the exhaust air circuit.
Finally, increased consumption may be largely unconscious, as when carrying out alterations to the building that result in a greater surplus of heat for a longer period during the year, leading to a correspondingly increased requirement for ventilation and cooling. We return to this in Figure 3.

The balance temperature of a building

All modern Swedish buildings have a very low energy consumption level. This means that, in general, they only need a very modest heat input. It also means that the heat released inside the building, which is always the case when a building is in use, will meet much of the heat losses from the building.

From the thermal balance of a building with its surroundings, we can calculate a simple measure of the thermal insulation performance of the building, based on the following reasoning: A building loses heat to its surroundings through its climate screen and through uncontrolled air leakage. The losses are proportioned to the difference between the indoor temperature and the external ambient temperature. As the ambient temperature drops, heat losses increase. At a particular outdoor temperature, the heat losses are balanced by the internal rate of heat release. This temperature is referred to as the balance temperature of the building. When the ambient temperature is below the balance temperature, additional heat must be supplied to the building to prevent the indoor temperature from falling. If the ambient temperature exceeds the balance temperature, heat must be removed in order to prevent indoor temperature from rising.
The three duration diagrams in Figure 2 illustrate how the balance temperature in newly-built detached houses has changed over a period of three decades, reflecting higher insulation standards and improved airtightness.
The diagrams show, for example, that the number of hours per year during which heat is required has fallen drastically. One of the reasons for this is that in present-day well-insulated houses with triple-glazed windows, interior surfaces are at higher temperature than they were in older houses. This has allowed room temperatures to be lower, while retaining the same subjective feeling of comfort.
New well-insulated detached houses therefore have an internal surplus of heat for almost half the year. However, in the case of this type of building, no particular problem is involved as it is easy to open the windows to ventilate excess heat.

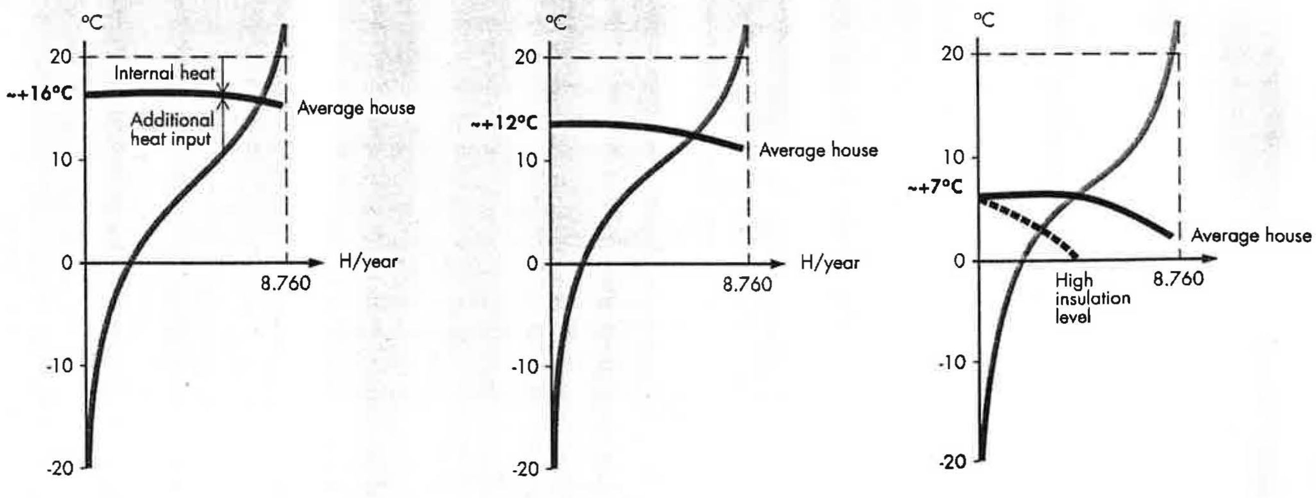

Figure 2. The three diagrams illustrate the balance temperatures for detached houses from the 1960s (+16°C), the 1970s (+12°C) and the 1980s (+7°C) and represent average values for normal households: naturally, wide variations can occur.

