ICCA-WBCSD Avoided Emissions Guidance Case Study

External Thermal Insulation Composite System (ETICS) for the refurbishment of an existing detached house in Germany

The study was commissioned by BASF SE and performed by Nicola Paczkowski, BASF SE.

This study was conducted to provide a case example for the document *Guidelines from the Chemical Industry for accounting and reporting GHG emissions avoided along the value chain based on comparative studies*, developed by ICCA and the Chemical Sector Group of the WBCSD. The analysis was designed to be in alignment with the requirements of the guidance document. The focus of this study as a case example is on chemical products only, since the guidance document was developed to support chemical companies in their efforts to measure, manage and communicate the avoided GHG emissions of their chemical products. Thus, this study does not consider other non-chemical solutions that may be used for the same user benefit.

1. Purpose of study

The purpose of this study is to provide the life cycle assessment (LCA) basis for a study on avoided emissions from chemical insulation materials, and hence to show and quantify the positive contribution of chemical insulation materials to emissions reductions in the building sector. This study does not intend to assess all technical possibilities to fulfill the defined user benefit (see also scope and limitations of the study) or to conduct a full-fledged analysis including the construction and disposal of the house, which are identical for the studied alternatives. Nevertheless, a more general goal of the study is also to understand and quantify the environmental impacts of the production, use and disposal of chemical insulation materials in the context of existing buildings within the limited scope of the study.

Scope of the study

The study focuses on a particular aspect to fulfill the defined user benefit that is the insulation of the house walls by using an external thermal insulation composite system (ETICS) based on expanded polystyrene (EPS). There are other (technical) solutions that can fulfill the same user benefit such as the use of a different heating system e.g. based on renewable energies or different insulation materials, which have not been considered in accordance with the objective of the study. In addition, wall insulation is often just one of the many steps in building refurbishment. In practice, the refurbishment of existing buildings comprises not only wall insulation, but also roof insulation, the replacement of windows or the heating system by more energy-efficient systems. Thus the present study is a simplified analysis with reduced complexity that only addresses one aspect in a building refurbishment. All other building components were assumed to remain unchanged and thus have the same impact before and after the refurbishment. This approach was chosen to solely demonstrate the contribution of the chemical insulation material.

2. Level in the value chain

The study focuses on a single family detached house with and without an exterior wall insulation system based on a chemical insulation material. Thus, the level in the value chain is the end-use level in accordance with the Guidance Document. This chosen calculation level is the lowest possible level closest to the chemical solution, which still allows the comparison of the two alternatives living with and without an exterior wall insulation system.

3. Solutions to compare

The study compares two alternatives for living in an existing detached house in Germany, one in which the house is left as it is without any refurbishment and one in which the façade is refurbished using an External Thermal Insulation Composite System (ETICS) based on expanded polystyrene (EPS), a product of the chemical industry. The production and disposal phases in the study only consider the differences between the two alternatives. These are the production and the installation of the ETIC System and the disposal of the insulation system at the end of its defined service life. The chemical product the study focuses on is expanded polystyrene (EPS), the main component of the exterior wall insulation system. EPS is a lightweight, rigid, plastic foam insulation material produced from solid beads of polystyrene made from styrene. EPS has been used for several years in ETICS in the German market and its market share is 87% based on sales in 2010. The only other material that is used in ETIC Systems is stone wool.[1]

The solutions to compare were selected on the basis of the following facts:

a. 83% of all buildings in Germany are detached and semi-detached houses (this corresponds to 43% of the total living area in Germany), thus the chosen building type of the case study represents the largest share of buildings in Germany.[2]
b. Only about 20 % of the existing detached and semi-detached house stock in Germany is renovated with wall insulation[3], hence the implemented mix of technologies is currently 80 % of non-insulated houses and 20% of insulated houses.
c. For the non-refurbished house, an average U-value[4] of 0.96 W/(m^2*K) for an exterior wall of a single family detached house in Germany was calculated taking into consideration i) For 80% of the total living area, the U-value (wall) of all existing single family homes in Germany that were built before 2011, which was defined to be the reference period. The average U-value was calculated as the sum of weighted U-values based on the relevant square meters of living space for the different building categories based on information of the German Institut Wohnen und Umwelt GmbH (IWU)[5], and ii) For 20% of the living area, that is the share of the already refurbished houses, an average U-value (wall) of 0.3 W/(m^2*K)[6] for all houses refurbished before 2011. This approach refers to a comparison to the weighted average based on the shares of all currently implemented technologies.
d. For the refurbished house a U-value (wall) of 0.2 W/(m^2*K) was selected since this value fulfills the requirements of the German Energy Savings Regulation (EnEV 2009), effective since 2009, for the renovation of existing buildings and at the same time qualifies for participating in the KfW Bankengruppe[7] loan and subsidy program, a well-established and frequently used loan program in Germany.
e. The U-values of the other construction components of the house (roof, windows and floor) that also affect the heating energy demand of the house but with equal impact on the different alternatives were selected according to the current requirements of the German Energy Savings Regulation EnEV 2009 for the refurbishment of buildings, again in conjunction with the criteria of the KfW Bankengruppe loan and subsidy program. Consequently, these building elements are state-of-the-art with a high thermal insulation.

4. Functional unit

4.1 Functional Unit: Living in an existing single family detached house in Germany with an average room temperature of 19°C for 40 years (from 2011 to 2051). The applied reference flows are:

- The insulated house with 224 m^2 of an External Thermal Insulation Composite System (ETICS) with an EPS Board (WLG 035 (lambda = 0.035 W/(m*K), density 20 kg/m^3) with a thickness of 14 cm achieving a U-value (wall) of 0.2 W/(m^2*K) and a net heating energy demand of 10018 KWh/a
- The non-insulated house with a net heating energy demand of 20875 KWh/a

4.2 Quality requirements:

Functionality: The main function of the studied solutions is to maintain an internal temperature of 19°C. This is achieved by both alternative solutions by means of solely burning fuel to generate heat or by using exterior wall insulation in conjunction with a lower consumption of heating fuel.

Technical quality: Both solutions are stable and resistant. The heating systems need to be maintained in both alternatives; the ETIC System does not need any specific maintenance. ETIC Systems have been used for more than 40 years. They do not have any underlying shortcomings. With proper care - for example painting of the façade, their life time is as long as the life time of the building.

Additional services rendered during use and disposal: Besides repainting, the ETIC System needs to be disposed of at the end of its life, which is considered in the life cycle assessment. A ventilation system to remove moisture in well-insulated buildings is often recommended, particularly in passive houses. However, it is not required by law. It was not considered in the analysis.

4.3 Service Life: The service life was defined to be 40 years. The life time of the insulation material is not limited to 40 years and may be as long as the life time of the building. A service life of 40 years was chosen in accordance with the assessment system for sustainable buildings, developed by the German Federal Ministry of Transport, Building and Urban Development (BMVBS) in collaboration with the German Sustainable Building Council (DGNB).[8]

4.4 Time and geographic reference*:* The reference year of the study is 2011. Homes that were built until the end of 2010 are referred to as existing buildings. The geographic region chosen is Germany.

5. Calculation methodology

Boundary setting: System boundaries and process map:

Qualitative description: Production and installation of the ETIC System: The ETIC System consists of an EPS foam board as the main component which is made from EPS beads provided by the chemical industry. EPS is manufactured from styrene, a liquid petrochemical, in the presence of small amounts of pentane (foaming agent) and a flame retardant (HBCD). Converters expand and mold the EPS beads to form boards or blocks by means of steam.[9] Besides EPS, the ETIC System contains adhesive, dowels, reinforcement plaster, reinforcement mesh and exterior plaster. The ETIC System is assembled at the construction site. Use of the house: The house is heated to obtain an average internal temperature of 19°C. The house does not have air conditioning, i.e. no cooling of the house in hot weather occurs. The energy carriers used represent the current heating structure in detached and semi-detached houses of the existing building stock in Germany, based on the numbers of buildings with the respective heating system. Disposal: At the end of the defined service life, the ETIC System is disposed of. 90% of the EPS is incinerated with energy recovery; the remaining components are landfilled. Transports of materials to and from the construction site are included in the study.

