Crossroad between sustainability and energy efficiency

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Abstract:
Based on the European directive (2002/91/EG) the European Parliament and Council decided that the Member States must apply performance low energy requirement for new and existing buildings. To ensure the certification of energy performance the regular inspection of boilers and air conditioning systems in buildings are necessary. The choice of individual building components but also heating, cooling and ventilation systems as well as lighting significantly influence the energy performance of buildings.
This paper deals with the comparison between two different standards for energy savings calculations of residential buildings: the German standard DIN V 4108-6 and the American standard ASHRAE 90.1.
Therefore an exemplary residential building is calculated with both standards and two different building components. A typical lightweight timber-frame construction is compared with a heavy lime sand brick wall construction. Both constructions are used to reach the German energy standard and also a low energy standard.
As a result, the energy demand of the variants is compared and analyzed by Life Cycle Assessments and their thermal comfort. For calculating the energy demand but also analyzing the thermal comfort and the life cycle assessment the software programs DÄMMWERK and WUFI Plus are used.

Keywords: *low energy building; energy efficiency; sustainable; life cycle assessment; thermal comfort*

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1. Standards

The German standard DIN V 4108-6 is used to calculate the energy demand of residential buildings. On one hand this standard considers heating and hot water demand but also if necessary ventilation and cooling demand. For calculating the energy demand it is also essential to calculate the internal and solar heat gains but also the ventilation and transmission heat losses. The energy demand is calculated by using tabular method following the German standard DIN 4701-10. This method is only applicable for residential buildings. Characteristic values for the technical equipment are listed and are related to effective area. The American standard ASHRAE 90.1 is also used for calculating the energy demand. Therefore, the building geometry, the thermal building envelope and the technical equipment as well contain the basis. But also it is essential for LEED-certifications.

2. Investigation

Fig. 1 shows the chosen exemplary residential building. It is a single-family house with a length of about 8.00 m and a width about 8.00 m. It is completely heated. Therefore, the external components are also the thermal building envelope.
The energy balances are calculated with the building physics software DÄMMWERK for the German standard DIN V 4108-4 and with the software WUFI Plus for the American standard ASHRAE 90.1.

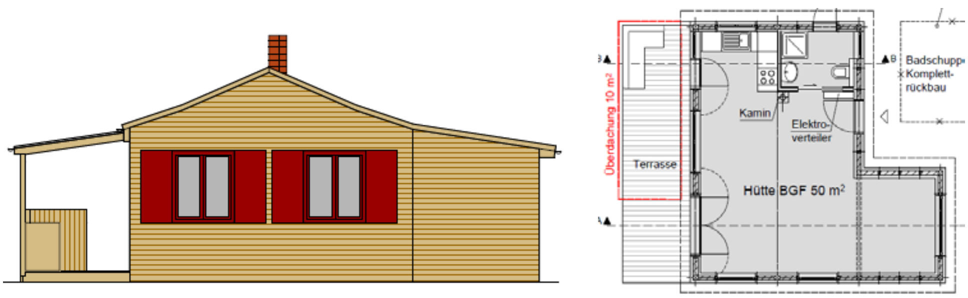

Fig. 1 Exemplary building.

An eco-balance analyses the ecological impacts of buildings across the entire life cycle. Therefore, the primary energy demand – renewable and non-renewable – but also the global warming and acidification potential are considered. Basically, the ökobaudat-database of environmental product declarations is used.

Table 1 shows the structural components and their heat transfer coefficients (U) but also the acceptable heat transfer coefficients according to the German Energy Saving Directive (EnEV 2012). These structural components with their heat transfer coefficients and also the gas condensing boiler as technical equipment form the standard versions. As mentioned above, there are four variants: German energy standard with lightweight timber-frame construction or heavy lime sand brick wall construction and low energy standard with lightweight timber-frame construction or heavy lime sand brick wall construction.

Table 1 Heat transfer coefficient and technical equipment of building construction

Structural component	**Heat transfer coefficient for german energy standard [W/(m²K)]**	**Heat transfer coefficient for low energy standard [W/(m²K)]**	**Acceptable heat transfer coefficient (EnEV 2012 – for refurbishment) [W/(m²K)]**
Base plate	0,26	0,14	0,50
Exterior wall	0,24	0,11	0,24
Steep roof	0,24	0,11	0,24
Doors and Windows	1,1	0,7	1,3
technical equipment	gas condensing boiler	pellets heating	-

3. Energy and Thermal Comfort

For the calculation the reference data of the German Meteorological Service for the city of Berlin was selected as climate boundary condition. The hourly climate data records include data amongst others for the temperature, the humidity and the solar insolation. Based on these meteorological data the ASHRAE 90.1 simulated hourly and the German standards DIN V 4108-6 with monthly mean values.

Table 2 energy demand by heating

Heating	**German energy standard - lightweight construction**	**German energy standard - heavy construction**	**low energy standard - lightweight construction**	**low energy standard - heavy construction**
DIN V 4108-6 [kWh/(m²a)]	137,1	123,2	63,9	55,2
ASHRAE 90.1. [kWh/(m²a)]	125,5	112,8	46,5	41,3

The standard DIN V 4108-6 uses as a storage mass 15 Wh/m³K for lightweight construction and 50 Wh/m³K for heavy construction. As shown in Table 1 the hourly calculated results of WUFI Plus are lower than the monthly calculated, because the solar radiation is taken into account in the simplified calculation model in winter only.

