BASF
The Chemical Company

Label

Eco-Efficiency Analysis

Refurbishment of Detached House (Germany)

July 17th, 2008

Summary (1)

- This eco-efficiency analysis compares various alternatives for living (and refurbishing) of one detached house in Germany (building year 1963) for 30 years (2008-2038), room temperature 19°C
- The house owner could:
  - leave the house as is, without any refurbishment (no improvement of insulation)
  - refurbish the façade with new plaster (no improvement of insulation)
  - refurbish the façade with an Exterior Insulation Finishing System (EIFS), among available EIFS systems the following are considered:
    - ✓ Neopor® (EPS) insulation board with WLG 032
    - ✓ Mineral Wool (MW) insulation board with WLG 040
    - ✓ Polyurethane spray foam (PUR) insulation with WLG 028

    EIFS based on EPS and MW are commercially available as HECK MultiTherm products by Colfirmit Rajasil GmbH & Co. KG

Summary (2)

- The eco-efficiency analysis shows that the three EIFS alternatives are overall the most eco-efficient solutions, with lower environmental impact and lower costs
  - **Among the EIFS systems the Neopor® (EPS) insulation board with WLG 032 is the most eco-efficient solution for refurbishment**
  - **The Mineral Wool (MW) insulation board with WLG 040 and the polyurethane spray foam (PUR) insulation with WLG 028 are the second best solutions, with equal eco-efficiency**

- Refurbishing the façade without any improvement of insulation is the less eco-efficient option, with higher environmental impact and higher costs
- Leaving the house ‘as is’ is slightly more eco-efficient than refurbishment without EIFS

The Eco-Efficiency Label Requirements

BASF The Chemical Company

1. Accomplished Eco-Efficiency Analysis according to the methodology certified by TÜV Rhineland/ Berlin-Brandenburg, Germany.

2. Verification of the investigated product to be more eco-efficient for the defined customer benefit than other alternatives as result of the analysis.

3. Presentation of a third party evaluation (so-called Critical Review according ISO 14040 et seq.).

4. Publication of the results via internet on website www.oeea.de, which is referred to on the label.

5. Payment of the license fee for the duration of three years.

Eco-Efficiency Labels
Certificates

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CERTIFICATE

Eco-Efficiency Analysis
"Influence of Refurbishment
on Use of Detached House (Germany)"

ÖKOEFFIZIENZ-ANALYSE · ECO-EFFICIENCY ANALYSIS
1st place
in an environmental and economic evaluation according to the independently audited BASF method for use in Refurbishment of Detached House (Germany)
www.oeea.de

The evaluation of environmental and economic effects of "Influence of refurbishment on use of detached house" using an eco-efficiency analysis according to the validated method is certified.

BASF Construction Chemicals, Colfirmit Rajasil GmbH & Co. KG

is granted the right to use the Eco-Efficiency Label in the presented form for

Heck EIFS EPS
with insulation board WLG 032

for a duration of three years.

The main results are published under www.oeea.de

Ludwigshafen, 17.07.2008

Dr. M. Kayser
Senior Vice President Product Safety

Dr. P. Saling
Group Leader Eco-Efficiency

BASF

CERTIFICATE

Eco-Efficiency Analysis
"Influence of Refurbishment
on Use of Detached House (Germany)"

ÖKOEFFIZIENZ-ANALYSE · ECO-EFFICIENCY ANALYSIS
2nd place
in an environmental and economic evaluation according to the independently audited BASF method for use in Refurbishment of Detached House (Germany)
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BASF Construction Chemicals, Colfirmit Rajasil GmbH & Co. KG

is granted the right to use the Eco-Efficiency Label in the presented form for

Heck EIFS MW
with insulation board WLG 040

for a duration of three years.

The main results are published under www.oeea.de

Ludwigshafen, 17.07.2008

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BASF Construction Chemicals, Colfirmit Rajasil GmbH & Co. KG

is granted the right to use the Eco-Efficiency Label in the presented form for

Heck EIFS PUR
with insulation board WLG 028

for a duration of three years.

The main results are published under www.oeea.de

Ludwigshafen, 17.07.2008

Dr. M. Kayser
Senior Vice President Product Safety

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Group Leader Eco-Efficiency

BASF

Eco-Efficiency Label

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The Chemical Company

The Eco-Efficiency label can be awarded to the listed External Insulation Finishing Systems.
It was shown that they are more eco-efficient than alternative solutions:

- **Heck EIFS EPS with insulation board WLG 032 (1st place)**
- **Heck EIFS MW with insulation board WLG 040 (2nd place)**
- **Heck EIFS PUR with insulation board WLG 028 (2nd place)**

Expert Opinion: Critical Review
Five Winds International

Critical Reviewer:	Dr.-Ing. Ivo Mersiowsky, Five Winds International

After critical review of the report titled '**Use and Possibly Refurbishment with Exterior Insulation Finishing System of Detached House (building year 1963) in Germany**' and the supporting inventory and impact assessment calculations, the main conclusions of the critical reviewers are as follows:

- The LCA data are appropriate and valid with respect to the stated goal and scope.
- Except where noted above with respect to weighting and aggregation, the LCA elements of the eco-efficiency analysis were conducted in accordance with ISO 14040–14044.
- The eco-efficiency analysis – including portions beyond the scope of LCA according to ISO 14040–14044 – was conducted in accordance with peer-reviewed publications on this methodology.
- The involvement of interested parties in the review of the LCA portion of this ecoefficiency analysis was beyond the scope of this critical review.
- This critical review does not imply an endorsement of the eco-efficiency method, nor of any comparative assertion based on this eco-efficiency analysis and its LCA elements.

Excerpt: In the course of the critical review, the practitioner responded openly and very competently to questions and suggestions by the reviewer. The eco-efficiency analysis is a peer-reviewed and very sophisticated method, its execution supported by a professional LCA database and well developed software model.

