GUA - Gesellschaft für umfassende Analysen
Corporation for Comprehensive Analyses

“The potential of plastic insulation to realise energy savings and de-coupling in Europe”

Final Report

Vienna, January 2006

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1 Summary

It is widely known that insulation materials save an enormous amount of energy during their life-time. This study quantifies this benefit of the “use-phase” for the current situation in Europe, taking plastics insulation boards for external walls as an example for calculation.

To calculate the net energy balance within the total life cycle of plastic insulation boards, the savings of the use phase are completed by the energy needed for production of insulation boards and by energy effects within waste management.

Plastics insulation boards used for thermal insulation of external walls (EPS, PUR, XPS) consume about 100 MJ of energy per kg product when they are produced. The results of this study show that the same amount of energy is already saved within the first 4 months of use. In their total use phase, plastics insulation boards save more than 14.500 MJ per kg insulation material or 150 times more energy that was needed for production.

The total net energy saving of plastics insulation boards sold in 2004, improving insulation standards of *external walls* in Europe, is estimated at 5.150 Mill GJ in their life-time of 50 years (uncertainty range: 5.150 – 10.800 Mill GJ). Total net-savings of greenhouse gas emissions by additional plastic insulation boards sold in 2004 for use on external walls are approximately 290 Mill tonnes of CO_2 equivalents in their life-time (uncertainty range: 290 – 610 Mill GJ).

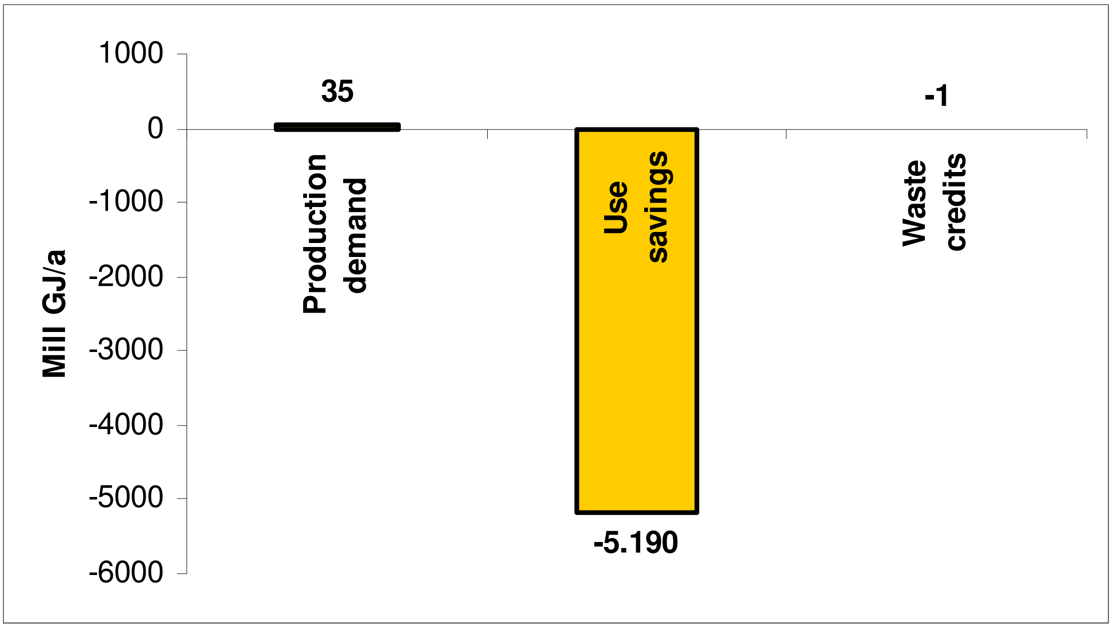

Figure 1: The energy balance throughout the total life cycle of plastics insulation boards applied on external walls in Europe in 2004 to increase insulation standards shows the energy demand for production, 150 times higher energy savings in the use-phase, and negligible energy effects within waste management.

A rough estimation of the total **net energy saving of all plastics insulation** including boards for roofs, floors and cellar walls, and sold in 2004 to improve insulation conditions, resulted in a minimum of **9.500 Mill GJ** in total life-time, which is equal to

- 20 % of the total final energy consumption of the EU 25 in 2002
- 800 big oil tankers (VLCC - very large crude oil carriers, typical load of 260 kt crude oil, length 330 m)
- the energy needed by 61 nuclear power plants with 1.500 MW power
- 2,3 times the total life-cycle energy demand of plastic products in 2002, i.e. more than twice needed for a "pay-back"
- 54 times the additional production energy needed for a 4,5% growth of plastic products, i.e. much more than needed for absolute de-coupling.

Other insulation materials will show similar results, as differences in production energy contribute with less than 1 % to the total life-cycle energy balance. Changes within waste management will affect the total life-cycle energy balance by less than 0,1 %.

In summary, increased use of any insulation material will give a significant contribution to sustainable resource management in Europe and should therefore by supported.

2 Introduction

2.1 Goal of the study

This study quantifies the net energy savings realised by plastics insulation boards sold in Europe in 2004 for use on external walls. Additionally net energy savings of *all* plastics insulation including boards for roofs, floors and cellar walls are roughly estimated.

An energy balance throughout the total life cycle shows energy demands for production, energy savings in the use-phase, and energy effects within waste management. All energy data include energy needed for production and delivery of fuels.

The calculations for plastics insulation boards used on external walls consider differences between plastic materials (thermal conductivity, density, etc.) and between European countries (especially regarding climate and insulation standards) to an extent where data was available in the given time frame of the study.

The study does not compare plastics insulation with other materials. The study also does not compare EPS versus XPS versus PUR insulation.

2.2 Methodology to calculate net energy savings by increasing plastic insulation used in the building sector

Relevant market volume

In this study, only net-effects of *increasing* insulation volumes used in the building sector are considered. Insulation that has already been used in the past and is now at the end of its lifetime has already enabled a certain amount of energy saving in the past. If these insulation volumes are replaced, the energy demand for heating buildings in Europe will not (significantly) change due to the replacement of insulation.[1]

Therefore, the total market volume of plastics insulation boards used in the building sector today is reduced by the estimated share which replaces insulation at the end of its lifetime. For the remaining market volume, the energy saved by insulation boards during their lifetime is an additional energy saving in the future and can be allocated to the life-cycle energy balance of the insulation boards.

Further calculations in this study refer to external walls of buildings. Therefore the remaining market volume is further reduced by market shares not used for thermal insulation of external walls.

During the discussion of the results for external wall insulation, extrapolated results are also estimated for other application sectors of plastics insulation.

Life-cycle energy balance of insulation materials

The net effects of insulation materials on energy demand during their total lifetime are calculated in three steps:

- Production: Energy to produce plastics insulation boards (positive sign)
- Use-phase: Energy saving per year times lifetime of insulation board (negative sign)
- Waste management: Effects on energy demands by recycling, energy recovery and disposal of plastics insulation boards (negative sign, if energy credits are higher than energy demand).

Algorithm to calculate energy savings of insulation materials during their use phase:

$$\text{Saved energy per year} = Q_{old} - Q_{new} \approx A \times HDS \times (U_{old} - U_{new}) =$$

$$= A \times HDS \times (L1/D1 - 1/(D1/L1 + D2/L2))$$

Q … Heat loss through external wall

A … Area of relevant insulation, derived from relevant market volume of insulation materials (see above) divided by density and an average thickness of boards

HDS = $\int (To-Ti).dt$ … heating degree seconds (values are given for specific places in Europe and are depending on the course of the outside temperature during the year). HDS are derived from heating degree days (HDS=HDD x 24 x 60 x 60).

L1 ... thermal conductivity in W/m.K of original situation

L2 ... thermal conductivity in W/m.K of additional insulation

D1 … thickness of original wall

D2 … thickness of additional insulation

Thermal transmission coefficient ("U-value"): $U = L/D$ $(W/m^2.K)$

$1/U_{new} = 1/U_{old\,(1)} + 1/U_{additional\,(2)}$

[1] In a more detailed calculation, also replacement of insulation material could lead to positive and negative effects on the energy demand for heating: Improved insulation properties per kg insulation used today compared to material used 40 years ago lead to additional energy savings per kg insulation material. On the other hand, outside walls (on which plastics insulation is applied) have often lower U-values today than 40 years ago. Therefore the additional energy saving of plastics insulation boards on new buildings is lower than on older walls. Both effects are not considered in this study, which rather aims at a rough estimate of the effects of plastic insulation in Europe.

Results of the formula given above refer to saved heat losses. Division by an assumed efficiency of heating systems of 90 % results in saved fuel energy, and addition of 30,5 % for energy needed to produce and deliver the fuels (heating energy mix is given in chapter 3.10, pre-combustion energy demand for fuels was taken from Ecoinvent 2004) gives the life-cycle energy values needed for the calculations in this study.

2.3 Resulting working steps

The calculation steps described above are carried out for all European countries and for EPS, XPS and PUR separately. The results are finally summed up to get the total net energy savings by increasing plastic insulation used in the building sector in Europe.