Figure 1: System boundary and process map for house with ETIC System

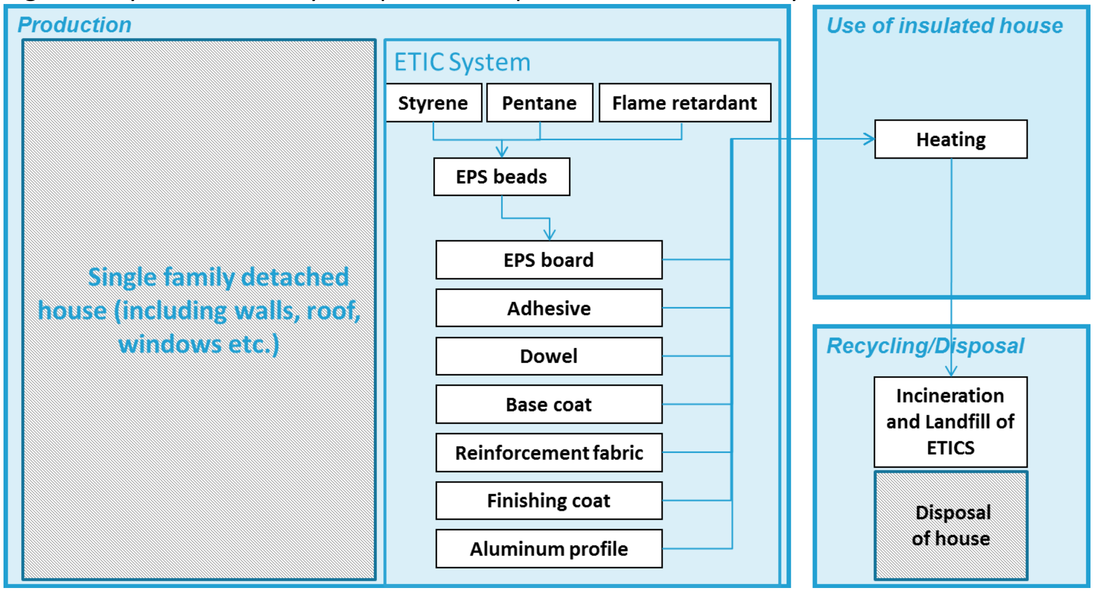
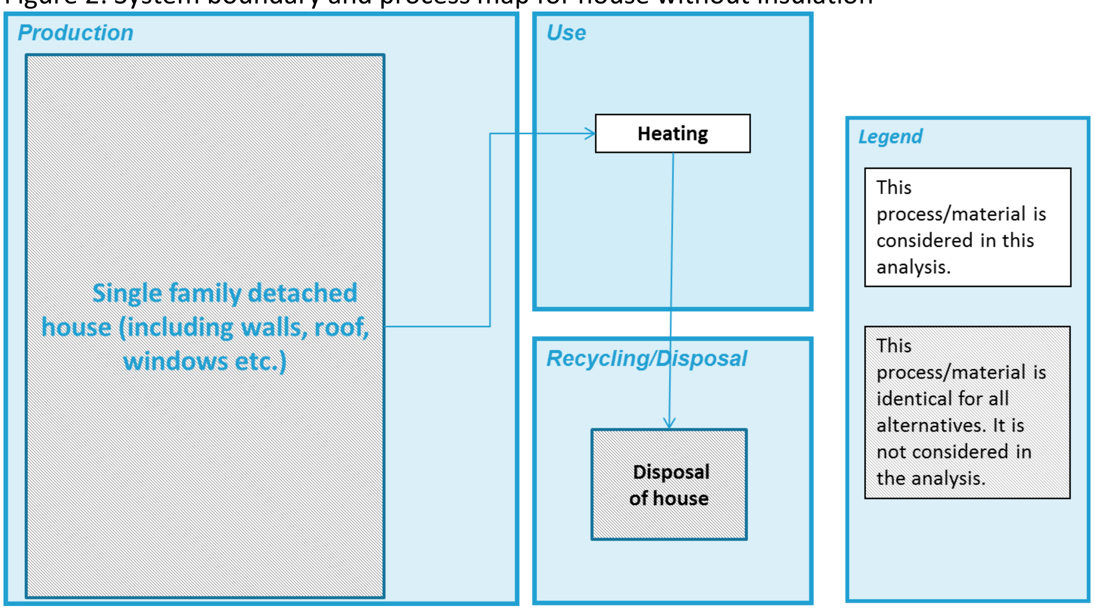