Eco-Efficiency Analysis

Use and Possibly Refurbishment with Exterior Insulation Finishing System of Detached House (building year 1963) in Germany

Ludwighsafen, June 6, 2008

Analysis: Kremena Borisova, diploma student, Construction Chemicals BASF SE

Supervisor: Dr Marianna Pierobon, Eco-Efficiency Analysis BASF SE

Commissioned by Herwig Heegewaldt, Construction Chemicals BASF SE

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Summary

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- This eco-efficiency analysis compares various alternatives for living in one detached house in Germany (building year 1963) for 30 years (2008-2038), room temperature 19°C
- In 2008 the owner can choice between following options:
    - leave the house as is, without any refurbishment (no improvement of insulation)
    - refurbish the façade with new plaster (no improvement of insulation)
    - refurbish the façade with an Exterior Insulation Finishing System (EIFS)

(These three options are the main alternatives examined in this eco-efficiency analysis)

Three different EIFS have been taken into account:

- Neopor® (expanded polystyrene EPS, organic material)
- Mineral wool (inorganic material)
- Polyurethane spray foam (PUR, organic material)

- The three EIFS alternatives are the most eco-efficient, with lower environmental impact and lower costs
- Refurbishing the façade without any improvement of insulation is the less eco-efficient alternative, with higher environmental impact and higher costs
- Leaving the house ‘as is’ is slightly more eco-efficient than refurbishment without EIFS

Customer Benefit and Alternatives

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Living in a detached house in Germany (building year 1963) with average room temperature 19 °C, for 30 years (2008-2038)

Façade Refurbishment (EIFS) in 2008 with **Neopor**® (8 cm), WLG 032

Façade Refurbishment (EIFS) in 2008 with **Mineral Wool** (10 cm), WLG 040

Façade Refurbishment (EIFS) in 2008 With **PUR Spray Foam** (7 cm)*, WLG 028

Façade Refurbishment in 2008 **(no EIFS)**

No Refurbishment

* Product under development

General Assumptions: Detached House

- 1 detached House, building year 1963: this special building was chosen for the analysis since it represents one of most common buildings in Germany
- The house façade has U-value **1,44 W/m²K**
- House volume – 728 m^3
- Effective area according to EnEV – 233m^2
- Surface (façade) to be insulated – 229 m^2
- Heating system gas-fired condensing boiler,13 years old
  energy loss of heating 40%
- Double-glazed windows
- After refurbishment with any of the exterior insulation finishing systems analyzed the house façade has U-value **0,31 W/m²K**
- Beside the EIFS, when applicable, no improvement of insulation of cellar or roof are carried out

General Assumptions
Costs

- Price for gas in 2008 – 0,0677 €/Kwh (average price in Germany in 2007)
- 6 % (inflation-adjusted): Gas-Price increase per year
- 3 % (inflation-adjusted): Disposal-cost increase per year
- 100% external financing of costs for refurbishment , i_s= 5%
- Amortization period – 3 years
- 7 % discounting for future investments

General Assumptions
End of Life

- The new owner is expected to live in the house for 30 years (2008-2038), with average room temperature of 19°C
- After 30 years the house will be destroyed: materials will be incinerated (organic) or landfilled (inorganic). This is an assumption since in 2008 no real data are available for end of life of EIFS

General Assumptions

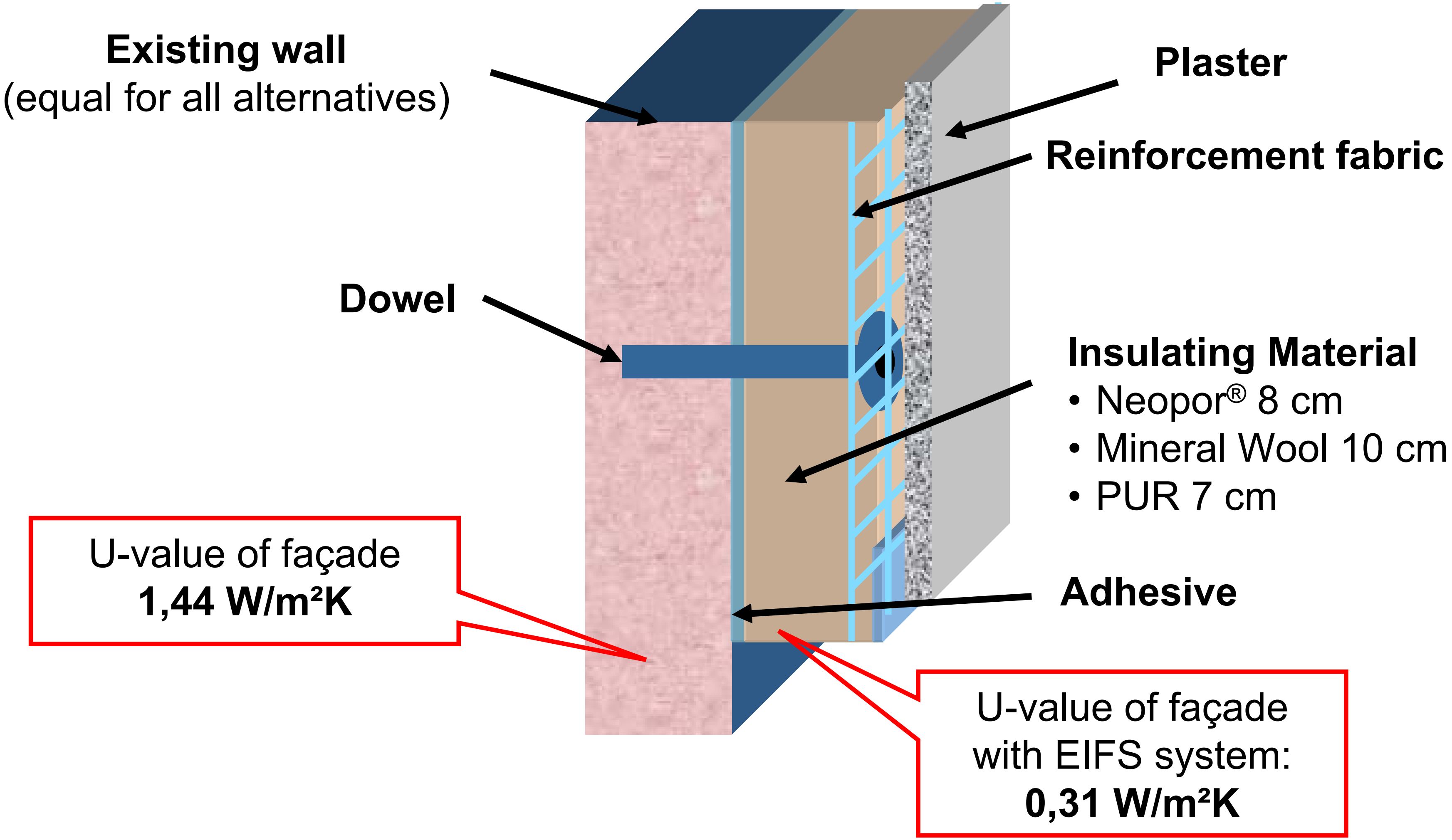
- In the analysis the heating (costs and environmental impact) for insulated alternatives is considered as zero-value for all alternatives: for remaining alternatives the heating is the difference between real heating and this zero-value