Data and estimations used for the calculations are described along the following working steps:

- Market volume of plastics insulation in European countries in 2004
- Market share replacing insulation at the end of its lifetime
- Market share used for thermal insulation of external walls
- Thermal conductivity and density of insulation boards
- Heating Degree Days for European countries
- Average insulation standards in European countries - typical thermal transmission coefficients (U-values) of external walls before and after application of additional insulation
- Lifetime of insulation boards used today
- Production energy of insulation boards
- Energy effects within waste management

3 Data and assumptions

3.1 Market volume of plastics insulation in European countries in 2004

Data on consumption of EPS, XPS and PUR in the building and construction sector in EU-25 countries plus Norway and Switzerland in 2004 were derived from the following sources:

Data on EPS consumption per capita in most European countries, given by Polimeri Europa [2004] for 2003 were completed (EPS consumption for missing countries[2] was taken from comparable countries), reduced by 5 % due to lower total consumption given in De Walque & Ass. [2004], increased by 3,5 % (growth 2003 – 2004, reported by market research of BASF) and multiplied with 65 % as share of EPS for construction in total EPS consumption, given by De Walque & Ass. [2004]. Resulting figures are given in tables of chapter 7.2 to 7.4.

Data on XPS consumption in most European countries, given in EXIBA [2005] for 2004 in cubic metres were completed as described above, multiplied with density given in De Walque & Ass.

[2] EPS consumption data was not yet available for Cyprus, Estonia, Latvia, Lithuania, Malta.

[2004] and multiplied with 87 % as share of XPS for construction in total XPS consumption, given by De Walque & Ass. [2004]. Resulting figures are given in tables of chapter 7.2 to 7.4.

Total PUR hard foam consumption in the building and construction sector in 2004 used as insulation in Europe was reported by BING (platform of the rigid polyurethane insulation industry in Europe; www.bing-europe.com) to be 605.000 tonnes. PUR in one component foam (spray) and PUR for technical applications (fridges, water-heaters, etc.) are not included in this figure. 3 % were subtracted as an estimate for PUR consumption in non-EU countries (= average EPS & XPS market share consumed in these countries). Data on the level of countries were not available except for Germany. To distribute the total PUR consumed to other countries than Germany, the following aspects were considered: population, climatic conditions (heating degree days) as well as consumption and growth of EPS in the countries. For countries with an unproportionally high EPS consumption lower PUR consumption than on average was assumed and vice versa. Resulting figures are given in tables of chapter 7.2 to 7.4. In a sensitivity analysis the distribution of PUR to countries was varied within reasonable boundaries (see chapter 4), which influenced the total result only within a range of ±3 %.

EPS	723.000 t
XPS	193.000 t
PUR	590.000 t
Total	**1.506.000 t**

Table 1: EPS, XPS and PUR used in the building and construction sector in EU-25 countries plus Norway and Switzerland in 2004

3.2 Market share replacing existing insulation at the end of its lifetime

Lifetime of plastics insulation becoming waste today is estimated at 30 or more years. Therefore the consumption of plastics insulation in 1970 is a good maximum estimate for the plastics insulation being replaced today.

Due to data given in Hohwiller [1999], EPS consumption in Europe in 1970 was 220 kt compared to 1.100 kt in 2004. If a similar share of insulation in total EPS consumption is assumed than today (earliest value is given in Hohwiller [1999] with 63 % for 1985), then about 20 % (or less) of total EPS consumed today replaces EPS insulation at the end of its lifetime.

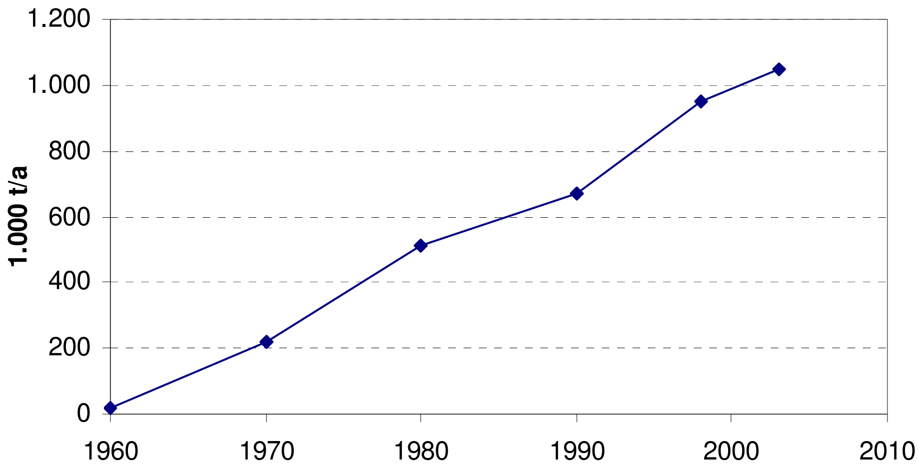

Figure 2: Growth of EPS consumption in Europe.

Additionally a part of plastics insulation used today also replaces insulation made of other materials which was already existing (thicker external walls, other insulation materials at the end of their lifetime). This share is estimated at a maximum of another 20 % of insulation used today.[3]

The total assumed replacement rate of 40 % is therefore considered as a conservative estimate. The true replacement rate could even be lower, resulting in even higher net energy savings realised by plastics insulation.

3.3 Market share used for thermal insulation of external walls

Data on distribution of EPS, XPS and PUR insulation boards to application sectors were only available for Germany (given by GDI – Gesamtverband Dämmstoffindustrie, Frankfurt):

Application	EPS	XPS	PUR
External wall	39%	38%	6%
Floor construction	41%	38%	25%
Flat roof	13%	18%	10%
Pitched roof	1%	1%	37%
Others	6%	5%	22%

Table 2: Application sectors of EPS, XPS and PUR slabs in % (estimates) in Germany.[4]

[3] To give an example: Typical U-values of external walls of old houses (35 – 40 cm, uninsulated) are 1,3 – 1,4 W/K.m^2. A concrete wall of 25 cm would need 1,6 cm of EPS to reach the same U-value, which is 16 – 20 % of the typical thickness of EPS boards of 8 – 10 cm used today.

[4] Several experts confirmed that the market share of PUR-boards for insulation of external walls is atypically low in Germany.

Corresponding data for Europe was not yet available at the respective European associations of plastics insulation producers. For PUR Table 3 shows a split of the European market into different types of products, given by BING (platform of the rigid polyurethane insulation industry in Europe; www.bing-europe.com):

Type of product	PUR
Insulation Boards	31%
Sandwich Panels	53%
Block	6%
Spray Foam	11%
Total	100%

Table 3: Distribution of European PUR insulation market to different types of products. One component foam and PUR for technical applications (fridges, water-heaters, etc.) are not included. Spray foam is thermal insulation produced on the building site, e.g. for insulation flat roofs. Sandwich panels are mostly used for industrial applications such as cold stores. Share of PUR used for external walls is estimated at 40 % (most of insulation boards, part of sandwich panels and block).

Based on Table 2 and Table 3, the share of insulation boards used on external walls in Europe was therefore roughly estimated at 40 % for all types of plastic insulation in this study.

3.4 Thermal conductivity and density of insulation boards

Table 4 shows typical values for thermal conductivity and density of plastics insulation boards. Various data for EPS, XPS and PUR were given by different producers for different products. In addition average values for the density of EPS and XPS boards were given by De Walque & Ass. [2004]. In this study the mean value of data available was used.

	Thermal conductivity [W/m.K]	Density [kg/m^3]
EPS	0,0375	17,0
XPS	0,0325	33,3
PUR	0,0268	33,5

Table 4: Typical physical properties of plastics insulation boards.

3.5 Heating Degree Days for European countries

Climatic conditions relevant for heating energy needed and insulation benefits are represented by Heating Degree Days (HDD, see chapter 2.2). Data on HDD were purchased from ZAMG (Central Institute for Meteorology and Geodynamics, Austria) for 5 cities in Europe: Paris, Budapest, Warsaw, Madrid and Munich. HDD for other European countries were calculated, based on data on average temperature between October and March in these countries [ZAMG 1996], as shown in Figure 3.

All values of heating degree days are 20/12 HDD. This means, that the HDD-calculation was based on a constant indoor temperature of 20°C and on a heating limit of 12°C outside temperature.

City	Av. Temp. Oct - March °C	HDD K.d
Paris	7,05	2.474,50
Budapest	4,33	2.911,30
Warsaw	2,33	3.739,70
Madrid	9,32	1.988,60
Munich	3,27	3.273,50

Best fit straight line method:
HDD = TEMP x -232,06 + 4098,1

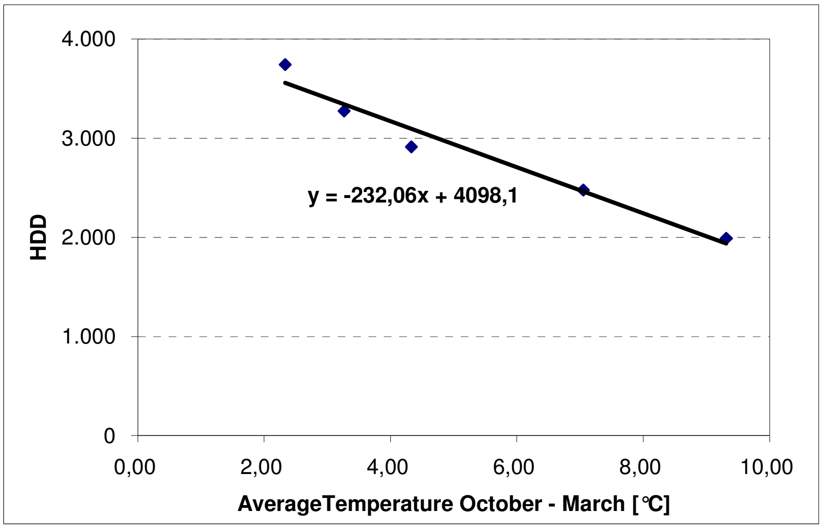

Figure 3: Calculation of HDD from values for five cities, based on average temperatures in these and other cities between October and March.

