ENVIRONMENTAL PAYBACK OF STONE WOOL IN A SOCIETAL ENERGY PERSPECTIVE

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Summary

The primary function of insulation materials is to save energy and to contribute to a good indoor climate. In many building applications savings of more than 100 times the energy invested in their production can be achieved during use. Additionally emissions are produced and saved during the insulation product lifecycle and the balance can be calculated. This paper discusses the environmental benefits of insulation on the basis of a life cycle assessment (LCA) on stone wool. The study shows the life cycle environmental savings by progressively increased insulation levels and discusses the implications for the indoor climate of the construction changes necessary. Finally the economic and environmental aspects of insulation are compared to other global warming mitigation technologies.

Keywords: Energy, stone wool, sustainability, savings potential, indoor climate, passivhaus, passive house

1 Introduction

Energy use is the dominant source of emissions in society. In the EU, buildings are the single largest source of energy use and energy related emissions, presently accounting for about 40 % of the total EU [1] energy use. Therefore it is important to estimate the energy payback rate (energy saved/energy invested) of the possible energy and emission mitigation solutions within societal economic reach in order to find sustainable solutions. This paper provides the background data for calculation of the payback rate of progressively thicker insulation, together with a discussion of the implications for indoor climate and building construction. The paper uses LCA of stone wool as the basis for a discussion going from the building material level and further to building level, European and global level. Finally the paper will discuss the indoor climate related impacts from insulation, in particular stone wool.

2 Methodology

The life cycle energy and emission cost for stone wool, is compared to the energy and emission savings in the use phase in a renovation situation for a building in average European climate and the payback rate is calculated for a roof construction. Using EU statistics for energy consumption and heat loss in present EU buildings, the impact on the European level is estimated. Thick insulation also means that constructions must be changed and care must be taken to ensure a good indoor climate. This aspect is discussed briefly with the German Passivhaus as an example. In the paper, each subject is discussed separately.

3 Stone wool, from material to global perspective

3.1 Stone wool "cradle to grave"

The energy and emission cost of manufacturing stone wool has been calculated in [2]. Basic data from this study (**Tab. 1**) are used as the basis for comparisons of the environmental payback rate. Increasing levels of insulation also result in changes in other building material use and construction dimensions. These changes are addressed quantitatively in section 3.2.1

Tab. 1 Energy consumption and emissions in the life cycle of stone wool

Per kilo Stone wool	Cradle to grave minus use phase
Primary Energy	17.5 MJ/kg
Global warming	1226 g CO_2 eq. /kg
Acidification	10 g SO_2 eq./ kg

The environmental profile of stone wool is characterised by the major energy use being in the production stage with minor contributions coming from binder, packaging, transport and disposal/recycling.

3.2 Building Lifecycle

In (**Tab. 2**) the building lifecycle energy use for two north European buildings is listed [3]

Tab. 2 Building lifecycle energy use in 50 years per m^2

For 1 m^2 floor space	Building weight/ m^2	All materials "cradle to grave minus use phase"	Building heating energy 50 years use phase	Building maintenance in use phase *	Building demolition/ disposal
Wooden house	850 kg	4729 MJ	18900 MJ	1600 MJ	60 MJ
Brick /expanded concrete	1050 kg	5510 MJ	18900 MJ	1600 MJ	74 MJ

Insulation level corresponds to a heating energy use of 105 kWh/m^2 floor space/year.
1 litre fuel oil = 10 kWh = 36 MJ
*) Maintenance is estimated by author as 1 change of windows, ½ floors, 1 new roof and 10 coats of water based paint during 50 years use phase

3.2.1 Construction changes as a result of increased insulation levels

An increase in insulation thickness will usually mean that constructions must change also. The filling of a cavity wall or an attic with granulate insulation will not change constructions much, but when increased insulation levels are used, the wall construction could change from heavy (concrete- brick) to lightweight wood element constructions. In a renovation an external insulation system might be added. An example will illustrate the impact.

For a cavity wall (brick/brick) stone wool an insulation increase from 100 mm to 250 mm for a new 140 m^2 building, the extra material for concrete, roof, rafter (foundation and roof) equals ~2 % of the initial primary energy cost for the whole building. Including the insulation the increase will be +3.4 % ([3] and own calculations). Other building components will usually be changed, balancing the heat loss from different building components. In well insulated buildings with a U value ~ 0.15 W/m^2K, the double “energy” glazing must be replaced with triple glazing and insulated frames, the building envelope must be made airtight and adequate air exchange must be ensured by ventilation with heat recovery.

3.2.2 EU building energy use

Energy for heating and production of hot water in buildings accounts for about 40% of the total energy consumption in EU[1]. Of the building energy use, the heating energy dominates (domestic 68 %, industry 57 %) [4] and an average EU building used ~140 kWh/m2/year for heating in 1997 [4].

3.2.3 Insulation level in the EU

The insulation level for new buildings reflects to some extent the climate zones, with a trend towards relatively less insulation in the warmer climates. Eurima [5] shows the insulation levels in Europe. In 2004 the required roof insulation thickness in the EU ranged from 50 mm in Italy to 450 mm in Sweden, with the major part of countries demanding between 125 mm to 270 mm. Building regulations are revised regularly so the 2004 levels have already changed in several countries.