- Neopor and mineral wool are available in the German market and have been used for several years in EIFS
- The PUR spray foam has been used in Germany mainly for roofs, containers and special applications, but not yet for façade insulation of houses

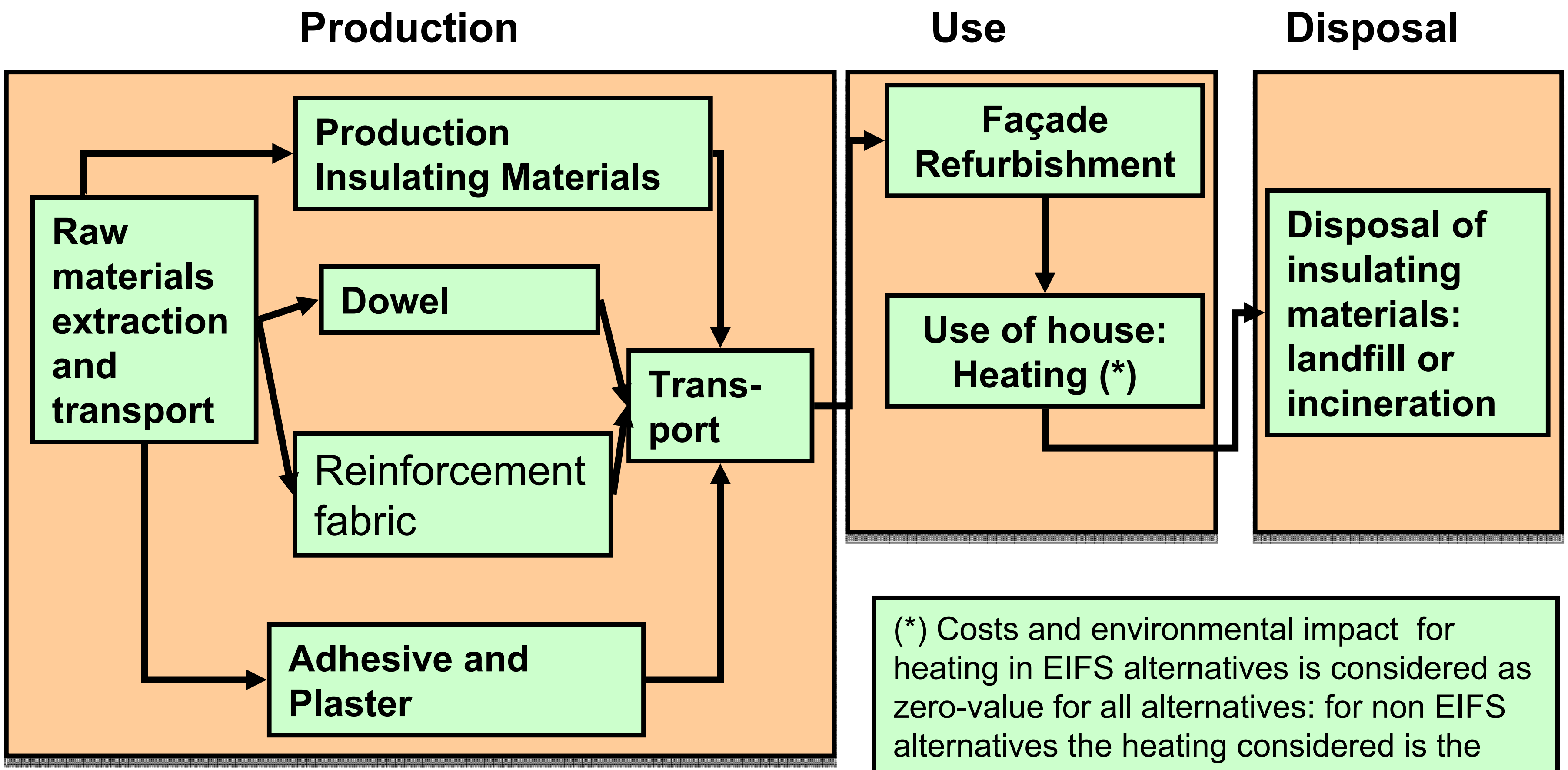
In other countries (US, China, Spain) it is used for insulation of façades, but not in combination with plaster. Plasters that can be used with such PUR foam are under development.

  - The PUR foam considered in the analysis is a product under development, not yet a commercial product
  - For the analysis the same plaster system as for other EIFS has been assumed
  - This assumption should not change the overall results since the plaster variation will be limited to admixtures and auxiliaries (1%-3% of plaster mass)

