Sustainable growth
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Carbon footprint of insulation materials beneath building foundations

Comparison of glass foam-granulate (Technopor) with XPS and foam glass sheet

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Table of contents

1 Introduction

The interest in the environmental impacts of products is constantly increasing on the part of both producers and distribution chains as well as of consumers. The media has highlighted climate change and in this case predominantly the greenhouse gas problem firmly within our consciousness.

The "carbon footprint" gives information about all the greenhouse gas-emissions, for which a product is responsible within its life cycle. The greenhouse gas emissions in the carbon footprint are specified in kilograms or tonnes CO_2-equivalent and are related to a functional unit (e.g. 1 kg product, 1 meter conduit pipe or 1,000 units).

In this carbon footprint analysis we compare three different insulation materials which are predominantly used if a high compressive strength is required as well as for their installation effect. One example is thermal insulation between the ground and the foundation slab of a building. The insulation materials compared are glass foam-granulate (Technopor), XPS and foam glass sheet.

XPS insulating materials are slabs of expanded polystyrene. Foam glass sheet is expanded glass in slab form. The main raw materials today mechanically cleaned float glass recyclate (69 Wght-%) and feldspar (22 Wght-%) (Thalmann 2006).

Glass foam granulate (Technopor) is manufactured by grinding glass from bottle banks etc. into powder and mixing it with a mineral activator. The glass compound is carried through a furnace on a steel conveyor where it sinters and forms a slab. The stresses caused by the rapid cooling on exit from the furnace cause the slab to breat into a granuale known as Technopor (www.technopor.at).

The following carbon footprint analysis of these insulation materials was carried out in accordance with the EU/JRC standard (http://lca.jrc.ec.europa.eu/Carbon_footprint.pdf).

2 Data principles

2.1 Definition of the functional unit

The present analysis of the thermal insulation against the ground below the foundation slab of a building is based on a functional unit comprising an area of 11 x 13 metres and/or 143 m^2. Thermal insulation should enable the achievement of a U-value of 0.30 $W/m^2.K$.

The carbon footprint results are given both in kg CO_2- equivalent for this functional unit, as well as in kg CO_2- equivalent per m^2 insulation material.

2.2 Material properties of insulation materials, calculation of required volumes

According to information from the company Technopor 45.5 m^3 glass foam granulate (Technopor) is required to achieve a U-Value of 0.30 $W/m^2.K$ in a given area of 143 m^2 . After compaction of the material on the site, the insulation layer is 24.5 cm thick. The compressive strength of the layer is specified as at least 0.5 N/mm^2 . In its uncompacted state, the density of the material is approx. 175 kg/m^3 (160 – 190 kg/m^3). This means that a total weight of 7,963 kg glass foam granulate (Technopor) is required for the designated functional unit.

XPS is based on a slab sold on the Austrian market which also exhibits a compressive strength of 0.5 N/mm^2. The slab density is 35 kg/m^3, the thermal transmittance is 0.035 W/m.K.[1] To ensure that the U-value achieved in this case is exactly 0.30W/m^2.K a mathematical slab thickness of 11.7 cm is assumed. The resultant total weight of XPS is 584 kg therefore in the case of XPS for the designated functional unit.

A hypothetical slab, with a compressive strength of 0.5 N/mm^2, is also employed in the case of foam glass sheet. The slab density is approximately 120 kg/m^3 (110 – 130 kg/m^3), the thermal transmittance is around 0.044 W/m.K (the manufacturer specifies between 0.038 – 0.05 W/m.K for the designated purpose).[2]In order that the U-value is also precisely 1 W/m^2.K in this case, a slab thickness of 14.7 cm is mathematically assumed. The resultant total volume is 2,517 kg therefore in the case of foam glass sheet for the designated functional unit.

2.3 Greenhouse gas emissions in the life cycle up to the final insulation material

2.3.1 General

The specified greenhouse gas emissions per kg of insulation material comprise emissions from the production process and from the upstream chain (production and provision of raw materials and energy carriers, energy production, etc.).

Electricity mix

Formerly the production of glass foam granulate (Technopor) used electricity whose production mix according to supplier information corresponds to the UCTE Mix (Average European Electricity Mix). After changing its electricity provider in 2008, however all electricity is now from hydroelectric sources. The latest eco-audit for foam glass sheet (Thalmann 2006) is also based on electricity produced 100 % from water- and/or wind power. XPS production data is based on the UCTE-Mix.