3.6 Insulation standards in European countries before and after improvement

For the calculations in this study, European countries (i.e. EU 25 plus Norway and Switzerland) have been classified into six different groups regarding insulation standards. High insulation standard is assumed for northern countries plus Austria and Switzerland due to their high share of Alpine regions. Low insulation standards are assumed for southern countries, and medium insulation standards for remaining countries. The classification distinguishes additionally between Western European countries and the 10 new Member States (“Eastern Europe” in table below).

Classification of countries	Western Europe	Eastern Europe
High insulation standard	Austria, Finland, Norway, Sweden, Switzerland	Estonia, Latvia, Lithuania
Medium insulation standard	Belgium, Denmark, France, Germany, Ireland, Luxembourg, The Netherlands, United Kingdom	Czech Republic, Hungary, Poland, Slovakia, Slovenia
Low insulation standard	Greece, Italy, Malta, Portugal, Spain	Cyprus

Table 5: Classification of European countries regarding insulation standards.

In this study, new insulation which is only replacing old insulation is not considered (see chapter 2.2). The remaining share of new plastics insulation boards applied to external walls in 2004 was either used for the improvement of insulation of old buildings or for new buildings with improved insulation standards replacing old buildings with comparatively low insulation standards.

Therefore U-values of external walls before application of additional insulation should refer to old houses. U-values after renovation or U-values of new houses should represent the typical insulation standard of renovated or new houses in the respective countries.

In this study, results of two different scenarios are based on two different sets of U-values:

U-values for Scenario 1 were taken from a recent study by ECOFYS [2004], which presents U-values for different climatic zones (cold, moderate, hot) and building ages in Europe. For "Western Europe" in this study, average values for facades built before 1975 not retrofitted / already retrofitted are used. For Eastern Europe values for facades built before 1975 and not retrofitted are used. The study further presents estimated U-values after implementation of the European EPB Directive (Directive 2002/91/EC on Energy Performance of Buildings) in different climatic regions. As the directive requires implementation in the Member States by January 2006, the given values are increased by a factor 1,2 to represent realistic values for new and renovated houses in 2004. The respective U-values for new member states have been adapted by multiplying the values for Western Europe (after additional insulation) with the ratio Eastern Europe/Western Europe before application of additional insulation (see table below).

U-values used in calc. model	**U-Values before add. insulation**		**U-Values after add. insulation**	
Scenario 1	**Western Europe**	**Eastern Europe**	**Western Europe**	**Eastern Europe**
High insulation standard	0,40	0,50	0,20	0,26
Medium insulation standard	1,25	1,50	0,46	0,55
Low insulation standard	2,00	2,60	0,58	0,75

Table 6: Thermal transmission coefficients (U-values) used in the calculation model for Scenario 1.

U-values for Scenario 2 and 3 were derived from own research activities regarding U-values at building physic institutes and technical Universities in various European countries (see chapters 7.6 to 7.8). From these data alternative U-values were derived for the six different groups regarding insulation standards described above. Scenario 2 (MAX) is based on maximum U-values before and after insulation. Scenario 3 (MIN) is based on minimum U-values before and after insulation.

U-values used in calc. model	U-Values before add. insulation		U-Values after add. insulation	
Scenario 2 & 3	Western Europe	Eastern Europe	Western Europe	Eastern Europe
High insulation standard	1,4 - 0,6	1,6 - 0,8	0,4 - 0,2	0,5 - 0,3
Medium insulation standard	2,0 - 1,4	2,2 - 1,6	0,6 - 0,4	0,7 - 0,5
Low insulation standard	2,5 - 2,0	2,7 - 2,2	0,8 - 0,6	0,9 - 0,7

Table 7: Thermal transmission coefficients (U-values) used in the calculation model for scenarios 2 and 3.

Average thickness of additional insulation is finally derived from the difference of U-values before and after implementation of additional insulation. The resulting values represent realistic orders of magnitude for different materials and different climatic regions (see chapter 7.2 to chapter 7.4).

3.7 Lifetime of insulation boards used today

Lifetime of insulation boards used today depends on the specific characteristics of wall construction and renovation cycles. Several building physic institutes estimated the lifetime at 30 – 80 years. For this study, a lifetime of 50 years is assumed for insulation boards being produced and used today.

3.8 Production energy of insulation boards

Data on energy demand for the production of EPS boards (94 MJ/kg) and XPS boards (86 MJ/kg) were taken from FhG-ISI (1999). Production energy of PUR boards (105 MJ/kg) is given in the PlasticsEurope eco-inventory for “PUR rigid foam” (www.plasticseurope.org).

3.9 Energy effects within waste management

Energy effects within waste management of insulation materials were calculated in a recent study of GUA [2005]. Based on a share of 20 % energy recovery (after separation in an automatic sorting plant for building rubble) and 80 % landfill, including credits of saved fuels by energy recovery, the specific net energy effects (savings) of 1 kg EPS and XPS waste are –4,2 MJ/kg and of 1 kg PUR waste are –2,4 MJ/kg.

3.10 Net-savings in greenhouse gas emissions

The energy savings by implementing additional plastic insulation cause significant savings in greenhouse gas emissions due to reduced energy demand for heating, too.

The calculation of saved greenhouse gas emissions in the use phase of insulation material has to be based on the mix of heating energy sources in Europe. Such data was not available for total Europe, but only for single countries or regions. The data used in this calculation model is derived from data for Bavaria (federal state in southern Germany), where a prognosis for heating energy sources used in 2005 shows data given in Table 8.

District heating	**3%**
Electricity	**1%**
Renewable (wood, etc.)	**8%**
Natural gas	**34%**
Liquid gas	**1%**
Heating oil	**52%**
Coal	**1%**
Total	**100%**

Table 8: Prognosis of heating energy sources used in Bavaria in 2005 [Fahl et al. 2000]

The prognosis further indicates that natural gas is strongly increasing to replace fuel oil, and wood is also increasing slowly. To build the calculation on a mix which will be typical for the next decades, heating energy in Europe is assumed to come from **45 % fuel oil (extra light), 45 % natural gas and 10 % wood**.

Table 9 displays the life cycle greenhouse gas emissions per MJ of the respective heating energy sources.

	Heating energy mix	CO_2 kg/MJ	CH_4 kg/MJ	N_2O kg/MJ
Gas	45%	6,8E-02	3,6E-04	1,2E-06
Fuel oil EL	45%	8,5E-02	4,4E-05	8,3E-07
Electricity (UCTE)	0%	1,3E-01	2,0E-04	3,1E-06
Wood	10%	2,5E-03	4,3E-06	2,4E-06
Global warming potential		1	23	296

Table 9: Shares of the assumed heating energy sources and life-cycle green house gas emissions per MJ used heating energy [Ecoinvent 2004].

Table 10 indicates (saved) greenhouse gas emissions per (saved) MJ of energy used for heating.

CO_2 kg/MJ	CH_4 kg/MJ	N_2O kg/MJ	**CO_2-Equiv. kg/MJ**
0,069	1,8E-04	1,2E-06	**0,074**

Table 10: (Saved) greenhouse gas emissions per average (saved) MJ of energy used for heating

Table 11 shows specific energy demand (life-cycle energy needed for final product) and emitted life-cycle green house gases for final product, taken from GUA [2005].

Production	Energy demand MJ/kg	CO_2 kg/MJ	CH_4 kg/MJ	N_2O kg/MJ	**CO_2-Equiv. kg/MJ**
EPS	94	0,032	1,1E-04	1,6E-09	**0,034**
PUR	105	0,038	1,9E-04	1,7E-07	**0,042**
XPS	82	0,032	1,1E-04	1,6E-09	**0,034**

Table 11: Production energy demand of polymer insulations and related green house gas emissions per MJ life-cycle energy demand.

The values given in the tables above were used to transform the results for production energy into emitted green house gases, and to transform saved energy sources for heating into saved green house gas emissions. Energy effects within waste management were neglected as they contribute with less than 0,1 % to the total life-cycle energy balance.

4 Calculation and Results

The tables below show results for EPS, XPS and PUR for each country and for Europe in total (EU 25 + Norway + Switzerland). As the split of total PUR consumption in Europe into country consumptions had to be based on very rough estimations (see chapter 3.1), **country specific results for energy saved by PUR insulation are quite uncertain**. However, the uncertainties are likely to be balanced out within the total result for Europe.

Sensitivity analysis on the influence of PUR-distribution to countries to the total result:

In a sensitivity analysis the distribution of the total relevant mass of PUR insulation to the countries of EU25 plus Norway and Switzerland was varied at random in such a way, that the masses per capita and heating degree day vary within an interval of ±50 % around the average value. This sensitivity analysis showed that the final result (total energy saving by EPS, XPS and PUR in all countries) only varied by **±3 %** due to different distributions of PUR to countries.

4.1 Results of scenario 1

Chapter 7 presents the detailed calculation of net energy savings in the total lifetime of plastics insulation boards used on external walls, following the calculation procedure described above and based on U-values of scenario 1 (U-values taken from ECOFYS and oriented at EPB directive). The following tables show the aggregated results for countries and for insulation materials.