External Insulation Finishing Systems Description



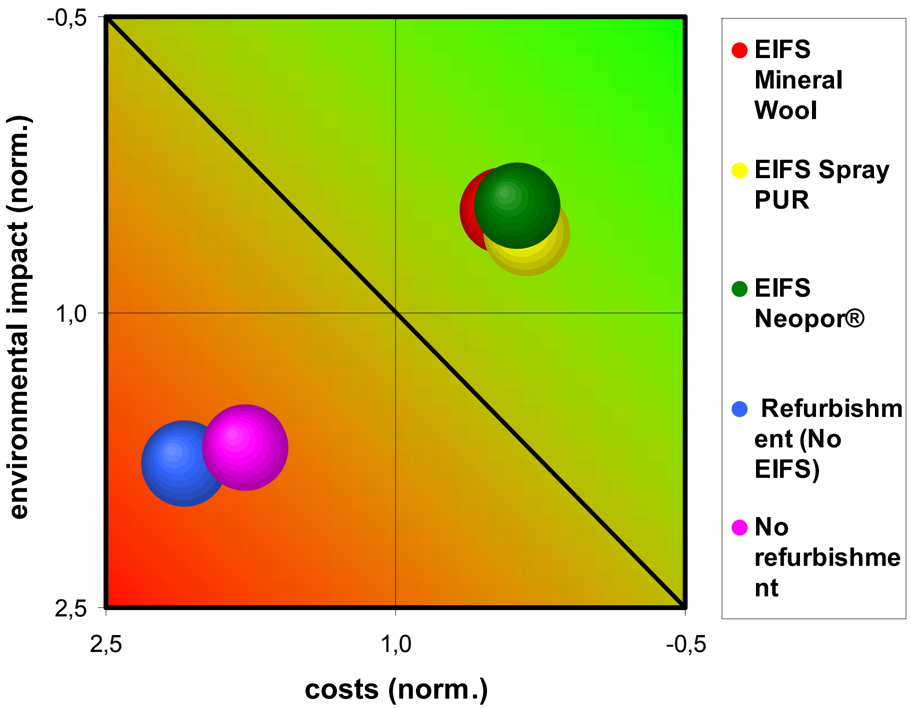
System Boundaries



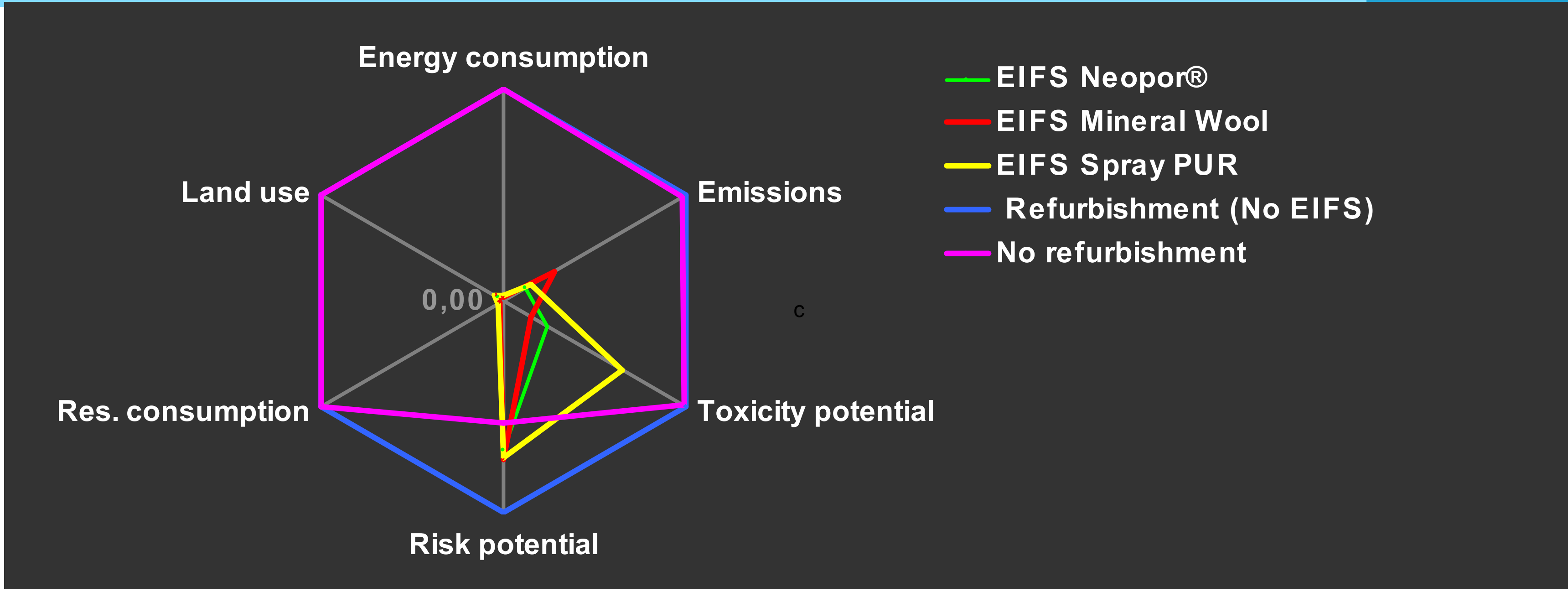
(*) Costs and environmental impact for heating in EIFS alternatives is considered as zero-value for all alternatives: for non EIFS alternatives the heating considered is the difference between real heating and this zero-value

Results
Eco-Efficiency Portfolio

- The three EIFS alternatives have lower costs compared with remaining alternatives
- The EIFS alternatives show ecological advantages, too
- EIFS systems are more eco-efficient than Refurbishment without EIFS and no Refurbishment at all
- The use of gas in the heating system has a major influence on the analysis result



Results
Environmental Fingerprint



- The three EIFS alternatives show lower impact in most environmental categories
- Only in the category Risk (working accidents and occupational diseases) the EIFS alternatives have a worse rating (working accidents during refurbishment)
- The EIFS PUR alternative have a worse rating for toxicity compared to other EIFS systems due to isocyanates in the pre-chain of PUR systems