In order to achieve optimum comparability of the datasets in the carbon footprint analysis, the results for all three insulation materials are shown in two different comparisons, one based on 100% hydroelectricity and an alternative comparison based on the UCTE electricity mix.

Proportional primary production of recycled glass

The eco-audits employ different approaches in relation to the use of recycled material the allocation of expenses for primary production which relate to the original production of the material.

1. No proportional expenses are assigned to the recycled material from the original primary production. This approach is questionable since it ignores the so-called ecological baggage carried by raw materials from other products systems and the original expenses primary production are allocated 100% to the originally produced products. At the same time however e.g. a recycling credit is generally applied to the float glass product system for recycled material at the end of the lifecycle which assumes that the reuse of the glass recyclate compensates to some

[1] See e.g. Austrotherm XPS® 50

[2] See e.g. Test results + technical data from Deutsche Foamglas GmbH

extent for the primary protection of the glass.

2. In the product system analysed, only so much recyclate, without the proportional primary production expenses, is used as is provided for this project system itself. If for example only 20 % of the product X is recycled at the end of its service life then those recyclate quantities used for the production of product X and which exceed a volume proportion of 20 % at least a percentage (e.g. 50 %) of the original primary production expenses shall be offset.

3. A special The company Technopor states for example that the majority of the glass recyclate used comprises waste from glass sheet collecting plants which cannot be currently used for any other purpose and which would otherwise have to be disposed of. In this case it is justified not to offset the glass recyclate against original prime reduction expenses.

The glass recyclates used in glass foam-granulate (Technopor) and foam glass sheet are initially therefore not offset against proportional primary production expenses in this carbon footprint analysis. A sensitivity analysis illustrates however how the results change if the original primary production expenses is taken into account for 25 % of the glass recyclate used.

Greenhouse gases taken into consideration

Along with CO_2 , this carbon footprint analysis also takes into account HFC-152A and HFC-134a; the propellants sometimes used in the production of XPS slabs.

2.3.2 Glass foam-granulate (Technopor)

Technopor state that the raw materials for the production of glass foam granulate (Technopor) are waste glass and 1.7 % silicon carbide. The data used for CO_2 and CH4 per kg material is from Ecoinvent (2007)[3].

Acording to Technopor, the electricity consumption for production is 97 kWh per m^3 for un-compacted glass foam granulate (Technopor). The data on the life cycle greenhouse gas emissions from hydroelectricity and/or from the UCTE mix are also from Ecoinvent (2007).

[3] A dataset is used for the variant which takes into account proportional glass primary products for glass recyclate, which relates to glass production from 100 % primary material (no recyclate used)

2.3.3 XPS

Data on CO_2 and CH4 per kg XPS (life cycle to final insulating boards) is from Ecoinvent (2007). In the case of XPS the effect of the greenhouse gases escaping during the usage phase was also taken into account: based on information from Exiba (European XPS Associations), by extrapolating the trends from 2004 to 2006 it was estimated that in the year 2007 around 82.6 % of the XPS-slabs used for insulation against the ground were expanded with CO_2. For other XPS slabs it has been assumed that the substitution of HFC- 134a is progressing more rapidly than substitution of HFC-152a and that therefore around 1/3 of the volume not expanded with CO_2 has been expanded with HFC-134a and around 2/3 with HFC-152a. It is also assumed that a maximum 10 % of the propellants will escape in the case of subterranean use of XPS. With a percentage by weight of 9 % of the whole expanded volume and GWP100 factors of 120 for HFC-152a and 1,300 for HFC-134a this estimate results in 0.64 kg CO_2-equivalent per kg XPS of propellants escaping during the usage phase.

2.3.4 Foam glass sheet

Data on greenhouse gas emissions with respect to finished foam glass sheet slabs has been taken from the current ecobalance for foam glass sheet (Thalmann 2006).