Total results (EPS+PUR+XPS)	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Production energy	GJ	1.096.104	832.296	28.328	889.802	720.411	146.402	836.968	4.302.958	5.130.546
Energy saving use-phase	GJ	-24.893.558	-107.409.348	-4.458.707	-212.791.227	-128.410.212	-7.187.465	-27.183.603	-486.251.687	-883.728.750
Energy effects waste management	GJ	-44.762	-26.719	-1.160	-29.766	-28.728	-4.758	-31.004	-140.442	-207.853
Net energy saving in total lifetime	**GJ**	**-23.842.217**	**-106.603.770**	**-4.431.539**	**-211.931.191**	**-127.718.529**	**-7.045.821**	**-26.377.639**	**-482.089.171**	**-878.806.056**

Total results (EPS+PUR+XPS)	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Production energy	GJ	469.178	808.658	411.953	3.552.700	248.729	394.670	37.370	14.941	623.704
Energy saving use-phase	GJ	-53.882.661	-163.645.769	-57.969.556	-546.265.240	-11.885.106	-19.261.108	-5.190.720	-902.363	-18.779.809
Energy effects waste management	GJ	-18.831	-28.110	-16.403	-143.655	-8.125	-12.841	-1.183	-632	-22.607
Net energy saving in total lifetime	**GJ**	**-53.432.314**	**-162.865.221**	**-57.574.005**	**-542.856.195**	**-11.644.502**	**-18.879.279**	**-5.154.533**	**-888.055**	**-18.178.712**

Total results (EPS+PUR+XPS)	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	United Kingdom
Production energy	GJ	4.480.599	292.825	432.534	217.509	2.485.356	853.247	802.048	1.435.052	3.300.397
Energy saving use-phase	GJ	-1.213.431.034	-24.156.841	-89.211.488	-51.191.674	-464.022.134	-20.685.559	-17.563.806	-195.852.882	-351.386.565
Energy effects waste management	GJ	-159.515	-10.683	-13.115	-7.928	-90.262	-25.626	-29.795	-51.926	-92.557
Net energy saving in total lifetime	**GJ**	**-1.209.109.949**	**-23.874.698**	**-88.792.069**	**-50.982.093**	**-461.627.040**	**-19.857.938**	**-16.791.553**	**-194.469.756**	**-348.178.725**

Table 12: Life-cycle energy balance and net energy savings in the total lifetime of plastics insulation boards used on external walls in Europe, split into 27 countries considered in the calculation model.

EPS-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-3.062.931.810
Production energy	GJ	15.996.651
Energy effects waste management	GJ	-714.744
Net energy saving in total lifetime	**GJ**	**-3.047.649.903**

PUR-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-1.701.114.984
Production energy	GJ	14.868.000
Energy effects waste management	GJ	-339.840
Net energy saving in total lifetime	**GJ**	**-1.686.586.824**

XPS-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-423.552.075
Production energy	GJ	3.980.634
Energy effects waste management	GJ	-194.403
Net energy saving in total lifetime	**GJ**	**-419.765.845**

Total results (EPS+PUR+XPS)	Unit	Total
Production energy	GJ	34.845.284
Energy saving use-phase	GJ	-5.187.598.869
Energy effects waste management	GJ	-1.248.987
Net energy saving in total lifetime	**GJ**	**-5.154.002.572**

Table 13: Life-cycle energy balance and net energy savings in the total lifetime of plastics insulation boards used on external walls in Europe for each material considered in the calculation model.

The total net energy saving of plastics insulation boards sold and applied on external walls in Europe in 2004 to increase insulation standards are 5.150 Mill GJ in total life-time in scenario 1.

The production energy needed to produce the relevant insulation boards was 35 Mill GJ, its relative contribution to the total life-cycle energy balance is 0,7 %. The same amount of energy was already saved within the first 4 months of the “use-phase” of the insulation boards. In their total life-time, the plastics insulation boards will save 5.190 Mill GJ or 150 times more energy than was needed for their production.

Energy effects within waste management are very small: 1 Mill GJ net energy savings due to energy recovery of 20 % of the insulation material at the end of its lifetime (contribution only 0,02 % to the total life-cycle energy balance).

Total net-savings of greenhouse gas emissions by additional plastic insulation boards sold in 2004 for use on external walls are approximately 290 Mill tonnes of CO_2 equivalents in their life-time in scenario 1 (see chapter 7.5).

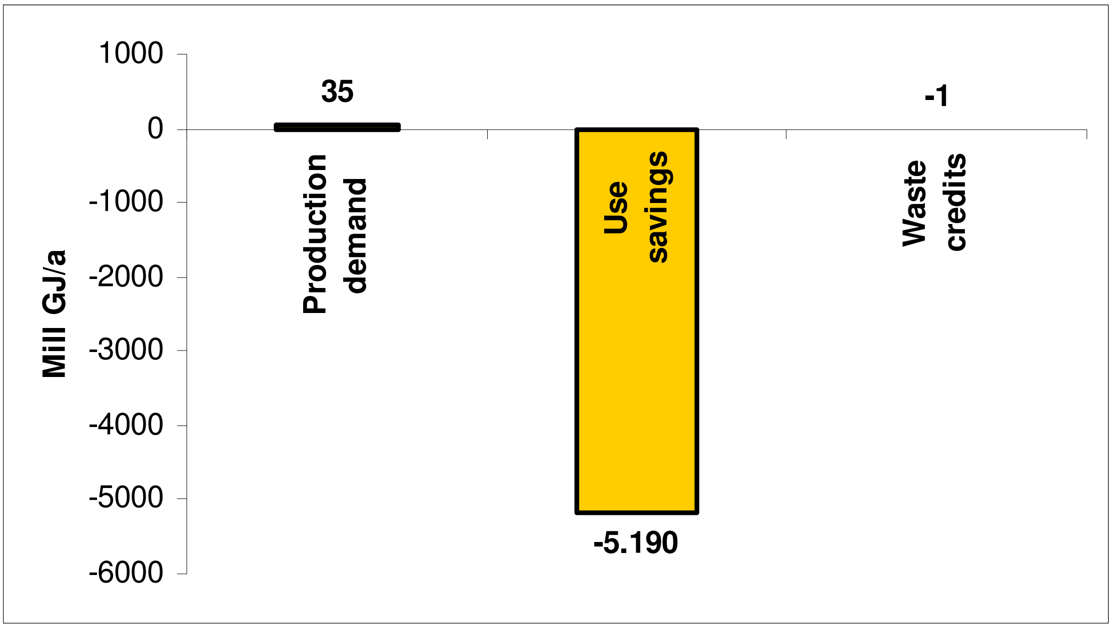

Figure 4: The energy balance throughout the total life cycle of plastics insulation boards applied on external walls in Europe in 2004 to increase insulation standards shows the energy demand for production, 150 times higher energy savings in the use-phase, and negligible energy effects within waste management.

4.2 Results of scenarios 2 and 3

Scenarios 2 and 3 are based on U-values derived from own research activities regarding U-values at building physic institutes and technical Universities in various European countries. These scenarios reflect the range of uncertainty regarding the U-values needed within the calculation procedure and the influence of that uncertainty on the final results (see chapter 3.6).

EPS-Boards	**Unit**	**Total**
Energy saving use-phase in total lifetime	GJ	-6.320.742.910
Production energy	GJ	15.996.651
Energy effects waste management	GJ	-714.744
Net energy saving in total lifetime	**GJ**	**-6.305.461.003**

PUR-Boards	**Unit**	**Total**
Energy saving use-phase in total lifetime	GJ	-3.587.229.463
Production energy	GJ	14.868.000
Energy effects waste management	GJ	-339.840
Net energy saving in total lifetime	**GJ**	**-3.572.701.303**

XPS-Boards	**Unit**	**Total**
Energy saving use-phase in total lifetime	GJ	-889.959.892
Production energy	GJ	3.980.634
Energy effects waste management	GJ	-194.403
Net energy saving in total lifetime	**GJ**	**-886.173.661**

Total results (EPS+PUR+XPS)	**Unit**	**Total**
Production energy	GJ	34.845.284
Energy saving use-phase	GJ	-10.797.932.265
Energy effects waste management	GJ	-1.248.987
Net energy saving in total lifetime	**GJ**	**-10.764.335.967**

Table 14: Scenario 2: Life-cycle energy balance and net energy savings in the total lifetime of plastics insulation boards used on external walls in Europe in 2004, based on relatively high U-values before and after insulation (see Table 7).

EPS-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-3.087.050.795
Production energy	GJ	15.996.651
Energy effects waste management	GJ	-714.744
Net energy saving in total lifetime	**GJ**	**-3.071.768.889**

PUR-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-1.715.548.092
Production energy	GJ	14.868.000
Energy effects waste management	GJ	-339.840
Net energy saving in total lifetime	**GJ**	**-1.701.019.932**

XPS-Boards	Unit	Total
Energy saving use-phase in total lifetime	GJ	-431.892.972
Production energy	GJ	3.980.634
Energy effects waste management	GJ	-194.403
Net energy saving in total lifetime	**GJ**	**-428.106.742**

Total results (EPS+PUR+XPS)	Unit	Total
Production energy	GJ	34.845.284
Energy saving use-phase	GJ	-5.234.491.859
Energy effects waste management	GJ	-1.248.987
Net energy saving in total lifetime	**GJ**	**-5.200.895.562**

Table 15: Scenario 3: Life-cycle energy balance and net energy savings in the total lifetime of plastics insulation boards used on external walls in Europe in 2004, based on relatively low U-values before and after insulation (see Table 7).