3.2.4 Building energy savings potential

A recent Danish study Tommerup[6] has shown that 80 % of the heating energy potential in private homes can be saved with a positive payback. The energy savings potential in German homes, correlated to building construction date, has also been estimated by Darup[7]. When renovating a factor 5 reduction in heating energy use is seen as economical.

The above examples show a heating energy saving potential of ~80 % by renovation in countries where the buildings otherwise are considered to be well insulated. With the EU [1] estimate of 40.7 % of the EU energy is spent in buildings, and up to 68 % of this for heating, the EU savings potential for heating energy in buildings can be estimated to about 20 % of the present EU energy consumption.

3.2.5 Energy payback rate

The energy payback rate of insulation of a typical Danish uninsulated (U = 1.54 W/m^2K) family home attic construction, can be seen in (**Tab. 3**) below. The construction is made with rafter / gypsum board ceiling (attic space usually not in use). Adding 250 mm stone wool insulation (U = 0.14 W/m^2K) has an energy payback rate of 128 times in 50 years. If the attic is already insulated with 80 mm and renovated to 250 mm then the energy payback rate of the renovation is 36 times.

Tab. 3 Energy payback for Stone wool attic insulation per m^2 in a Danish climate. [2] plus author calculations. approx. 3200 HDD

Insulation layer thickness mm	Construction U- value W/m^2K	Heat loss 50 years MJ	Life cycle energy cost for stone wool MJ	Energy payback rate 50 years
0	1.54	19958	0	-
80 mm	0.42	5424	44.8	323
250 mm	0.14	1855	140	128
350 mm	0.10	1338	196	94
500 mm	0.072	943	280	67

It is obvious from the table that the energy payback rate is very positive for stone wool insulation levels up to at least 500 mm which is similar or better than Passive house level (U-value ~0.08-0.15 W/m^2K, depending on climate). This is also the case for building renovations. To put things in perspective, then up to 450 mm insulation [5] can already be found in attics in Sweden and Finland.

3.2.6 CO_2 payback rate of insulation

CO_2 emissions saved by insulation are almost proportional to the energy savings, when seen from a national or EU level. The energy mix for the EU is still ~80 % fossil. Therefore the energy payback rates in (**Tab. 3**) are also representative for CO_2 emission payback rates.

3.3 Indoor climate

It is often discussed how the indoor climate will be in well insulated homes because of the changes in the construction. This is exemplified with the Passivhaus, the insulation level of which is at the moment considered a future target for new build and renovation, because it is technically and economically within reach for almost all new buildings, and the principles can be applied to renovation also.

The Passivhaus constructions have a heating energy loss below 15 kWh/m^2 floor/year. This is achieved with insulation U-values below 0.08-0.15 W/m^2K, depending on the climate zone. The building envelope is almost airtight, windows are triple glazed with insulated frames (U-value <= 0.80 W/m^2K) and fresh air is ensured by ventilation with heat recovery.

The improved insulation, the reduction of heat bridges, better windows and ventilation with heat recovery will make the inside walls of buildings warmer in winter, reducing the risk for condensation and mold. This is important for the indoor climate as illustrated by a Scandinavian investigation by Hall [8] showing that close to 78 % of indoor climate problems are related to water or moisture. Another point is the emission from building materials. The focus on emission from building materials in the indoor climate has resulted in better products with low emissions as certified by (national) labelling schemes. To mention a few, the Danish/Norway indoor climate label, the Finnish M1 label for building materials and the German Agbb scheme.

Stone wool products fulfil relevant labelling criteria, where emission of formaldehyde is the main concern.

3.4 Insulation and CO2- mitigation cost

Well insulated and constructed buildings are important in an increasingly energy constrained future. In section 3.2.4. it has been demonstrated, that heating energy savings with insulation are economical to a large degree for the building owner. The question is however, if the savings also can be realized without hurting the public economy. McKinsey [9] has calculated abatement costs for 26 different CO_2 mitigation technologies. Building insulation came out with the lowest abatement cost- negative in fact (-150 € /ton CO2 eq.). Egenhofer [10] has similarly studied CO_2 mitigation technologies and abatement costs and found that IGCC (Integrated gasification combined-cycle power (coal), nuclear and insulation had the lowest (and negative) abatement costs. Finally the IPCC III [11] shows the potential for unspecified savings in energy and CO_2 in the world buildings to 5.5-6 Gton CO_2eq. /year, with a mitigation cost ranging from 20-100 US$/ton, the major part in the low price range.

4 Conclusions

The study shows that the environmental payback of stone wool insulation in buildings is positive for insulation thicknesses that far exceed the existing European building regulation demands. Present stone wool insulation thicknesses can have a 100 times energy payback in a 50 year lifecycle perspective. Finally the study shows that insulation is one of the most cost effective CO_2 mitigation technologies with a high savings potential. Savings of 20 % of the present EU energy use is possible with low societal cost and it is also economical for the individual home owner with present energy prices. The study also indicates the importance of energetically matching all the building components, windows, heating, insulation, ventilation and air tightness in order to get the best result.

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