Results
Costs

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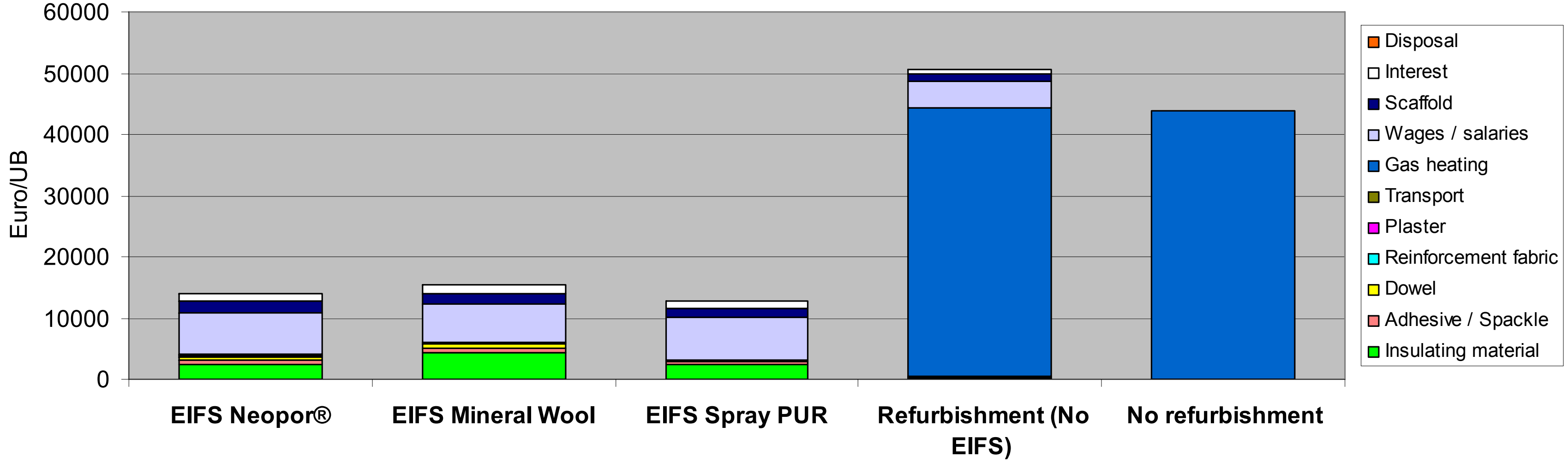
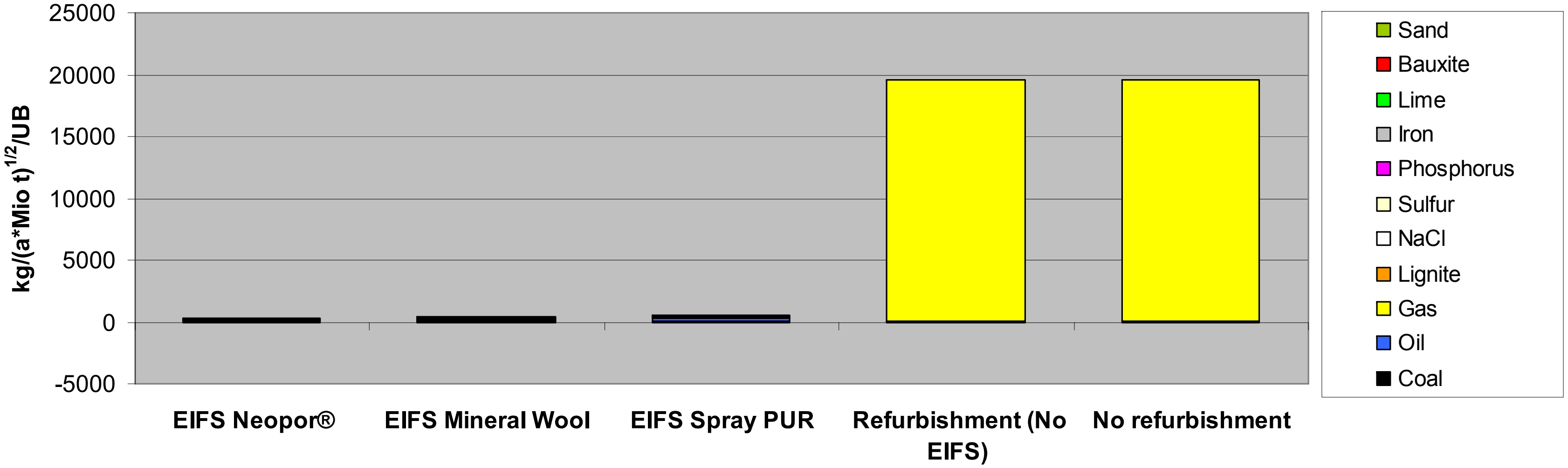
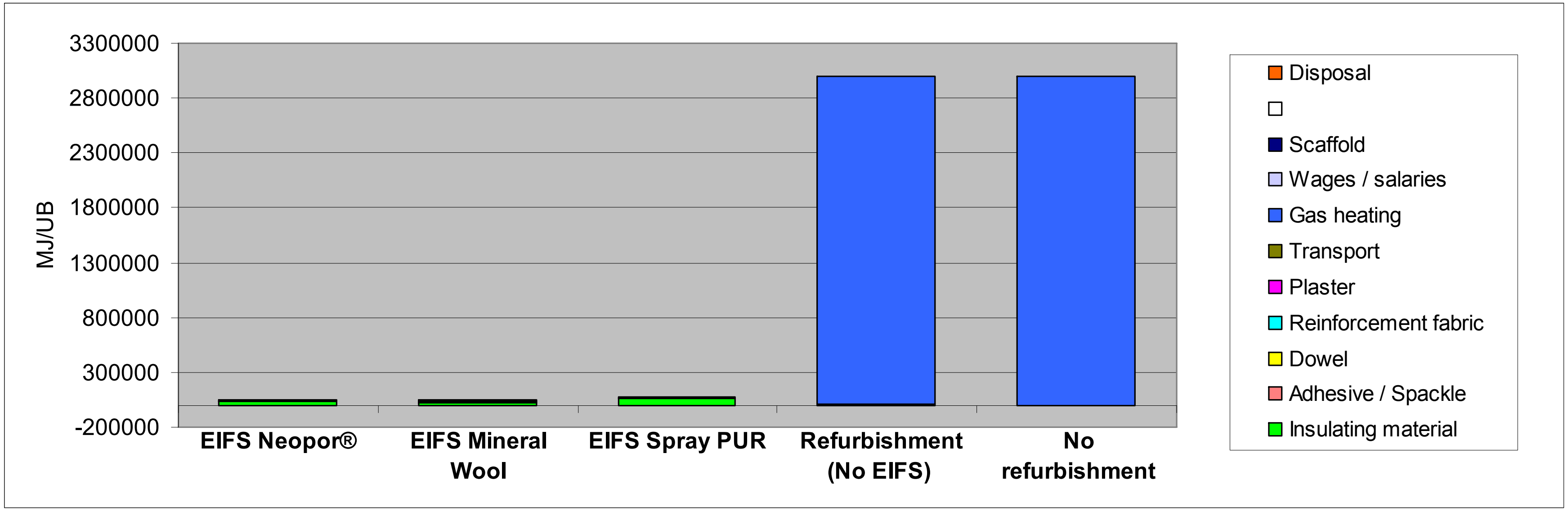


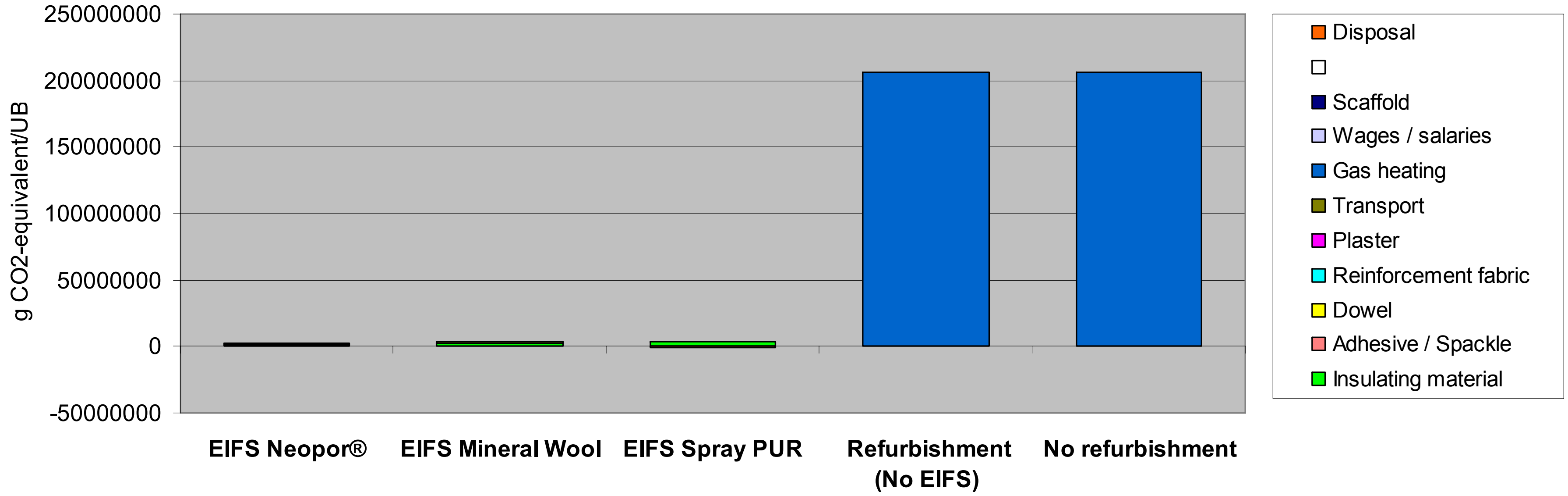
Environmental Categories
Resource Consumption