Surplus heat increases energy demand

The situation is different when we leave the residential sector and consider non-industrial non-residential premises. These buildings are generally more compact, and can have considerably higher internal heat release rates than residential buildings.
Figure 3 shows the duration diagrams for two newly-built office buildings and their balances between internal heat release and heat losses through transmission and air leakage. Both buildings incorporate office rooms along the outer walls, with an inner zone between them.
The first diagram relates to a building with only very modest internal heat release, a lighting power density of 10W/m2 in inner rooms, few occupants and only a few items of office equipment. Window area amounts to about 30% of facade area, and the windows are well shaded.
The second diagram represents a building with lighting powers twice as high, i.e. 20 W/m2 and 30 W/m2 respectively, and with more office equipment. However, it is in no way extreme, and both buildings comply with present-day building regulations.

The two buildings have balance temperatures of about +3°C and - 6°C respectively. If we consider ambient temperatures as encountered in central and southern Sweden, we find that the ambient temperature is lower than +3°C for about 2500 of the 8760 hours in the year, while it is below - 6°C for only about 600 hours of the year.
This illustrates that there is little demand for heat in present-day offices and non-industrial non-residential premises: instead, it is cooling that tends to dominate the energy situation. Normally, the ventilation equipment is sufficient to provide the necessary cooling.
Summing up, it can be said that the justified requirements of the residential sector for high insulation performance tend to have been transferred to all other buildings without stopping to think if this was really necessary or appropriate.
It is particularly disturbing when even higher standards of insulation and improved windows are mooted for individual non-residential projects without simultaneous analysis of, and allowance for, the unavoidable internal heat load.
Designers do not always appear to appreciate that they are achieving only very marginal reductions in heat losses at the cost of more complicated internal climate control systems. At the same time, there is an increase in the amount of energy required for the internal climate control equipment, primarily in the form of electrical energy, which is presumably far from negligible.

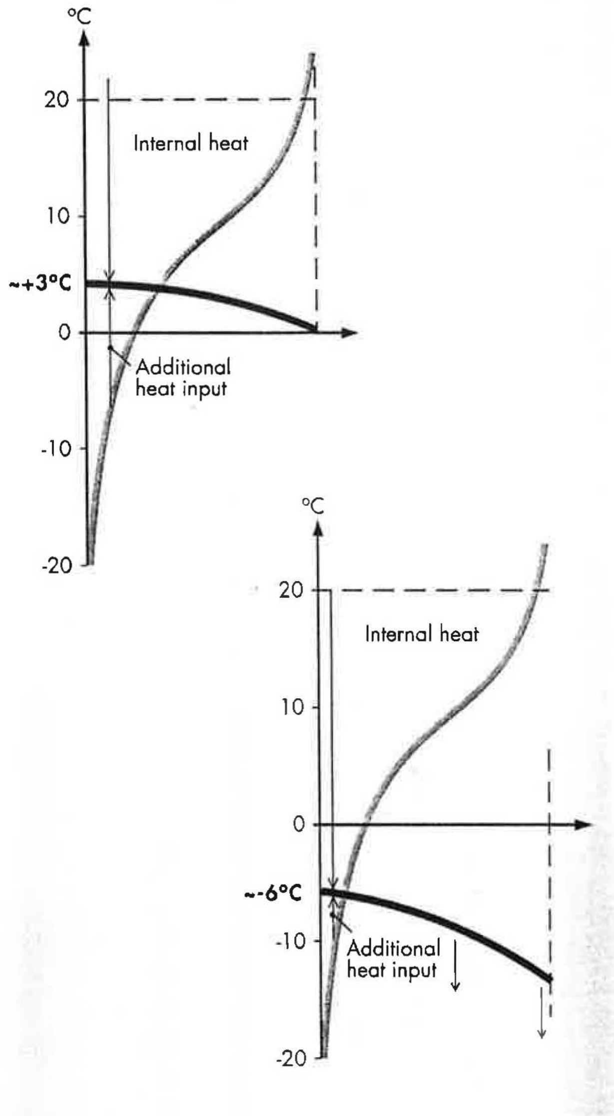

Figure 3. Balance temperatures for two newly-built office buildings

Conclusions

It is very important that designers carefully consider energy requirements at an early stage, with particular attention being paid to the need for electrical energy. This applies to all types of buildings and in particular to non-industrial non-residential premises.
Building design features that result in the need for high fan powers and considerable quantities of artificial cooling should be avoided as much as possible.

Further reading:
Energy 85 - Energy use in the built environment
BFR D1: 1985.