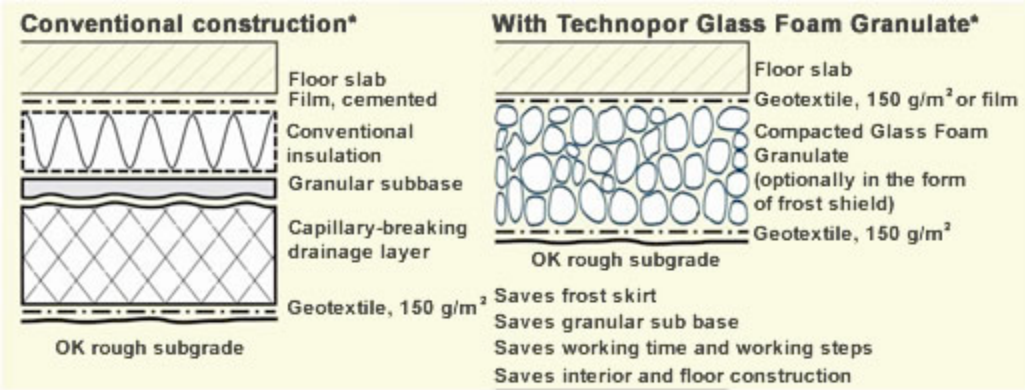
2.4 Shipping in Austria from the producer to the place of use

A distance of 200 km has been assumed for shipping in Austria from the producer to the place of use. The CO_2 emissions have been calculated based on a HGV with max. 16 tonnes laden weight depending on the necessary mass for the selected functional unit.

2.5 Installation

The conventional construction beneath a foundation slab generally comprises a geotextile, 20 – 25 cm gravel, 3-5 cm concrete, insulating material and film. When using glass foam granulate (Technopor), the properties of the sealed glass foam granulate (Technopor) mean that there is no need for the layers of gravel and concrete (see figure below from a Technopor brochure). There is also less excavation required.

These differences have also been taken into account in the present carbon footprint-analysis in which all required data has been taken from Ecoinvent (2007).



2.6 Usage phase

Since a U-value of 0.30 $W/m^2.K$ has been achieved in the present comparison of all insulation materials, there are no differences between the insulating materials in the usage phase. The use phase is therefore not taken into account in this carbon footprint analysis. Basically the energy and/or CO savings achieved by all insulation materials in the usage phase are generally at least 100 times greater than the emissions resulting from production of the insulation materials (GUA/denkstatt 2006).

2.7 Wastes

It is assumed that the insulation materials remain permanently below the foundation slab and there are no waste economy affects to take into account.

3 Carbon footprint calculation table

	Unit	GFG (Technopor)	50 XPS	Foam glass sheet
Functional unit				
Area	m^2	143	143	143
Volume	m^3	35	17	21
Density	kg/m^3	227	35	120
Thermal transmittance	W/mK	0.074	0.035	0.044
Thickness	cm	24.5	11.7	14.7
U value	W/m^2K	0.30	0.30	0.30
mass	kg	7.963	584	2.517
Compressive strength	N/mm^2	*0.50*	*0.50*	*0.50*
Insulation material production				
Raw material				
Allocation of glass primary products for glass recyclate				
Cumul. energy expenditure	MJ/kg	16.51		16.51
THP CO_2 equivalent	kg CO_2/kg	0.60		0.60
Proportion taken into account	0–50% of recyclate	0%		0%
SiC for GSG	MJ/kg	167		
	kg CO_2/kg	7.08		
	kg SiC / kg GSG	0.017		
Processing				
Electricity	kWh/m^3	97		
Electricity	MJ/kg	2.00	3.49	5.47
Total production phase				
Cumul. energy expenditure	MJ/kg	8.50	93.43	27.44
THP CO_2 equivalent	kg CO_2 / kg prod.	0.12	3.75	1.24
THP CO_2 equivalent	**t CO_2 / FU**	**0.98**	**2.19**	**3.11**
Comparison with CO_2-equ. per kg material		*1.0*	*30.3*	*10.0*
Comparison with mass per functional unit		*1.0*	*0.1*	*0.3*
Comparison with CO_2-equ. per functional unit		*1.0*	*2.2*	*3.2*
Shipping				
Outward journey only (return journey used otherwise)				
	kg CO_2 / km	0.85	0.85	0.85
	Use of loading capacity	50%	4%	16%
	km	200	200	200
THP CO_2 equivalent	**t CO_2 / FU**	**0.14**	**0.11**	**0.11**
Installation /usage phase				
Geotextil	Mass [kg]	21.5		
	t CO_2 / FU	**0.06**		
Film	Mass [kg]		26.8	26.8
	t CO_2 / FU		**0.07**	**0.07**
3-5 cm compact concrete	Mass [m^3]		5.7	5.7
	t CO_2 / FU		**1.81**	**1.81**
20-25 cm gravel	Mass [t]		64.4	64.4
	t CO_2 / FU		**0.17**	**0.17**
Overbreakage	Mass [m^3]		19.5	19.5
	t CO_2 / FU		**0.01**	**0.01**
Total installation phase	**t CO_2 / FU**	**0.06**	**2.06**	**2.07**