Figure 2: System boundary and process map for house without insulation



Simplified calculation methodology

The construction and disposal phases of the house were not considered since these processes are identical for the two alternatives and their non-consideration does not change the overall conclusion of the study as shown in the scenario analysis below (scenario 2). The omitted GHG emissions of the construction and disposal phases of the house represent 17% of the total emissions of the solution to compare to. The omitted emissions were estimated by adding available Life Cycle Impact Assessment (LCIA) results for the construction and demolition of a single family detached house (built in 1997 in Belgium) to the base case results of the study. The data were derived from a comprehensive LCA study on insulation in buildings conducted by PricewaterhouseCoopers (PwC) in 2013[10].

Methods used

This study is a complete Life Cycle Assessment including all material and energy inputs and outputs from raw materials acquisition through production, use and disposal (cradle-to-grave analysis). Although the study focuses on life cycle greenhouse gas emissions, other environmental impact categories were assessed as well such as acidification potential, ozone creation potential, ozone depletion potential, primary energy demand, resource consumption, water emissions, solid wastes and land use. The environmental impact categories were evaluated according to BASF's eco-efficiency methodology[11], which follows the ISO norms 14040 and 14044 for life cycle assessment. For GHG emissions, the impact method used was IPCC 2007 GWP, with characterization factors for a timeframe of 100 years [IPCC 2007].

Assumptions

- Installation of the ETIC System: Loss of insulation material (cuttings) during installation: 5%
- Heating of the house: The heating energy demand of the detached house to keep the internal temperature at 19°C on average was calculated by Luwoge Consult[12] based on a monthly energy balance of the house with and without the wall insulation system[13].

Table 1: Mix of energy carriers[3] and assumed efficiencies of heating systems[14]

	Share in %	**Efficiency heating system**
District heating	2.1	-
Natural gas	50.3	85%
Oil	35.9	85%
Biomass (wood)	6.3	75%
Coal	0.7	85%
Electricity (thereof 2% heat pump)	4.8	-

- End-of life treatment of the ETIC System: A selective demolition was assumed according to Muster ESD-EVW-2011511-D: 90 percent of the EPS (mono-material) is recovered and incinerated with energy recovery. The remaining EPS, plaster and other materials are landfilled. For the incineration with energy recovery, the net energy produced in the municipal solid waste incinerator (3.67 MJ electricity/kg EPS and 7.39 MJ thermal energy/kg EPS) was accounted for as a credit.

Data sources and quality

In this study, primarily secondary data available from literature, previous LCA studies, and life cycle databases were used for the analysis. The Life Cycle Inventory (LCI) data for the upstream production processes of the materials/energy carriers/electricity as well as for the disposal of the materials were taken either from the Boustead database (The Boustead Model, Version 5.0, extended by company-specific data) or from Simapro 7.3.2. A detailed description of data sources and quality can be found in the full LCA study.

Allocation

No allocation was performed, as no new processes were evaluated within the scope of this study. Credits and impacts due to incineration of waste EPS are allocated 100% to the ETIC System.