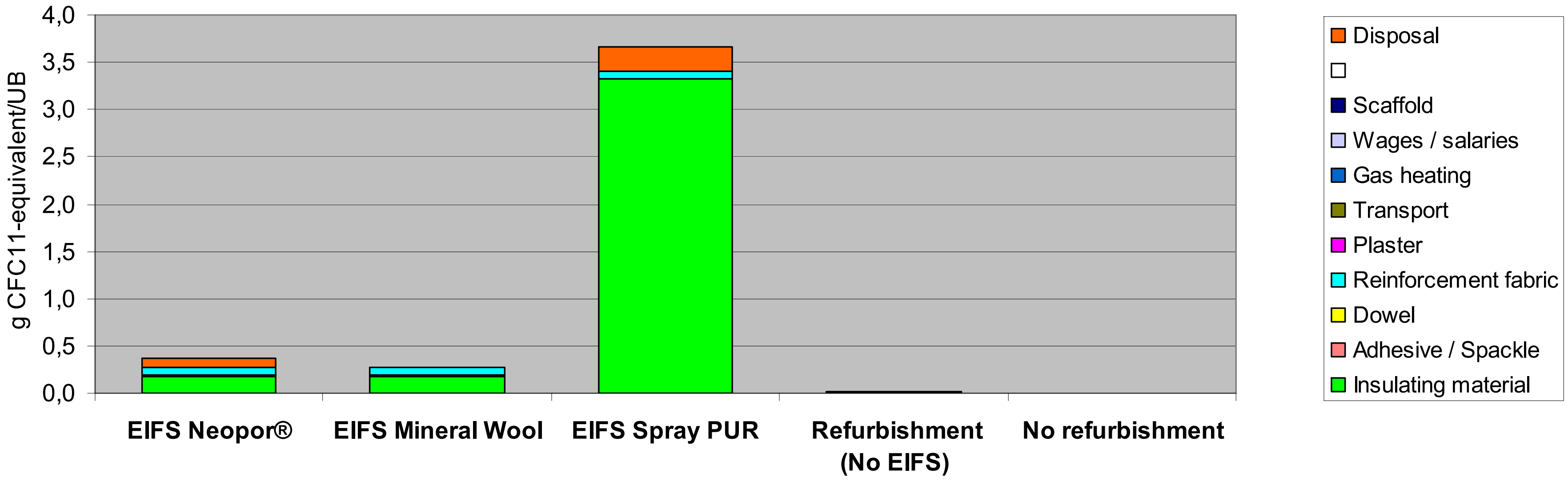
Environmental Categories
Energy Consumption



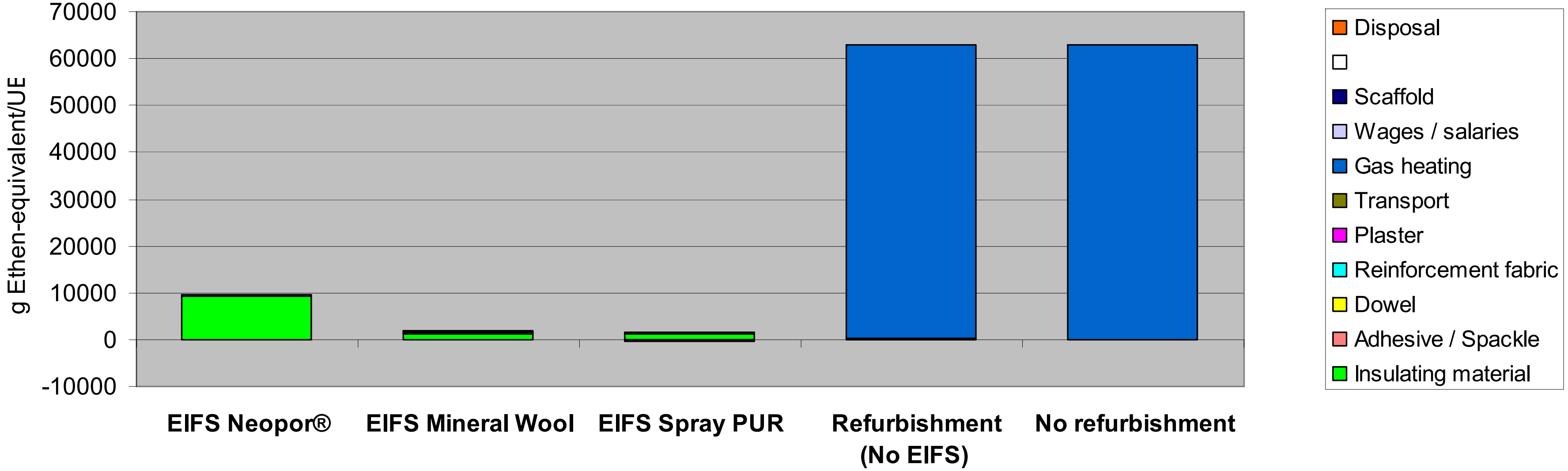
Environmental Categories
Global Warming Potential
(CH_4, CO_2, N_2O, Chlorofluorocarbons)