Due to the range of uncertainty regarding insulation conditions in European countries, the main result of this study can vary between **5.200 – 10.800 Mill GJ**. The corresponding range of saved greenhouse gas emissions is 290 – 610 Mt CO_2 equivalents.

Data from ECOFYS [2004], used for the main scenario in this study, are therefore related to the *lower* limit of the given range. The **results of the main scenario are consequently a *conservative* estimation of the net energy savings** in the total lifetime of plastics insulation boards used on external walls in Europe today.

4.3 Extrapolated results including insulation of roofs, floors and cellar walls

Based on the results for insulation boards used on external walls, extrapolated results can also be estimated for other application sectors of plastics insulation: For roofs (25 mass-% average market share[5]) the effects will be in the same order of magnitude per kg plastics insulation due to similar temperature differences and similar insulation properties of other roof parts. For floor constructions and cellar walls (35 mass-% average market share) the average temperature difference will only be around 5°C instead of 20°C, therefore only 25 % of the net savings per kg external wall insulation are assumed for these application sectors.

The respective factor to extrapolate the results from facade boards to total plastics insulation in the building sector is therefore 1,8. The resulting **estimate for net energy savings in Europe by all plastics insulation sold and applied in 2004 is 9.500 – 19.900 Mill GJ** in total life-time. The corresponding savings in greenhouse gas emissions are 536 – 1.120 Mill tonnes of CO_2 equivalents.

4.4 Description of energy amounts given in results

Total net energy saving of plastics insulation boards, improving insulation standards of external walls, sold and applied in 2004 in Europe was estimated at 5.150 Mill GJ in total life-time (uncertainty range: 5.150 – 10.800 Mill GJ, see results of scenarios 2 and 3).

A rough estimation of the total **net energy saving of all plastics insulation** including boards for roofs, floors and cellar walls, and used in 2004 to improve insulation conditions, resulted in a minimum of **9.500 Mill GJ**, which is equal to

- 20 % of the total final energy consumption of the EU 25 in 2002 (1.080 Mill tonnes oil equivalent or 48.600 Mill GJ (gross calorific value) according to DG TREN [2004])
- 800 big oil tankers (VLCC - very large crude oil carriers, typical load of 260 kt crude oil, length 330 m)
- the energy needed by 61 nuclear power plants with 1.500 MW power
- 2,3 times the total life-cycle energy demand of plastic products in 2002 (3.900 Mill GJ, according to GUA [2005]), i.e. more than twice needed for a “pay-back”
- 54 times the additional production energy needed for a 4,5% growth of plastic products (180 Mill GJ, according to GUA [2005]), i.e. much more than needed for absolute decoupling.

5 Conclusions

The results of this study show that plastics insulation materials enable enormous energy savings throughout their total life cycle, even if they are made from fossil fuels. Energy needed for production is already balanced by energy savings within the first 4 months of the use-phase. In their total life cycle, plastics insulation boards save 150 times more energy that was needed for production.

Other insulation materials will show similar results, as differences in production energy contribute with less than 1 % to the total life-cycle energy balance.

Changes within waste management will affect the total life-cycle energy balance by less than 0,1 %. Therefore “recyclability” of insulation materials should not be used as an important parameter to assess sustainability of insulation materials.

In summary, increased use of any insulation material will give a significant contribution to sustainable resource management in Europe and should therefore by supported.

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5 German market data (see Table 2). For European market a split into application sectors was not available.

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7 Annex

The tables below present the detailed calculation of net energy savings in the total lifetime of plastics insulation boards used on external walls, following the calculation procedure described above and based on U-values of scenario 1 (U-values taken from ECOFYS and oriented at EPB directive).

Results are presented for EPS, XPS and PUR for each country and for Europe in total (EU 25 + Norway + Switzerland). As the split of total PUR consumption in Europe into country consumptions had to be based on very rough estimations (see chapter 3.1), country specific results for energy saved by PUR insulation are quite uncertain. However, the uncertainties are likely to be balanced out within the total result for Europe.

7.1 General data

General data	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Inhabitants (2002)	Mill.	8,14	10,29	0,67	10,27	5,36	1,36	5,19	59,34	82,36
Heating degree days (HDD)	K.d	3.181	2.907	869	3.456	3.359	4.651	4.489	2.475	3.433
Heating degree seconds (HDS)	K.s	274.878.403	251.152.589	75.046.896	298.604.218	290.250.058	401.861.635	387.826.646	213.796.800	296.599.219
Insul. standard before improvement (U)	$W/m^2.K$	0,40	1,25	2,60	1,50	1,25	0,50	0,40	1,25	1,25

General data	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Inhabitants (2002)	Mill.	10,59	9,97	3,87	58,01	2,35	3,68	0,44	0,38	4,52
Heating degree days (HDD)	K.d	1.085	2.911	2.605	1.491	4.512	4.620	3.151	551	4.249
Heating degree seconds (HDS)	K.s	93.760.214	251.536.320	225.087.610	128.847.686	389.831.645	399.188.304	272.205.072	47.645.251	367.108.330
Insul. standard before improvement (U)	$W/m^2.K$	2,00	1,50	1,25	2,00	0,50	0,50	1,25	2,00	0,40

General data	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	United Kingdom
Inhabitants (2002)	Mill.	38,63	10,30	5,40	1,99	40,43	8,91	7,25	16,10	60,07
Heating degree days (HDD)	K.d	3.740	996	3.189	3.247	1.989	3.978	3.406	2.802	2.559
Heating degree seconds (HDS)	K.s	323.110.080	86.074.387	275.546.736	280.559.232	171.815.040	343.716.682	294.260.054	242.130.096	221.077.613
Insul. standard before improvement (U)	$W/m^2.K$	1,50	2,00	1,50	1,50	2,00	0,40	0,40	1,25	1,25

7.2 Detailed calculations for EPS

EPS-Boards	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Total consumption	t/a	26.474	10.889	872	18.379	22.224	2.765	21.519	67.619	127.315
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	6.354	2.613	209	4.411	5.334	664	5.165	16.229	30.556
Average thickness of additional insulation	cm	9,0	5,2	3,6	4,4	5,2	7,2	9,0	5,2	5,2
Resulting area of additional insulation	m^2	4.150.930	2.944.070	345.521	5.962.878	6.008.464	541.997	3.374.005	18.281.478	34.420.862
Resulting energy saving in 1 year	GJ/a	-324.314	-851.393	-69.612	-2.460.238	-2.008.075	-77.386	-371.932	-4.500.457	-11.755.357
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-16.215.700	-42.569.637	-3.480.602	-123.011.919	-100.403.730	-3.869.306	-18.596.578	-225.022.835	-587.767.853
Production energy	GJ	597.259	245.666	19.681	414.641	501.373	62.388	485.471	1.525.487	2.872.229
Energy effects waste management	GJ	-26.686	-10.977	-879	-18.527	-22.402	-2.788	-21.691	-68.160	-128.334
Net energy saving in total lifetime	**GJ**	**-15.645.126**	**-42.334.947**	**-3.461.800**	**-122.615.805**	**-99.924.759**	**-3.809.705**	**-18.132.799**	**-223.565.507**	**-585.023.957**

EPS-Boards	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Total consumption	t/a	13.789	17.032	13.530	94.388	4.779	7.483	466	495	14.701
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	3.309	4.088	3.247	22.653	1.147	1.796	112	119	3.528
Average thickness of additional insulation	cm	4,6	4,4	5,2	4,6	7,2	7,2	5,2	4,6	9,0
Resulting area of additional insulation	m^2	4.200.998	5.525.842	3.657.999	28.757.229	936.539	1.466.580	125.888	150.744	2.304.939
Resulting energy saving in 1 year	GJ/a	-813.401	-1.920.545	-948.068	-7.651.688	-129.716	-208.005	-39.457	-14.832	-240.510
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-40.670.042	-96.027.246	-47.403.379	-382.584.385	-6.485.785	-10.400.236	-1.972.858	-741.589	-12.025.506
Production energy	GJ	311.073	384.251	305.240	2.129.395	107.804	168.816	10.505	11.162	331.648
Energy effects waste management	GJ	-13.899	-17.169	-13.638	-95.143	-4.817	-7.543	-469	-499	-14.818
Net energy saving in total lifetime	**GJ**	**-40.372.868**	**-95.660.164**	**-47.111.778**	**-380.550.133**	**-6.382.798**	**-10.238.963**	**-1.962.823**	**-730.926**	**-11.708.676**