Key parameters of the study

Table 2: Key parameters of the study

Key parameter	Refurbished house with ETICS	House w/o ETICS	Unit
Internal temperature of the house	19		degree C
Façade, insulation area	224		m^2
U-value (wall)	0.20	0.96	$W/(m^2*K)$
U-value (window)	0.95		$W/(m^2*K)$
U-value (roof)	0.14		$W/(m^2*K)$
U-value (floor)	0.25		$W/(m^2*K)$
Thickness of insulation material	14	-	cm
Density of the insulation material	20	-	Kg/m3
Amount of EPS board	658.6	-	Kg
Heating energy demand of the house	10018	20875	KWh/a
Service life of house	40		years
Mix of energy carriers	See Table 1		-
Efficiency of heating system	See Table 1		-

6. Results

Figure 3 shows the cradle-to-grave GHG emissions for living in a detached house for 40 years with and without wall insulation. The results are clearly dominated by the use phase that is the consumption of heating fuel with its related GHG emissions. The impact of the manufacture and disposal of the ETIC System is small and hence not visible in Figure 3. Comparing the results of the two alternatives demonstrates that the insulated house has a lower carbon footprint and thus reduces GHG emissions.

Figure 3: Cradle-to-grave GHG emissions of the base case

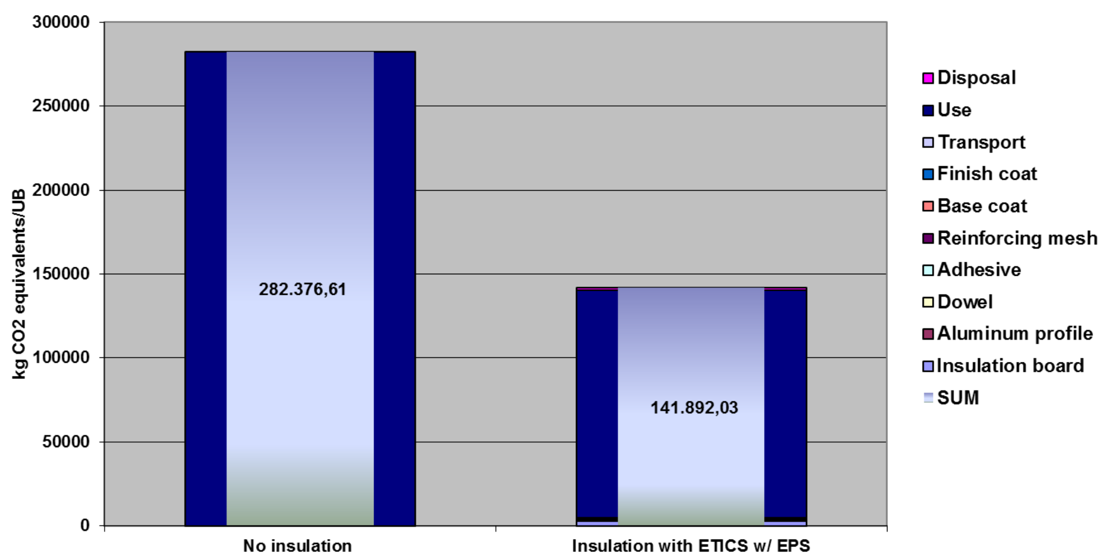


Table 3: GHG emissions per life cycle phase [in kg CO_2e per user benefit/solution]

Life Cycle Phase	Component	No Insulation	Insulation w/ EPS
Production	EPS insulation board	0	2902.7

	Aluminum profile	0	624.1
	Dowel	0	286.6
	Adhesive	0	325.3
	Reinforcing mesh	0	104.0
	Base coat	0	292.5
	Finish coat	0	201.1
Transport		0	91.2
Use phase	Heating	282,376.6	135,513.7
Disposal	Incineration & landfill		1550.8
SUM		**282,377 (P2)**	**141,892 (P1)**
Avoided emissions	**= P2-P1**	**=140,485**	

Since the use phase of this study covers a time period of 40 years (from 2011 to 2051), a number of changes are expected to occur over this timespan, in particular with regard to the use phase that has the most significant impact on the results of this study. Uncertainties mainly exist with regard to the fuel mix for meeting the heating energy demand of the house, the heating system itself, the service life of the product or the life time of the building. Looking at the policy goal of meeting the 2 degree C target, it is anticipated that in the long-term a complete change of the energy and building sector will take place. This will have a tremendous impact on the results of this study, meaning that the value for the GHG emissions avoided will most likely be significantly reduced (please see scenario 1 in section 10 below). A continuous change already takes place in the area of modernization/retrofitting of heating systems (modernization rate at about 2-4% per year in Germany), which is often linked to a change in the energy carrier away from coal and oil to gas or biomass.