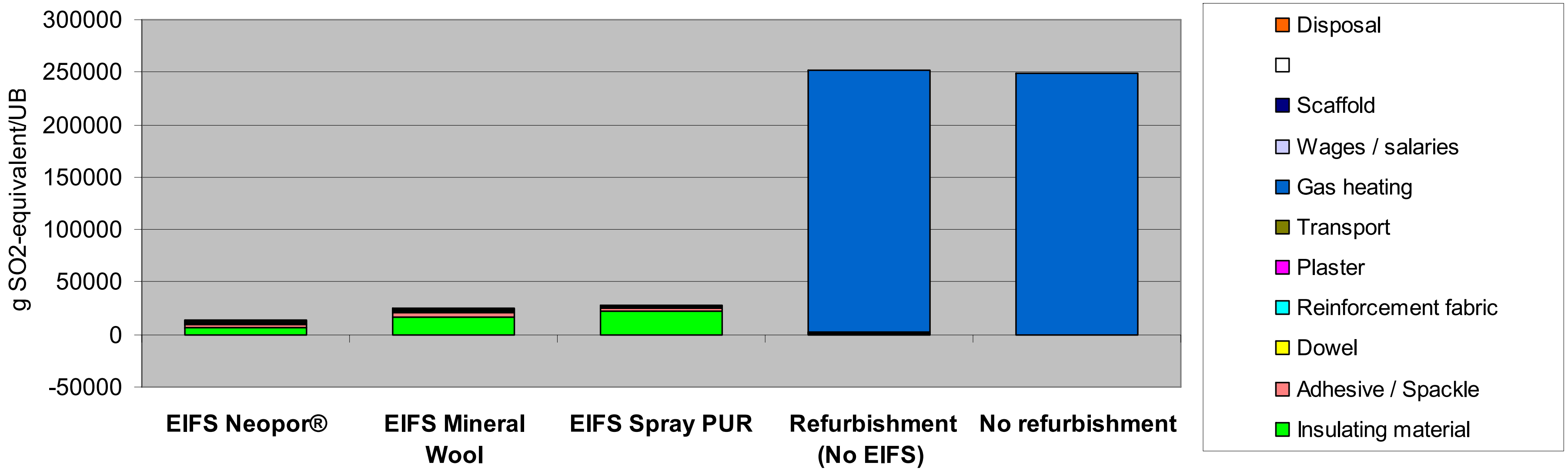
Environmental Categories
Ozone Depleting Potential
(Chlorofluorocarbons)



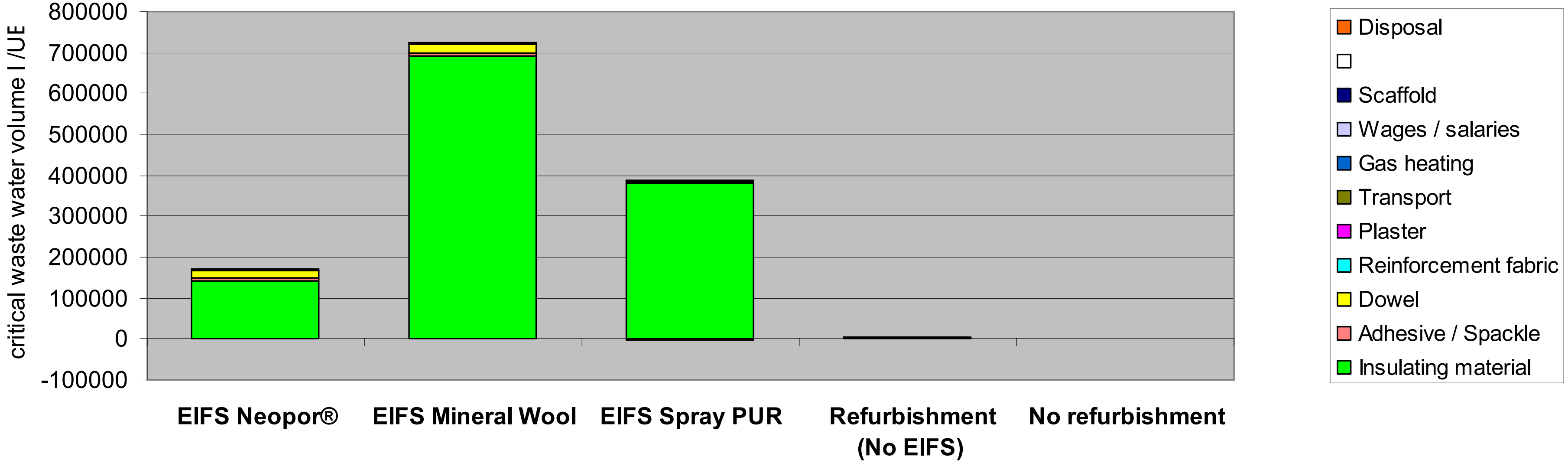
Environmental Categories
POCP (Photochemical Ozone Creation Potential: NMVOC, CH_4)



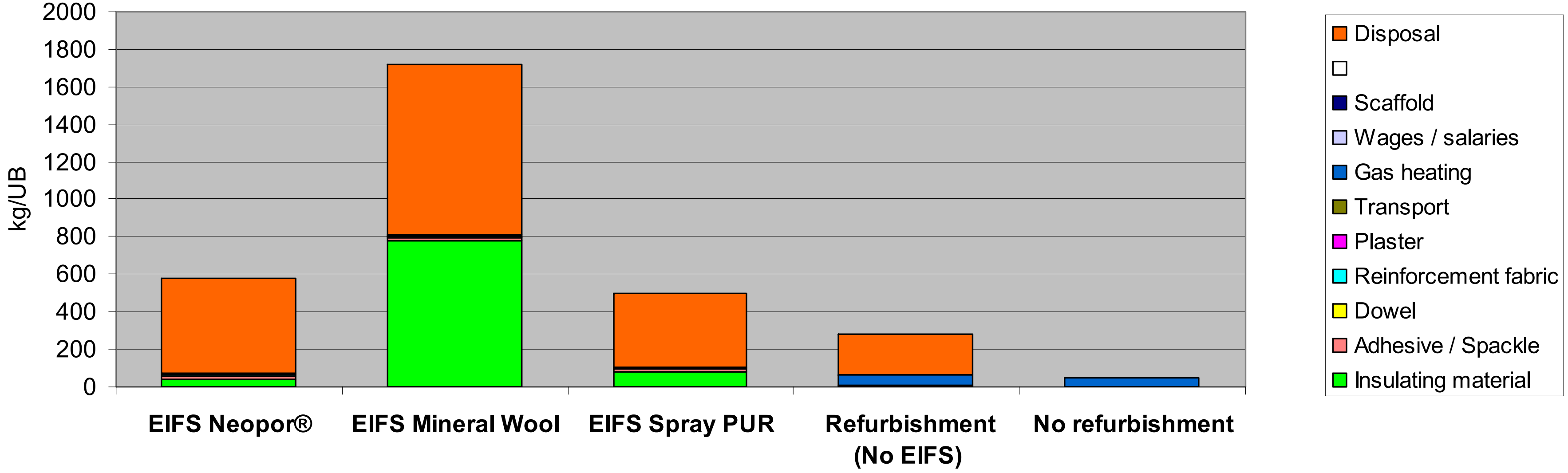
Environmental Categories
Acidification Potential (SOx, NO_x, NH_3, HCl)