EPS-Boards	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	United Kingdom
Total consumption	t/a	113.082	1.693	6.153	5.502	42.785	7.981	11.207	31.430	24.518
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	27.140	406	1.477	1.320	10.268	1.915	2.690	7.543	5.884
Average thickness of additional insulation	cm	4,4	4,6	4,4	4,4	4,6	9,0	9,0	5,2	5,2
Resulting area of additional insulation	m^2	36.687.401	515.779	1.996.360	1.784.998	13.035.410	1.251.343	1.757.208	8.497.312	6.628.562
Resulting energy saving in 1 year	GJ/a	-16.379.204	-91.679	-760.080	-691.971	-4.625.082	-122.252	-146.972	-2.369.051	-1.687.362
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-818.960.176	-4.583.963	-38.004.005	-34.598.528	-231.254.108	-6.112.609	-7.348.592	-118.452.560	-84.368.084
Production energy	GJ	2.551.133	38.192	138.821	124.123	965.237	180.050	252.837	709.053	553.117
Energy effects waste management	GJ	-113.987	-1.706	-6.203	-5.546	-43.128	-8.045	-11.297	-31.681	-24.714
Net energy saving in total lifetime	**GJ**	**-816.523.031**	**-4.547.478**	**-37.871.387**	**-34.479.951**	**-230.331.999**	**-5.940.604**	**-7.107.051**	**-117.775.188**	**-83.839.681**

7.3 Detailed calculations for PUR

PUR-Boards	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Total consumption	t/a	9.601	19.715	216	18.277	6.676	3.257	11.996	96.781	47.000
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	2.304	4.732	52	4.386	1.602	782	2.879	23.227	11.280
Average thickness of additional insulation	cm	6,4	3,7	2,5	3,1	3,7	5,1	6,4	3,7	3,7
Resulting area of additional insulation	m^2	1.070.546	3.790.453	60.771	4.216.729	1.283.505	453.976	1.337.559	18.607.446	9.036.388
Resulting energy saving in 1 year	GJ/a	-83.642	-1.096.157	-12.244	-1.739.791	-428.957	-64.819	-147.445	-4.580.702	-3.086.093
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-4.182.111	-54.807.856	-612.180	-86.989.525	-21.447.865	-3.240.929	-7.372.251	-229.035.110	-154.304.628
Production energy	GJ	241.952	496.815	5.437	460.572	168.229	82.082	302.299	2.438.879	1.184.400
Energy effects waste management	GJ	-5.530	-11.356	-124	-10.527	-3.845	-1.876	-6.910	-55.746	-27.072
Net energy saving in total lifetime	**GJ**	**-3.945.690**	**-54.322.397**	**-606.867**	**-86.539.480**	**-21.283.481**	**-3.160.723**	**-7.076.862**	**-226.651.976**	**-153.147.300**

PUR-Boards	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Total consumption	t/a	4.261	14.946	3.738	32.073	5.460	8.755	914	78	9.889
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	1.023	3.587	897	7.698	1.310	2.101	219	19	2.373
Average thickness of additional insulation	cm	3,3	3,1	3,7	3,3	5,1	5,1	3,7	3,3	6,4
Resulting area of additional insulation	m^2	923.131	3.448.301	718.659	6.949.094	760.962	1.220.235	175.666	16.833	1.102.657
Resulting energy saving in 1 year	GJ/a	-178.737	-1.198.481	-186.260	-1.849.006	-105.397	-173.066	-55.059	-1.656	-115.057
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-8.936.869	-59.924.057	-9.312.983	-92.450.313	-5.269.865	-8.653.283	-2.752.943	-82.809	-5.752.867
Production energy	GJ	107.369	376.641	94.195	808.246	137.587	220.626	23.025	1.958	249.209
Energy effects waste management	GJ	-2.454	-8.609	-2.153	-18.474	-3.145	-5.043	-526	-45	-5.696
Net energy saving in total lifetime	**GJ**	**-8.831.955**	**-59.556.025**	**-9.220.941**	**-91.660.541**	**-5.135.423**	**-8.437.700**	**-2.730.445**	**-80.895**	**-5.509.354**

PUR-Boards	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	United Kingdom
Total consumption	t/a	74.389	5.284	11.351	3.327	41.400	23.363	12.715	23.233	101.308
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	17.853	1.268	2.724	799	9.936	5.607	3.051	5.576	24.314
Average thickness of additional insulation	cm	3,1	3,3	3,1	3,1	3,3	6,4	6,4	3,7	3,7
Resulting area of additional insulation	m^2	17.162.657	1.144.794	2.618.836	767.692	8.969.766	2.604.930	1.417.676	4.466.864	19.477.824
Resulting energy saving in 1 year	GJ/a	-7.662.321	-203.486	-997.077	-297.603	-3.182.555	-254.493	-118.574	-1.245.362	-4.958.260
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-383.116.065	-10.174.308	-49.853.874	-14.880.134	-159.127.731	-12.724.665	-5.928.681	-62.268.094	-247.912.990
Production energy	GJ	1.874.592	133.150	286.043	83.851	1.043.270	588.735	320.406	585.472	2.552.960
Energy effects waste management	GJ	-42.848	-3.043	-6.538	-1.917	-23.846	-13.457	-7.324	-13.382	-58.353
Net energy saving in total lifetime	**GJ**	**-381.284.320**	**-10.044.201**	**-49.574.370**	**-14.798.200**	**-158.108.307**	**-12.149.386**	**-5.615.598**	**-61.696.004**	**-245.418.384**

7.4 Detailed calculations for XPS

XPS-Boards	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Total consumption	t/a	12.446	4.351	156	707	2.462	94	2.384	16.405	52.031
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	2.987	1.044	37	170	591	22	572	3.937	12.487
Average thickness of additional insulation	cm	7,8	4,5	3,1	3,8	4,5	6,2	7,8	4,5	4,5
Resulting area of additional insulation	m^2	1.150.831	693.792	36.326	135.232	392.488	10.818	220.398	2.615.509	8.295.675
Resulting energy saving in 1 year	GJ/a	-89.915	-200.637	-7.318	-55.796	-131.172	-1.545	-24.295	-643.875	-2.833.125
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-4.495.747	-10.031.855	-365.925	-2.789.783	-6.558.618	-77.231	-1.214.774	-32.193.743	-141.656.269
Production energy	GJ	256.892	89.815	3.210	14.589	50.810	1.932	49.198	338.591	1.073.917
Energy effects waste management	GJ	-12.546	-4.386	-157	-712	-2.481	-94	-2.403	-16.536	-52.447
Net energy saving in total lifetime	**GJ**	**-4.251.401**	**-9.946.426**	**-362.872**	**-2.775.906**	**-6.510.289**	**-75.394**	**-1.167.979**	**-31.871.688**	**-140.634.799**

XPS-Boards	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Total consumption	t/a	2.458	2.314	607	29.799	162	253	186	88	2.076
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	590	555	146	7.152	39	61	45	21	498
Average thickness of additional insulation	cm	4,0	3,8	4,5	4,0	6,2	6,2	4,5	4,0	7,8
Resulting area of additional insulation	m^2	441.662	442.774	96.706	5.354.095	18.693	29.273	29.667	15.848	191.946
Resulting energy saving in 1 year	GJ/a	-85.515	-153.889	-25.064	-1.424.611	-2.589	-4.152	-9.298	-1.559	-20.029
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-4.275.750	-7.694.466	-1.253.194	-71.230.543	-129.456	-207.588	-464.919	-77.965	-1.001.436
Production energy	GJ	50.737	47.766	12.519	615.059	3.338	5.228	3.840	1.821	42.847
Energy effects waste management	GJ	-2.478	-2.333	-611	-30.038	-163	-255	-188	-89	-2.093
Net energy saving in total lifetime	**GJ**	**-4.227.491**	**-7.649.032**	**-1.241.286**	**-70.645.521**	**-126.281**	**-202.616**	**-461.266**	**-76.234**	**-960.682**

XPS-Boards	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	United Kingdom
Total consumption	t/a	2.659	5.886	372	462	23.103	4.092	11.085	6.808	9.415
Share for improvement of external walls	%	24%	24%	24%	24%	24%	24%	24%	24%	24%
Relevant insulation mass for this study	t/a	638	1.413	89	111	5.545	982	2.661	1.634	2.260
Average thickness of additional insulation	cm	3,8	4,0	3,8	3,8	4,0	7,8	7,8	4,5	4,5
Resulting area of additional insulation	m^2	508.667	1.057.509	71.105	88.377	4.150.981	378.372	1.025.003	1.085.525	1.501.064
Resulting energy saving in 1 year	GJ/a	-227.096	-187.971	-27.072	-34.260	-1.472.806	-36.966	-85.731	-302.645	-382.110
Lifetime of insulation	years	50	50	50	50	50	50	50	50	50
Energy saving use-phase in total lifetime	GJ	-11.354.793	-9.398.570	-1.353.608	-1.713.011	-73.640.296	-1.848.284	-4.286.533	-15.132.228	-19.105.491
Production energy	GJ	54.875	121.483	7.671	9.534	476.850	84.461	228.805	140.527	194.320
Energy effects waste management	GJ	-2.680	-5.933	-375	-466	-23.288	-4.125	-11.174	-6.863	-9.490
Net energy saving in total lifetime	**GJ**	**-11.302.598**	**-9.283.020**	**-1.346.312**	**-1.703.943**	**-73.186.734**	**-1.767.948**	**-4.068.903**	**-14.998.564**	**-18.920.660**

7.5 Calculation of saved greenhouse gas emissions

Saved GHG emissions	Unit	Austria	Belgium	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany
Energy demand production	GJ/a	1.096.104	832.296	28.328	889.802	720.411	146.402	836.968	4.302.958	5.130.546
CO_2-equivalents	t/a	38.846	32.036	1.003	33.829	25.771	5.615	30.770	164.819	182.407
Saved heating fuels	GJ/a	-19.073.083	-82.295.481	-3.416.196	-163.037.545	-98.386.038	-5.506.932	-20.827.682	-372.558.974	-677.100.121
CO_2-equivalents	t/a	-1.404.408	-6.059.663	-251.545	-12.004.943	-7.244.459	-405.492	-1.533.605	-27.432.634	-49.856.911
Total CO_2-equivalents	**Mio t/a**	**-1,37**	**-6,03**	**-0,25**	**-11,97**	**-7,22**	**-0,40**	**-1,50**	**-27,27**	**-49,67**