7. **Significance of contribution**
The focus product of this study, namely the expanded polystyrene, fundamentally contributes to the GHG emissions avoidance effect of the solution since it is the key component in the ETIC System, providing the thermal insulation function and thus significantly reducing the energy demand for heating the house. However, it must be noted that without the other components of the ETIC System and the many services along the supply chain (such as foaming the EPS beads to form the EPS boards, the adhesive that keeps the insulation material at the wall or the construction worker, who actually applies the insulation to the wall) as well as the home owner who pays for everything, the wall insulation would not be possible. Therefore, the efforts of various partners along the value chain contribute to the avoided emissions.

8. **Attribution**
The calculated avoided emissions were not attributed to individual value chain partners.

9. **Review of Results**
A critical review (but not a panel review)[15] of the underlying Eco-Efficiency Analysis was carried out by DEKRA Consulting GmbH, July 2013.

10. **Scenario Analysis:** Please note that more scenario analyses can be found in the full LCA study.

Scenario 1: This scenario shows the impact of a low-carbon energy carrier mix as defined by WWF for the year 2050 (**"**Scenario 2050")[16] on the cradle-to-grave GHG emissions of the study.

Table 4: Results Scenario 1 [in kg CO2e per user benefit/solution]

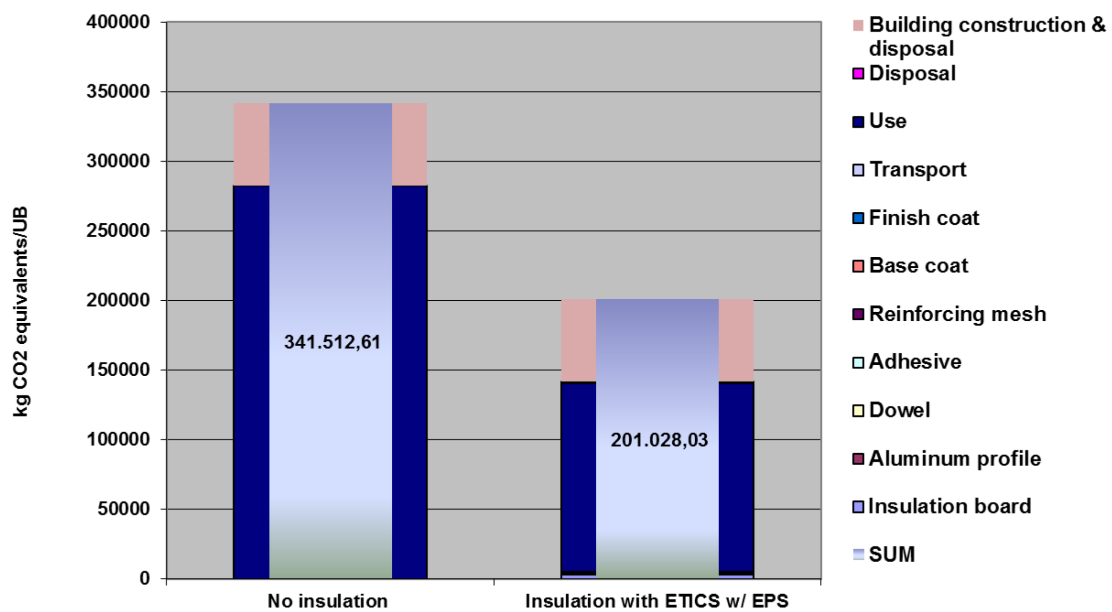
Phase	Component	No Insulation	Insulation w/ EPS
SUM		75,312.6 (P2)	42,521.2 (P1)
Avoided emissions	= P2-P1	=32,791	

Scenario 2: Evaluation of the impact of the construction and disposal phase of the house on the results of the analysis