4 Results

The following table summarises the results of the carbon footprint analysis of the insulation materials analysed:

		GFG (Technopor)	50 XPS	Foam glass sheet
Carbon Footprint of insulation materials beneath building foundations				
Variant - 100% hydroelectricity				
	t CO_2-equ. / FU	1.18	4.36	5.29
	kg CO_2-equ. / m^2	**8.3**	**30.5**	**37.0**
Variant - UCTE mix electricity				
	t CO_2-equ. / FU	3.23	4.62	7.06
	kg CO_2-equ. / m^2	**22.6**	**32.3**	**49.4**
Variant - hydroelectricity and 25% primary production glass taken into account				
	t CO_2-equ. / FU	2.38	4.36	5.59
	kg CO_2-equ. / m^2	**16.6**	**30.5**	**39.1**

Table 1: Results of the carbon footprint analysis for the insulation materials, glass foam granulate (Technopor) XPS and foam glass sheet used for thermal insulation against the ground below the foundation slab. Greenhouse gas emissions over the entire lifecycle up to installation are specified firstly in tonnes CO_2- equivalent per selected functional unit (area of 11 x 13 metres) and secondly in kg CO_2 per m^2 of insulation material. A U value of 30 $W/m^2.K$ is achieved in all cases. The variants illustrated are described in more detail in section 2.3.1.

In all three illustrated variants, glass foam granulate (Technopor) exhibits the lowest carbon footprint. In the use of 100 % hydroelectricity, as contractually planned by the producer of Technopor for the year 2008, greenhouse gas emissions over the life cycle are the equivalent of **8.3 kg CO_2 per m^2 insulation material for a U value of 30 $W/m^2.K$**.

The results further show that both in the case of glass foam granulate (Technopor) as well as in the case of foam glass sheet the carbon footprint essentially depends on the type of electricity generation. In the case of glass foam granulate (Technopor) the carbon footprint in the case of UCTE mix electricity is 2.7 times higher than 100% hydroelectricity.

Taking into account the proportional expenses for the original primary production of glass in the use of glass recyclate (see 2.3.1) can also affect the results significantly. Given however that 67 % of the glass reproduction in the case of the use of hydroelectricity was calculated for the product glass foam granulate (Technopor), it has the same carbon footprint as XPS. In the case of the use of UCTE-mix electricity it is level with XPS if 29 % of the glass primary production is calculated for the product glass foam granulate (Technopor). The fact that the glass recyclates used for glass foam granulate (Technopor) are largely waste glass from bottle banks and the like which would otherwise have to be disposed of however means that little or no proportion of the glass primary production should be calculated for the product glass foam granulate (Technopor).