Saved GHG emissions	Unit	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Malta	Norway
Energy demand production	GJ/a	469.178	808.658	411.953	3.552.700	248.729	394.670	37.370	14.941	623.704
CO_2-equivalents	t/a	16.742	30.374	14.745	126.404	9.525	15.131	1.444	522	23.103
Saved heating fuels	GJ/a	-41.284.111	-125.383.009	-44.415.431	-418.540.486	-9.106.195	-14.757.581	-3.977.054	-691.377	-14.388.817
CO_2-equivalents	t/a	-3.039.873	-9.232.327	-3.270.441	-30.818.390	-670.516	-1.086.645	-292.842	-50.908	-1.059.492
Total CO_2-equivalents	**Mio t/a**	**-3,02**	**-9,20**	**-3,26**	**-30,69**	**-0,66**	**-1,07**	**-0,29**	**-0,05**	**-1,04**

Saved GHG emissions	Unit	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	The Netherlands	UK
Energy demand production	GJ/a	4.480.599	292.825	432.534	217.509	2.485.356	853.247	802.048	1.435.052	3.300.397
CO_2-equivalents	t/a	166.979	10.824	16.917	8.041	92.006	33.459	29.459	53.190	131.716
Saved heating fuels	GJ/a	-929.713.219	-18.508.620	-68.352.545	-39.222.316	-355.527.014	-15.848.974	-13.457.133	-150.059.631	-269.227.278
CO_2-equivalents	t/a	-68.457.571	-1.362.845	-5.033.003	-2.888.057	-26.178.520	-1.167.007	-990.889	-11.049.340	-19.824.011
Total CO_2-equivalents	**Mio t/a**	**-68,29**	**-1,35**	**-5,02**	**-2,88**	**-26,09**	**-1,13**	**-0,96**	**-11,00**	**-19,69**

7.6 Insulation standards in Europe

U-values given in the table below were given by building physic institutes and technical Universities in various European countries.

Country	External wall - description	W/m^2.K
A	OÖ WBF-regulation	0,5
A	25 cm brick, VZ-insulationbrick	1,16
A	30 cm brick, plaster inside + outside, + 10 cm full thermal insulation	0,32
A	25 cm brick, plaster inside + 10 cm full thermal insulation	0,33
A	25 cm concrete, plaster inside + 10 cm full thermal insulation	0,36
A	New building in A. (1996), external wall, average insulation standard	0,58
A	New building in A. (1996), external wall, low energy house ("passive house")	0,28
A	old buildings, external wall; before renovation (in brackets after renovation)	1,5 (0,4)
A	old buildings, external wall; before renovation	1,22
B	Old, non insuleted buildings	1,4-2,1
B	Actual normal practice	0,45-0,6
B	High tech	0,1-0,25
B	Legal value, is in force since 1993	0,6
CH	Typical U-value of "low standard house"	0,4-0,6
CH	Typical U-value of "medium standard house" (forced by law)	<0,3
CH	Typical U-value of "good standard house"	<0,2
CH	Passive house (MINENERGY-P)	<0,01
CZ	Sample for a modern insulation recommondation: Czech Republic; external wall	0,25
D	External wall, solid brick 24 cm	2
D	External wall, solid brick 36,5 cm	1,2
D	EnEV (Energy Conservation Decree)	0,2-0,5
D	Low energy house	0,2-0,3
D	Passive house	ca. 0,1
D	Sample for a modern insulation prescription: Germany; external wall	0,35
H	House built befote 1985; external wall	1,34
H	House built after 1992; external wall	0,7
H	House insulated according to national recommondations; external wall	0,3
H	Solid brick wall (38 and 25 cm) and cavity brick wall with few holes	1,9 - 1,4
H	Cavity brick wall with few (38 cm) and with much holes (25), B30 blockwall	1,4 - 1,1
H	Cavity brick wall with much holes (38 cm), UNIFORM blockwall (30cm)	1,1 - 0,8
H	POROTON (36 cm, 30 cm); THERMOPOR (36 cm); HB (38cm); HB (30cm);	0,8 - 0,6
PL	Building built before 1966	1,16-1,4
PL	Building built between 1967-1985	1,16
PL	Building built between 1986-1992	0,75
PL	Building built between 1993-1998	0,55
PL	Building built after 1998	0,3-0,55
PL	Current Polish standard requirements	0,3

Table 16: U-Values of external walls of various types of houses in different countries

7.7 Contacted institutes for data on U-values in European countries

Country	Institute	Reply	Adress	Homepage / e-mail
B	Laboratory of Building Physics	Yes	Kasteelpark Arenberg 40 B-3001 Heverlee	http://www.kuleuven.be/bwf/eng/about_contact.htm
CH	Institute of Building Technology Chair of Physics of Buildings	Yes	HIL E 46.2 CH-8093 Zürich	gass@hbt.arch.ethz.ch
D	IWU – Institue for Dwelling and Environment Ltd.	No data	Annastrasse 15. 64285 Darmstadt	http://www.iwu.de/
D	Bundesamt für Bauwesen und Raumordnung	No	Fasanenstraße 87 10623 Berlin	zentrale@bbr.bund.de
D	Fraunhofer-Institue for Buildig Physic (IBP)	No data	Fraunhoferstraße 10 83626 Valley/Oberlaindern	info@hoki.ibp.fraunhofer.de
D	Institute for Sustaining and Modernising of Buildings at TU Berlin IEMB	Yes	Salzufer 14. 10587 Berlin	www.iemb.de
D	German Energy Agency (DENA)	No	Chausseestr. 128a 10115 Berlin	info@dena.de
DK	Technical University of Denmark Department of Civil Engineering	No	Brovej, building 118 DK - 2800 Kgs. Lyngby	http://www.byg.dtu.dk/English/About/Contact_and_practical_info.aspx
E	Universitat Politècnica de Catalunya Department of Building Engineering (EC)	No	Jordi Girona 1-3. Mòdul C-1.Campus Nord, U.P.C. 08034-Barcelona	http://www-ec.upc.edu
FIN	VTT Building and transport Building Physics and Indoor Climate	No	P.O.Box 1806 (Betonimiehenkuja 5) FI-02044 VTT	http://www.vtt.fi/rte/bp/contacts/
GB	Department of Civil and Building Engineering Loughborough University	No	Loughborough Leicestershire LE11 3TU	Civ.Eng.enq@lboro.ac.uk
GR	School of Civil Engineering National Technical University of Athens	No	Heroon Polytechniou 9 Zografou 157 80 - Athens	admin@civil.ntua.gr
H	ÉMSZ-Hungarian Association of Building Insulators, Roofers and Tinsmiths	No data	H-1113 Budapest, Diószegi út 37.	www.emsz.hu
H	Non-Profit Company for Quality Control and Innovations in Buildings	?	1518 Budapest, Pf. 69.	Info@emi.hu
H	TU-Budapest; Department of Building Energetic and Mechanical Engineering in Buildings	?	H-1111 Budapest Műegyetem rpt. 3. K.I. 16.	zold@egt.bme.hu
PL	Instytut Budownictwa Division of Environmental and Building Physics	Yes	Plac Grunwaldzki 11, 50-377 Wrocław	Inst.Bud@pwr.wroc.pl
SE	BLOCON SWEDEN	No	Iliongränden 159, S-224 72 Lund	www.buildingphysics.com
SE	Department of Building Technology Building Physics Chalmers University of Technology	No	S-412 96 Göteborg	http://www.buildphys.chalmers.se/adress/default-e.htm

7.8 Insulation standards in Germany

German building typology; IWU December 2003				
Building code	**Building age class**	**Roof U-value**	**External wall U-value**	**Comment**
EFH (Einfamilienhaus) Family House				
EFH_A	before 1918	1,8	1,9	
EFH_B	before 1918	1,11	1,7	
EFH_C	1919-1948	1,11	1,7	
EFH_D	1949-1957	1,11	0,93	
EFH_E	1958-1968	0,92	1,44	
EFH_F	1969-1978	0,63	1,21	
EFH_G	1979-1983	0,43	0,8	
EFH_H	1984-1994	0,3	0,68	
EFH_I	1995-2001	0,22	0,5	
EFH_J	after 2002	0,22	0,35	
EFH_Sonder	1969-1978	0,52	0,4024	Prefabricated house
RH (Reihenhaus) Terraced House				
RH_B	1918	0,78	1,7	
RH_C	1919-1948	0,78	1,39	
RH_D	1949-1957	0,78	0,86	
RH_E	1958-1968	1,23	1,44	
RH_F	1969-1978	0,52	0,8	
RH_G	1979-1983	0,43	0,68	
RH_H	1984-1994	0,3	0,77	
RH_I	1995-2001	0,22	0,49	
RH_J	after 2002	0,14	0,24	
MFH (Mehrfamilienhaus) Owner-occupied Block				
MFH_A	before 1918	2,6	1,9	
MFH_B	before 1918	2,6	1,45	
MFH_C	1919-1948	1,41	1,64	
MFH_D	1949-1957	1,17	1,44	
MFH_E	1958-1968	2,3	1,21	
MFH_F	1969-1978	0,59	0,74	
MFH_G	1979-1983	0,44	0,8	
MFH_H	1984-1994	0,3	0,66	
MFH_I	1995-2001	0,21	0,28	
MFH_J	after 2002	0,22	0,35	
MFH_NBL_MFH	1946-1960	1,14	1,21	Industrial building production
MFH_NBL_MFH	1961-1969	1,14	1,46	Industrial building production
GMH (big multiple dwelling?)				
GMH_B	before 1918	2,6	1,45	
GMH_C	1919-1948	0,78	1,45	
GMH_D	1949-1957	2,08	1,21	
GMH_E	1958-1968	0,82	1,3	
GMH_F	1969-1978	0,82	1,46	
NBL_GMH_F	1970-1980	0,97	0,88	Industrial building production
NBL_GMH_G	1981-1985	0,97	0,88	Industrial building production
NBL_GMH_H	1986-1990	0,84	0,76	Industrial building production
HH (Hochhaus) High-rise Building				
HH_E	1958-1968	0,68	1,11	
HH_F	1969-1978	0,35	0,82	
NBL_HH_F	1970-1980	1,14	0,99	Industrial building production
NBL_HH_G	1981-1985	0,68	0,99	Industrial building production

