

Comparison of energy efficiency of buildings build to different standards and rules.

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Introduction

The total emissions from a building depend on a number of factors which are more or less mutually dependent. However, when trying to evaluate the quality of a building with respect to emissions it can be useful to describe these factors individually.

In the following the factors are grouped under the following captions:

- 1 *Building characteristics*
- 2 *Climate and site*
- 3 *Use of building*
- 4 *Energy sources*

1 Building characteristics

These characteristics ought to be independent of the actual site, use and energy supply if they should represent the building as such. However, no 'best' building exists, the most desirable features depends on the site, the use and the supply source of energy.

Transmission loss

An important measure is:

The transmission loss per m^2 usable floor space (W/m^2K)

This is the energy need pre degree temperature difference between inside and outside and therefore not dependent on the actual site. A problem is that the loss to the ground depends somewhat on the temperature variation over the year.

Th3 loss shall include all 2D effect (2 dimensional effect or line losses) or and 3D effects (point losses). The usable floor space is the area measured inside the exterior walls, but including the internal walls. Generally, it yields that the lower the better, with an exception for the contribution from windows as discussed below.

Heat accumulation

Another interesting feature is the heat (or coldness) accumulation ability. At least two different characteristics are of interest:

The ability to even out short time temperature variations (24 h period)

The ability to even out long time temperature variations (a week or so)

Especially the first depends on how fast the heat can get in and out of the building parts, which means that both the thermal conductivity and the heat capacity of the building components are of interest. A high accumulation ability is advantageous if the temperature should be kept constant, but decreases the gain that can be achieved by eg decreasing the temperature during night or when the building is not being used.

How can these characteristics be described in numbers??

Glass characteristics

The glass of the windows (including doors) should also be characterized because the U-value included in the transmission loss is far from sufficient to describe the glass. It can be described by 4 types of information:

- 1 *The glass area per m² usable floor area and its distribution towards each compass direction*
- 2 *The energy transmission factor (solar factor)*
- 3 *The daylight transmission factor*
- 4 *The centre U-value*

The glass area is only the visible area. It can be less than 50% of the area of the window opening in the wall, and is almost never more than 80%. The distribution between different orientations is important for estimating the energy transmission.

The energy transmission factor describes how much of the sun energy that is transmitted into the building. The factor ranges from 76% for 2 layers of normal glass down to about 25%. It is used to estimate the passive solar gain and/or the cooling need. Possible shadows from eg roof overhang should in principle also be described, but it is difficult to describe in a simple way.

The daylight transmission factor describes how much visible light that gets into the building. The factor ranges from 80% for 2 layers of normal glass down to about 30%. The factor is necessary for estimation of the daylight level inside and therefore also the need for electric light. The factor is physically limited to twice the energy transmission factor because half of the energy of the sunlight is the visible part. Generally, a high value is preferable and if the daylight factor becomes below about 65% many people will find the quality of light dissatisfactory due to the 'sunglasses' effect.

A glass area equal to about 10% of the floor area is often regarded as satisfactory. Shadows, position of the windows in the facade, colouring of light and reflections properties of eg the sealing ought also to be described, but again it is quite complicated.

The centre U-value is the 1D insulation properties of the glass including coatings and gas filling when the edge effects are ignored. Both the centre U-value and the edge effects are included in the transmission loss. One reason to specify the value is that if a low transmission loss is achieved by choosing glass with a very low centre U-value there is a risk of outside condensation, which reduces the visual comfort. Centre U-values below about 1 W/m²K are likely to cause such problems, depending on the site.

Other U-values?

The U-value of exterior walls, roof and ground floor are also characteristic values for the building. But the 2D effect along all joints between different building parts can be significant and depends strongly on how well the two parts match each other. If the 2D effects are distributed to the U-values of the joining building parts, how should it then be divided?

This becomes even more complicated when it comes to windows. Besides the 1D loss through the main part of the glass there are 2D effects where the glass meets the window frame, both due to the frame and the spacer profile in insulating glass units. Then there is loss through the frame and 2D loss where the frame meets the wall. The wall might also have reduced insulation around the window in order to accommodate for the window which causes extra 1D loss and a further 2D effect. So which of these losses should be attributed to the glass, the window and the wall?

The conclusion is that it will be very complicated to define meaningful U-values for building parts, so only the transmission loss can be a key parameter.

2 Climate and site

The climate on the building site is very important for the energy consumption. Both high and low temperatures are challenges, so the outdoor temperature should be known over the year. The effect of the sun depends both on the latitude and the number of hours of sunshine.