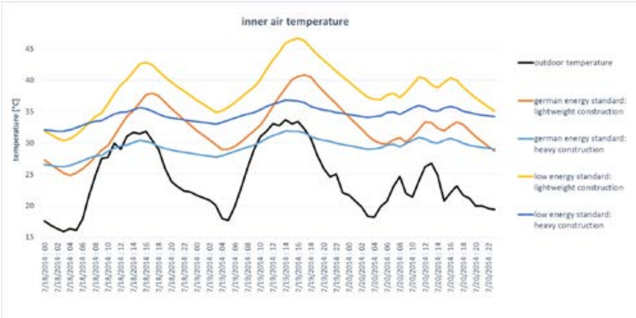

Fig. 2 Compare inner air temperature and outside air temperature.

Fig. 2 shows the calculated inner air temperature of the building for an extreme summer day. The inner air temperature is lower for the heavy construction. For all building simulations the same air tightness is assumed. Due to the fact that for the lightweight construction the thermal mass is lower, the inner temperature is increased. In this case the inner air temperature oversteps the thermal comfort level of maximal 26°C and a mechanical ventilation or cooling is necessary.

4. Life Cycle Assessment

To compare the variants ecologically the environmental aspects are calculated based on a life cycle of 80 years. For this purpose, the building is considered during the whole lifetime for construction, maintenance and operation. As quantifiable impacts the annual global warming potential (GWP), the acidification potential (AP), the input of renewable and not renewable primary energy (PEI) is chosen. In Figs. 3 - 5 the annual impacts relating to the building area are illustrated. It is obvious that it is also ecologically useful to optimize the heat transfer coefficient in northern Europe in any case, because the operation is higher as the construction and maintenance. Comparing the German energy standard with the low energy standard a decrease of environmental impact is possible (Fig. 3). The thermal mass and cooling down have an influence on the total primary energy. With the use of renewable energy sources is also increases the renewable primary energy and falls the non-renewable primary energy.

Fig. 4 shows that also GWP can be reduced up to 80% with the central wood pellet heating. The GWP in construction is lower for timber frame construction as for lime sand brick construction, but varies with the maintenance and operation. This is caused by the maintenance intervals and the thermal mass.

In Fig. 5 the acidification potential of the different variants are displayed. The most serious effect on AP are provoked by the type of fuel. A central pellet-heating with wood as a renewable resource has the worst effect on AP. The central gas heating in contrast has the lowest AP.The maintenance intervals have an influence on AP of the variants, as well. Wood needs a special attention in coating protection.

In summary it is difficult to assess which variant is the most ecological in total. As there are no state of the art for ecological parameters in Germany, the weighting depends on aims of the building owner. Moreover, there are further possible considerable impacts on the environment which were not part of the calculation but could provide advanced aspects.

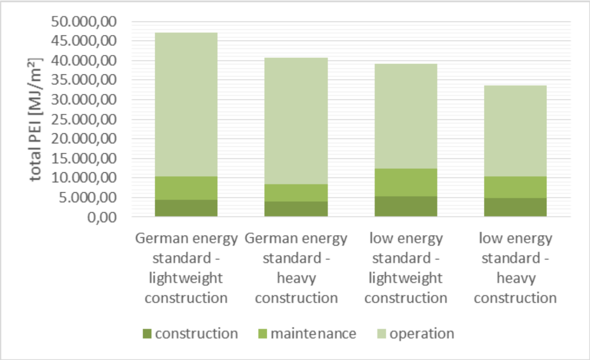

Fig. 3 total Primary energy input (PEI).

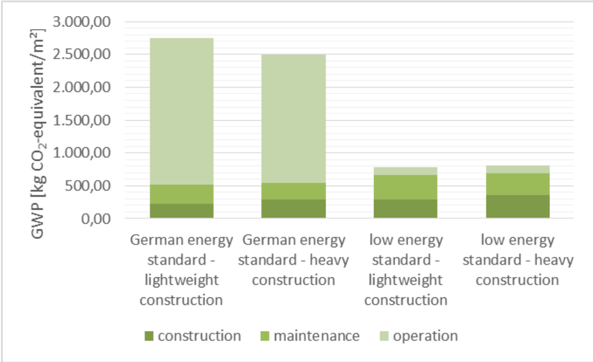

Fig. 4 Global warming potential (GWP).

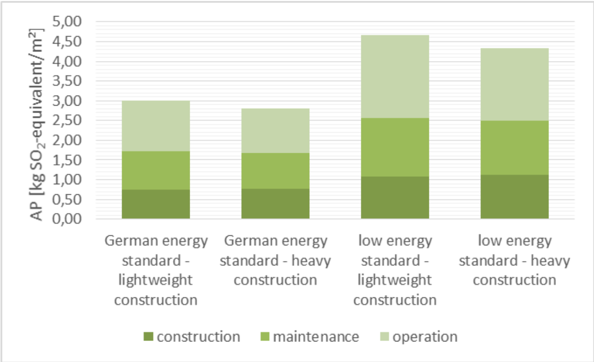

Fig. 5 Acidification potential (AP).

5. Conclusion

The investigation shows that in any case the reduction of the useful energy over current standards is ecologically reasonable. Even an optimization up to a low energy standard is possible. Parameters as the PEI (renewable and not renewable), GWP and AP could help to facilitate the decision between different possibilities. In the calculated example the central wood pellet-heating system and lime sand brick construction is the best choice. The reason is the day-night temperature amplitude of the temperate climate zone. In the interest of sustainability also ecological facts have to be included in decisions. In the time beeing, with expectations of the building owner to obtain a voluntary sustainability certificate ecological parameters are accounted. To improve this situation a political change has to be initiated to create legal frameworks. However, the weighting of impact indicators is still difficult.

6. References

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