Table 17: German building typology [IWU 2003]

The potential of plastic insulation to realise energy savings and de-coupling in Europe

Critical Review Report

by

Roland Hischier

for

PlasticsEurope,

Brussels (Belgium)

Date

February 1, 2006

Status

Final Version

The potential of plastic insulation to realise energy savings and de-coupling in Europe, commissioned by PlasticsEurope, Brussels

Critical Review Report

1 Origination and Course of Action

The herein described critical review process, commissioned by PlasticsEurope, has been established mainly in November 2005, and finalized, based on a revised version of the report, in February 2006. Although the examined study is not a traditional life cycle assessment (LCA) study according to the ISO EN DIN 14040 series [1a-d], a critical review process in the spirit of the terms of ISO series [1a] has been established. This on hand critical review report is based on the final report, dated from January 2006. It will be integrated in the very final version of the mentioned report.

The study has been established by collaborators of Austrian “Gesellschaft für umfassende Analysen” (GUA), Wien, Austria.

The critical review was established as a so-called **‘a posteriori’ survey**, i.e. the review took place after completion of the study. Besides a first version of the final report (dated October 2005), the reviewer got during the review time in November 2005 additional information about changes / additions done to this received final version of the report by e-mail. A revised version of the final report, dated January 2006, was the basis for this critical report.

Within the framework of the complete review process, no actual meetings took place due to the limitations in time but also due to the quite simple calculation method used in the study. Instead a telephone conference between the reviewer and GUA took place on November 23, 2005. This telephone conference allowed among others to the reviewer to discuss and check, based on beforehand calculated random samples, the calculation work done within the framework of the study, and thus enhanced the value of the whole review process for the commissioner.

2 Comments about the report

2.1 Criteria

The whole review process is based on the review work established in the framework of a previous study from GUA for PlasticsEurope, dealing with the contribution of plastics in general to resource efficiency [2]. Apart the above mentioned check of the calculations, the following criteria have been examined for this study here:

- *Is method scientifically sounded and reasonable within goal of the study?*
- *Are used data sufficient and appropriate in respect of goal of the study?*
- *Does conclusion take into account the recognized limitations of the study, especially in the framework of original aim of the study?*
- *Is the report transparent and coherent?*

2.2 Scientific background and Practicability of the used Method

This study had, similar to [2] never the aim of establishing a complete “classical” LCA study according to the international ISO standards [1a-d] and thus cannot be compared with those standards in the framework of the critical review process here.

According to chapter 2.1 of the study, the goal of the study is to quantify the net energy savings due to the use of plastics insulation materials. Neither a comparison with other insulation materials, nor a comparison between different types of plastic insulation materials is in the focus of this study. For this objective, GUA presents in chapter 2.2 in a logical and transparent manner the approach that has been used for this study here, allowing to the reader to follow the calculations in all details.

The method, based on a life-cycle approach, is clearly in accordance with the aim of the study. It is admissible, like described in chapter 2.2, to use this approach only to calculate the effects of additional insulation. However, the so achieved energy savings are not specific to the plastic insulation materials, but they can be achieved by either insulation materials. Although this limitation is not explicitly mentioned in chapter 2 – the fact that this limitation is mentioned as well at the end of chapter 1 (“summary”) as well as in chapter 5 (“Conclusions”) and thus in the two most read chapters of a report, is judged sufficient from the reviewer’s point of view.

For the aggregation of the few air emissions factors to one common global warming potential value, the method used is taken from the most recent developments in the field of LCA (see e.g. [3]).

All in all, the chosen methods can be qualified as scientifically adequate and reasonable in the context of the objectives and the timeframe of this study. The examination of the complete model by random examples during the telephone conference brought no errors up, the model is mathematically correct.

2.3 Appropriateness of data

But more important than this method for the calculation of the net energy savings is the approach and use of adequate data requested for the calculations. Again, the report from GUA presents in a very clear and transparent manner across chapter 3 how the various values have been collected and/or calculated in order to be able to calculate the energy saving potentials for each European country (EU25 and Norway and Switzerland).

The present project has shown (once again) that for such a study, where real market situation shall be represented, adequate, comparable but country specific data are necessary. Actually, data on three different levels have been necessary for this study here:

1. data about the market situation of the various plastic insulation materials
2. data about the geographical situation in each of the included countries
3. data about the energy consumption and the corresponding global warming potential of all materials in the various steps of the complete life-cycle

For the market data, depending on the plastic type, more or less adequate data, representing more or less the situation on the European market around 2004 have been used. Especially for the distribution of total PUR consumption to countries, the data had to be based on assumptions (except for Germany), thus, creating quite high uncertainties for the further calculation steps.

Concerning these weak PUR data on the level of countries, a sensitivity analysis has been established that shows that even big variations will lead only to very small changes in the results – thus, the here presented energy saving potentials are of a good quality despite the weak PUR data on the level of countries.

The quality of the data of the U-value and their respective influence on the results has been examined with two additional scenarios in the calculation and result chapter. Again this is done in a transparent way, allowing critical reader easy to see what these changes result in.

For the geographical data used, the estimation procedure used is clearly described in chapter 3.5 of the report. According to the graph shown, this estimation procedure ends up with a quite good correlation between the average temperature and the heating degree days. Thus, the here used approach is surely sufficient for this study.

For the life cycle information of the different materials, up-to-date literature and databases (like e.g. [3]) representing Western European conditions have been used. The quality of the various datasets used is more than sufficient for this type of study, especially taken into account that the use phase is dominating the overall life-cycle results in all three cases.

2.4 Conclusions of the Report

The respective chapters (Calculations and results, conclusions) are transparent and in a logic manner (from specific field – i.e. external walls – to an overall estimation, including roof, floors and cellar walls) build up. By using own data about the "U-value" in two additional scenarios, what can be estimated to be a kind of sensitivity analysis, the influence of this central value (U-value) for the total results is examined and the standard values of the first scenario are positioned in a more comprehensive environment.

In the final chapter "conclusion", a clear link back to the limitations but also the peculiarities of the examinations undertaken within this study is made – i.e.:

(1) the reported results for plastic insulation materials ("enormous energy savings throughout their total life cycle") are also valuable for any other insulation material;

(2) that changes in the end-of-life treatment of insulation materials are neglectable due to their very small influence on the overall life cycle – and thus, "recycability" can't be used as a central parameter in the sustainability discussion of any type of insulation materials.

2.5 Transparency and Coherence of the Report

The complete report is clear and logic structured, most of time easy understandable and properly designed. The calculation spreadsheets are shown in the annex of the report, allowing an easy access to the complete study.

3 Summary and Conclusion

The complete study has been established in a transparent and logic way, although based on partly limited market information for the included plastic insulation materials. As the uncertainty from this limited information is small, this allows the authors of this study nevertheless to make clear statements in favour of the use of additional insulation materials. All in all, the study can be recommended for publication. This will certainly open a more adequate discussion about insulation materials and the relevance of the various life stages.

4 References

[1a] International Standard (ISO); Norme Européenne (CEN): Environmental management - Life cycle assessment - Principles and framework. Prinzipien und allgemeine Anforderungen ISO EN DIN 14040 (1997)

[1b] International Standard (ISO); Norme Européenne (CEN): Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis. Festlegung des Ziels und des Untersuchungsrahmens sowie Sachbilanz ISO EN DIN 14041 (1998)

[1c] International Standard (ISO); Norme Européenne (CEN): Environmental management - Life cycle assessment - Life cycle impact assessment (Wirkungsabschätzung). International Standard ISO EN DIN 14042 (1999)

[1d] International Standard (ISO); Norme Européenne (CEN) Environmental management - Life cycle assessment - Interpretation (Auswertung).ISO EN DIN 14043 (1999)

[2] GUA (2005): The Contribution of Plastic Products to Resource Efficiency. GUA – Gesellschaft für umfassende Analysen, Vienna for PlasticsEurope, Brussels.

[3] Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Dones R., Hischier R., Hellweg S., Humbert S., Margni M., Nemecek T. and Spielmann M. (2004c) Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000 No. 3. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.ch.

St. Gallen, February 1, 2006

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