3 Use of building

The actual use of the building, such as dwelling, office, school, store etc, defines important parameters as

- acceptable max and min temperatures during the day and over the year*
- ventilation need (air changes per hour)*
- electricity for lighting*
- energy for production of hot water*
- electricity for appliances (computers, cookers, etc)*
- heat contribution from people*

The design of the building itself has little or no effect on these parameters but they influences the energy consumption and possibly the quality of the indoor environment significantly.

The wider the acceptable temperature range is, the smaller is the energy consumption for staying within the limits. Similarly, a low air exchange rate consumes less energy than a high. This becomes a choice between energy consumption and the quality of the indoor environment This yields no matter if it is heating or cooling that is needed.

The need for electrical light is both dependent on the use of daylight and the effectiveness of the lamps used. Depending on the type of building the designer has some influence on the lamps used, but the main influence is to ensure effective use of daylight because lamps are likely to be replaced. As regard hot water the designer might have some influence on the choice of showers and tabs, until they are replaced. The influence on electric appliances is even smaller.

The electricity used for light and appliances together with the heat contribution from people will always contribute to the heating, whether it is desirable or not.

4 Energy sources

The above discussed three factors defines the Net Energy Need, after the passive gains are taken into account. The energy needed can be:

- A. *supplied from external sources,*
- B. *produced on site, or*
- C. *obtained by multiplying externally supplied energy.*

A. Among external sources are:

- 1 *Electricity from power plant*
- 2 *Coal*
- 3 *Oil*
- 4 *Gas*
- 5 *District heating*
- 6 *Wood and similar renewable source*

B. On-site sources should require none or very little external supply of energy. It could be:

- 1 *PV solar cells*
- 2 *Wind mills*
- 3 *Solar panels – water based*
- 4 *Home grown wood*

C. The externally supplied energy can be multiplied by equipment on site such as:

- 1 *Heat pumps, requires electricity and a reservoir*
- 2 *Heat exchangers, requires electricity for ventilators*
- 3 *Local combined heat and power plant*
- 4 *Fuel cells*

It is tempting to regard the environmental impact only as the energy supplied externally, but it is actually difficult to assign even on site sources entirely to the site.

A reduction of the electricity consumption for a specific building means that the electricity produced on site could be sold and thereby reduce the need for producing electricity with fossil fuel somewhere else. Further, most tools producing electricity (B1, B2, C3) depends on the possibility to 'store' excess energy on the electricity network. The environmental impact from using on-site produced electricity can therefore be argued to be the same as for electricity from a power plant.

Solar panels for producing hot water (B3) is a more truly on site production with storage on site. But it is absurd to claim that it should be better for the environment to use the roof for such solar panels than for solar cells producing electricity.

Burning home grown wood is usually cheap, but it could alternatively be used in a power plant where it is likely to produce more valuable energy (electricity) and cause less emissions. This requires some transportation, but the energy for that is usually small compared to the gain. The wisdom depends much on which other sources that are available for heating on the actual site, but from a global point of view the wood is not free.

Heat pumps and heat exchangers might be efficient, but it depends on the local conditions. If a attractive reservoir is available on site the heat (or coldness) taken from it could be regarded as free, so that only the electricity needed should be accounted for. But the only case where the gain factor will be significant is if cold see water can be used for cooling or a hot spring for heating. In most other cases the gain factor is quite close to the rate between electricity and heat with regard to both value and emissions.

In conclusion, the way the needed energy is obtained is usually not very important for the environmental impact. There might be circumstances where an energy source could be regarded as 'free', but it is rare.

Accounting

The best building for a specific purpose on a given site is not necessarily the building that requires the least energy. It is necessary to weigh the need for electricity as a high quality type of energy against the need for simple heating that can be fulfilled by low quality heating such as district heating from a combined heat and power plant.

The 'true' minimum environmental impact of a specific building could be estimated using average factors for recalculating the need energy for heating, cooling, lighting etc.

Removing 1 kWh of heat with an air condition equipment might require 3 kWh of electricity. Supplying 1 kWh for heating with a heat pump might only require 0,3 kWh of electricity.

In order to account for the net energy consumption without dealing with the specific sources of energy supply it is suggested to investigate two scenarios that weigh the needs with factors as follows:

<u>Scenario</u>	<u>I</u>	<u>II</u>
<i>Heating of floor space and hot water:</i>	<i>0,3</i>	<i>0,4</i>
<i>Electricity for light and appliances</i>	<i>1,0</i>	<i>1,0</i>
<i>Cooling of floor space</i>	<i>3,0</i>	<i>2,5</i>

These scenarios reflects that it is often more important to design so that the cooling need is minimized rather than trying to gain 'free' energy for heating.