Table 5: Results Scenario 2 [in kg CO2e per user benefit/solution]

Phase	No Insulation	Insulation w/ EPS
Construction & Disposal House[10]	59,136.0	59,136.0
Production ETICS	0	4,736.4
Transport ETICS	0	91.2
Disposal ETICS		1550.8
Use phase	282,376.6	135,513.7
SUM	**341,513 (P2)**	**201,028 (P1)**
Share of omitted emissions in relation to total emissions	17%	29%
Avoided emissions	**=140,485**	

Figure 4: Cradle-to-grave GHG emissions of scenario 2



The scenario results show that the total life cycle GHG emissions are driven by the energy consumption in the use phase, which remains the dominant factor of the study (this also applies to other environmental impacts considered). Thus, not considering the GHG emissions of the construction and disposal phases of the house does not change the overall conclusion of the study, moreover due to the fact that these processes are identical for the two alternatives and the absolute emissions avoidance remains the same. However, it is acknowledged that by omitting the construction & disposal phase of the house, the results of the impact assessment do not represent total but only major impacts.

11. Study limitations and future recommendations

The present study analyzes just one of the many aspects in the low-energy modernization of a house and in this context only the impact of a chemical solution. This simplified approach does not (necessarily) reflect the current practice and thus limits the conclusiveness of the study. The study is based on specific conditions and assumptions that were selected to demonstrate an average situation for Germany. Consequently, the study results are less realistic and are not transferable to other conditions that might be present in the real case. The results of this analysis are dominated by the use phase, i.e. the heating energy demand of the house and the service life. Therefore these results are very sensitive to the applied heating mix or the underlying energy carriers, respectively, the efficiencies of the heating systems, the life time of the house as well as to the climatic conditions of the location of the studied house. Thus the conclusions of this study cannot be applied unreservedly to other conditions. The results of the study should be seen within its limited boundaries and thus are only to be used in an appropriate manner in accordance with the goal and scope of the study.

12. References

[1] B+L Marktdaten GmbH, "Insulation Application Germany 2011", market study.

[2] Dena Gebäudereport, 2012, Deutsche Energie-Agentur.

[3] IWU, Institut für Wohnen und Umwelt, Darmstadt, Germany, „Datenbasis Gebäudebestand", 9.12.2010.

[4] A U-value is a measure of heat loss in a building element such as a wall, floor or roof.

[5] IWU, Institut für Wohnen und Umwelt, Darmstadt, Germany; „Deutsche Gebäudetopologie", 22.06.2005, „Basis für Hochrechnungen mit der deutschen Gebäudetopologie des IWU, 25.08.2011.

[6] EnEV 2009, effective since October 2009, requires a U-value (wall, max) of 0.24 W/(m^2*K). Before 2009, the EnEV 2007 (2002) was in place calling for a U-value (wall, max) of 0.35 W/(m^2*K) in refurbished homes.

[7] KfW Bankengruppe is a German government-owned development bank.

[8] http://www.nachhaltigesbauen.de/baustoff-und-gebaeudedaten/nutzungsdauern-von-bauteilen.htm

[9] http://www.eumeps.org/manufacturing_4106.html

[10] PUEurope; Environmental and economic analysis of insulation products in low energy buildings, PwC, April 2013.

[11] http://www.nsf.org/business/eco_efficiency/models.asp?program=EcoEff

[12] Luwoge Consult is a subsidiary of BASF and a consultancy in the real estate area.

[13] Calculation program: „Energieberater 18599 3D Plus 7.4.0 - Hottgenroth Software"

[14] Industry survey „Bundesverband Erneuerbare Energien e.V." and „Agentur für Erneuerbare Energien", 10/2009.

[15] A panel review was not deemed to be necessary as the reference case or product for comparison, respectively, does not comprise a competing product such as another insulation material.

[16] Heating structure of detached and semi-detached existing buildings in Germany in the year 2050 (Scenario "Innovation"), Blue print Germany – A strategy for a climate safe in 2050, a study conducted on behalf of WWF, Germany, prepared by PROGNOS/Öko-Institut and WWF.