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Research Project

Ecological Optimization of the Thermal Insulation of Buildings

(Abstract)

17 January 2013

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MA 50 – Mi 10133/12
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Directives 2002/91/EC and 2010/31/EU of the European Parliament and of the Council of 16 December 2002 and 19 May 2010 on the energy performance of buildings were translated to national level in the OIB Richtlinien 6 „Energieeinsparung und Wärmeschutz“, issue April 2007 and issue October 2011, in regard to mandatory energy certificates for buildings and minimum requirements for new buildings and major renovation/extensive refurbishment projects. Based on these directives and guidelines as well as the National Plan which Austria has to submit to the EU, the requirements for the thermal quality of the building envelope have become ever stricter since 2008 – a development which already started when the first thermal protection requirements for buildings were established after the first Oil Crisis in the 1970s. The potential reduction of environmental impacts due to the higher energy efficiency strongly depends on the source of energy used to cover the heating energy demand.

In this project the reduction of ecological impacts due to the higher thermal quality of the building envelope was calculated for natural gas, light fuel oil and wood pellets and compared with the higher impacts due to the required greater thickness of the insulation, using EPS (expanded polystyrene) as an example for an insulation material.

The model buildings with different surface-area-to-volume ratios were the single family building according to Austrian standard ÖNORM B 8110-6, Supplement 1, with a characteristic length l_c of 1.33 m, representing the worst case, and a building with dimensions near to the passive houses at Utendorfgasse, 1140 Vienna, with a characteristic length l_c of 2.73 m, which is roughly the lower limit for apartment complexes in Vienna.

Energy performance indicators and the required thermal insulation thicknesses to obtain the highest permitted heat demand for new residential buildings as defined by lines 26, 19, 16 (according to the OIB Guidelines 6) as well as 14, 12 and 10 (according to the draft National Plan) were calculated. The heating energy demand per m² of net floor space and year was used as reference indicator. Calculations were done for both buildings with and without ventilation system with heat recovery. According to Commission Delegated Regulation (EU) No. 244/2012 of 16 January 2012, which establishes a comparative methodology framework for the calculation of cost-optimal levels of total energy efficiency requirements for buildings, the calculations were performed for a period of 30 years. In order to quantify the influence of the calculation period on the results a period of 20 years was calculated too.

Ecological indicators were determined on the basis of the ecoinvent v2.2 database, using GaBi 5.0 software and the CML 2001 (November 2010) method. The following indicators were analysed:

- Primary Energy (total and non-renewable),
- Abiotic Depletion Potential, elements,
- Abiotic Depletion Potential, fossil fuels,

- Global Warming Potential,
- Acidification Potential,
- Eutrophication Potential,
- Ozone Depletion Potential and
- Particulate Matter.

The photochemical ozone creation potential was not taken into account, because the method does not include seasonal weighting and it does not make sense to correlate the emissions of heating in winter with the summer-smog potential.

The contributions of the insulation material and of the energy needed to cover the heating energy demand to the indicators were plotted against the heating energy demand. The contribution of the needed energy decreases with higher thermal quality of the building envelope whereas the contribution of the insulation material to the respective indicator rises due to the greater thickness of the insulation material. The environmental optimum for each indicator is characterised by the minimum of the cumulative curves of these two contributions. The cumulative curves of the three energy sources were compared.

The results of the research project can be subdivided into the following 4 categories:

Surface-area-to-volume ratio

One of the most important criteria for saving energy and therefore reducing ecological impacts is to adjust the surface-area-to-volume ratio in the planning stage of new buildings. The smaller the heat-dissipating surface of the building envelope in relation to the heated (gross) volume, the smaller is the heating energy demand of a building. For the model buildings calculated in this project, the mean environmental impact of the multifamily building per m² net floor space and year over the calculated lines corresponds to, at the most, 72 % of the environmental impacts caused by the single family building in case of window ventilation, and, again at the most, 74 % of the environmental impacts caused by the single family building in case of a ventilation system with heat recovery.

Ventilation System with Heat Recovery

By installing a ventilation system with heat recovery the thickness of the insulation material required to achieve the highest permitted heat demand can be considerably reduced, but the heating energy demand increases by the auxiliary energy required to run the ventilation system. An ecological advantage does not occur for every indicator and only with lines of very high thermal insulation; it is low in comparison with the benefits drawn from other measures, i.e. the surface-area-to-volume ratio or choice of energy source.

Comparison of the Energy Sources

Light fuel oil compares unfavourably concerning all indicators except total primary energy and particulate matter, where the performance of the wood pellets is worst. From an ecological point of view light fuel oil should be considered as the last possibility as energy source.

Natural gas and wood pellets show advantages and disadvantages depending on the indicator considered. Concerning the non-renewable primary energy, the abiotic depletion potential - fossil fuels and the ozone depletion potential wood pellets show the best performance; concerning the total primary energy, the abiotic depletion – elements, the acidification potential, the eutrophication potential and the particulate matter, natural gas performs best. The emission of PM 2.5 of the pellets heating system is ten times higher than that of the gas heating system.

The carbon dioxide assimilated by photosynthesis is released into the atmosphere again when wood is burned. The greenhouse gas emissions of pellets heating systems are markedly higher than those of the other two heating systems, The facts that wood is a renewable source of energy and that it previously absorbed most of the carbon dioxide emitted, should not result in a wasteful use of this energy source. The advantages and disadvantages of using wood as an energy source should be weighed carefully, especially in urban areas, if particulate matter is already an issue.

Optimization of the Environmental Impacts of Heating and Insulation Material

The ecological optima for the single family building and the multifamily building with window ventilation for a calculation period of 30 years are the lines 10 to 12 for natural gas as an energy source, line 10 for light fuel oil, and lines 10 to 14 for wood pellets. For a calculation period of 20 years, the optima for natural gas shift to the lines 10 to 14 for the single family building whilst the optima for light fuel oil and wood pellets remain unchanged (10 and 10 to 14, respectively). For the multifamily building with window ventilation there is no significant shift toward lines of lower insulation when the calculation period is changed to 20 years. The single family building and the multifamily building with a ventilation system with heat recovery show ecological optima at line 10 for all three energy sources.

The ecological optima for the thickness of the insulation material of the external thermal insulation composite systems for the buildings modelled in this project are for the single family building as well as the multifamily building with window ventilation 30 cm for the heating system with light fuel oil, between 20 cm and 30 cm for the gas heating system and between 15 cm and 30 cm for the pellets heating system. For the single family building with a ventilation system with heat recovery the optimal thickness of the insulation is about 15 cm, for the multifamily building with a ventilation system with heat recovery 10 cm are sufficient to reach the optimum, line 10.

Good thermal insulation is important from an ecological point of view. The results for the energy sources examined in this project correlate quite well with presently available results of studies on cost-optimal levels of minimum energy performance requirements for buildings.