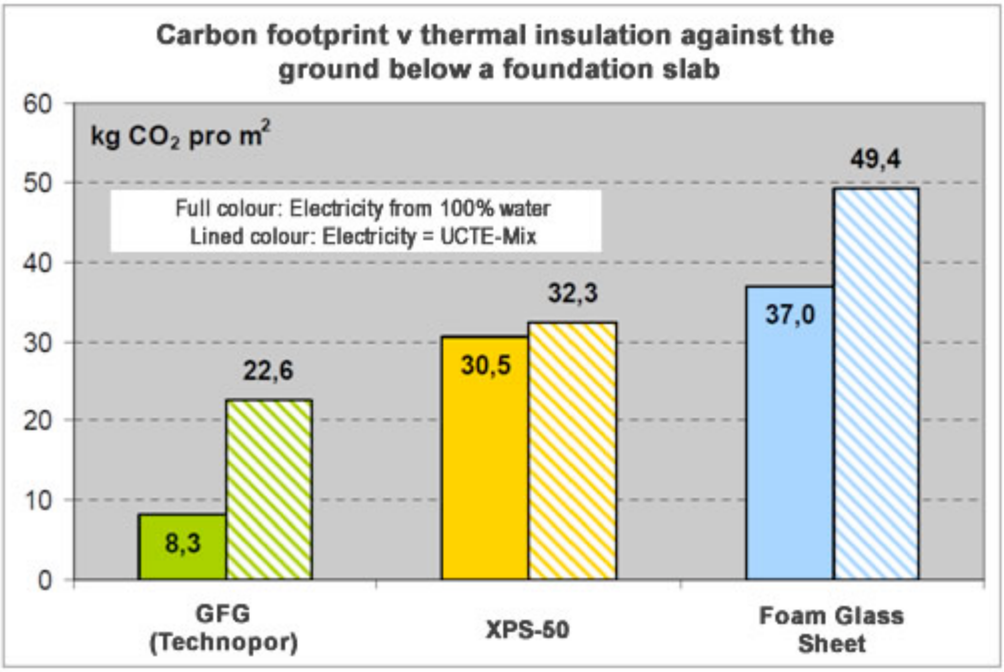


Figure 1: Greenhouse gas emissions (in kg CO2-equivalent), produced per m2 insulation material (glass foam granulate (Technopor), XPS and foam glass sheet) throughout the whole lifecycle to achieve a U value of 30 W/m2.K for thermal insulation against the ground below a foundation slab. In the case of the solid-filled columns the energy used in the production of insulation material is 100% hydroelectricity. The dashed columns however are based on the Average European Electricity Mix (UCTEMix).

The results are based on the selected input data and may vary particularly in the case of varying material density and thermal transmittance data For example, the bandwidths for the thermal transmittance (0.038 – 0.05 W/m.K) and for the density (110 – 130 kg/m3) in the case of foam glass sheet for the "100 % hydroelectricity" variant gave a result variation of 32 to 42 kg CO2/m2.

Other manufacturers of glass foam granulate (Technopor) produce the heat required for expansion from gas rather than electricity so that somewhat less end-energy is required. The CO2 emissions per MJ of heat from gas are around 65% of the CO2 emissions per MJ heat from UCTE electricity. The production energy related proportion of the carbon footprint for glass foam granulate (Technopor) which can be expanded with gas can therefore by roughly estimated as 50-60% of the carbon footprint in the case of production with UCTE-Mix electricity. The overall carbon footprint for glass foam granulate (Technopor) expanded with gas is then around 16 kg CO2/m2.

In the comparison of XPS and foam glass sheet one should finally note that under the selected general conditions the expediture on *non-renewable* energy in the lifecycle of XPS (453 MJ/m^2, resulting from 92.4 MJ/kg) is somewhat higher than that of foam glass sheet (435 MJ/m^2 resulting from 20.6 MJ/kg) but that XPS performs better than foam glass sheet in terms of greenhouse gas emissions. The reason is that the cumulated energy of XPS also includes the energy counted as "feedstock" (the mineral oil or and/or natural gas converted to plastic), which in this case however does not lead to CO_2 emissions.

Summary

The present analysis shows, that glass foam granulate (Technopor) from Technopor exhibits the lowest "carbon footprint" in comparison with the alternative materials 50 XPS-50 and foam glass sheet. This means that the CO_2-emissions given off over the lifecycle - from recovery of the raw materials through the production to installation - are significantly lower than in the case of the alternative materials analysed with similar properties with regard to thermal insulation and compressive strength.

Thanks to the use of waste glass and hydroelectricity in the manufacture of glass foam granulate (Technopor) by Technopor the carbon footprint is only around 8 kg $CO_2{}^2$ per m^2 (in the case of a U value of 30 W/m^2.K) and can thereby be counted as one of the most environmentally friendly insulation materials. In addition during the service life of the insulation material, due to the associated saving of thermal energy, at least a hundred times more CO_2-emission is saved than is produced by the manufacture.

5 Bibliography

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