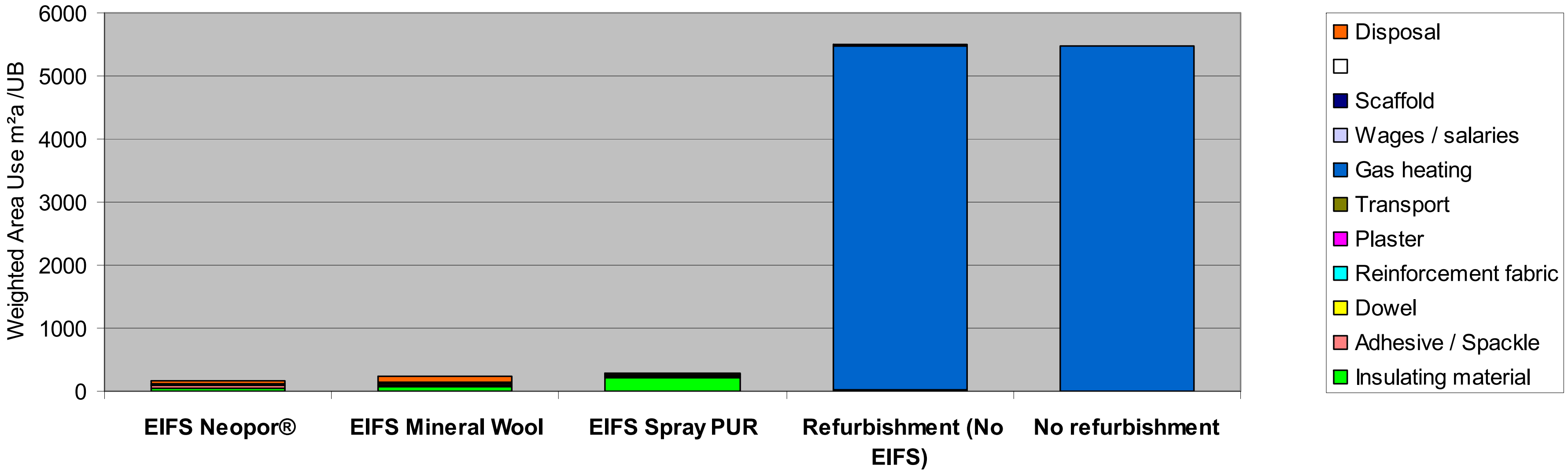
Environmental Categories
Water Emissions



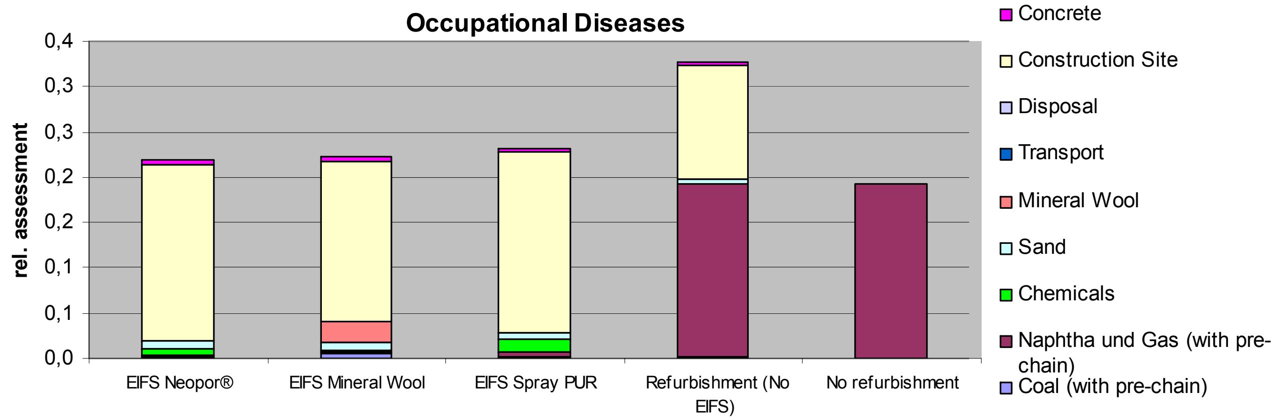
Environmental Categories
Wastes

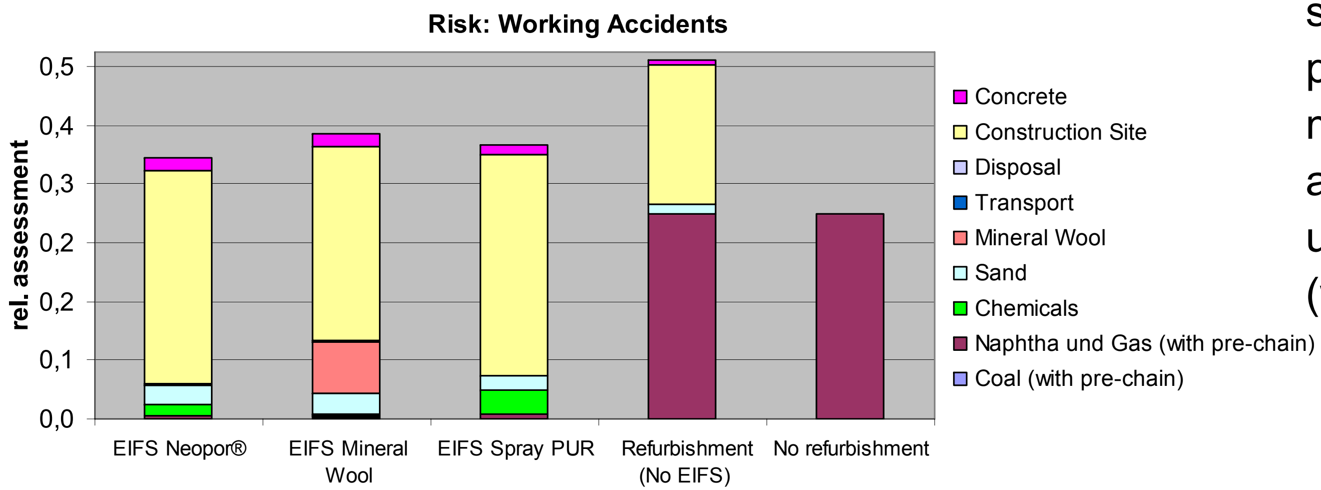


Environmental Categories
Land Use



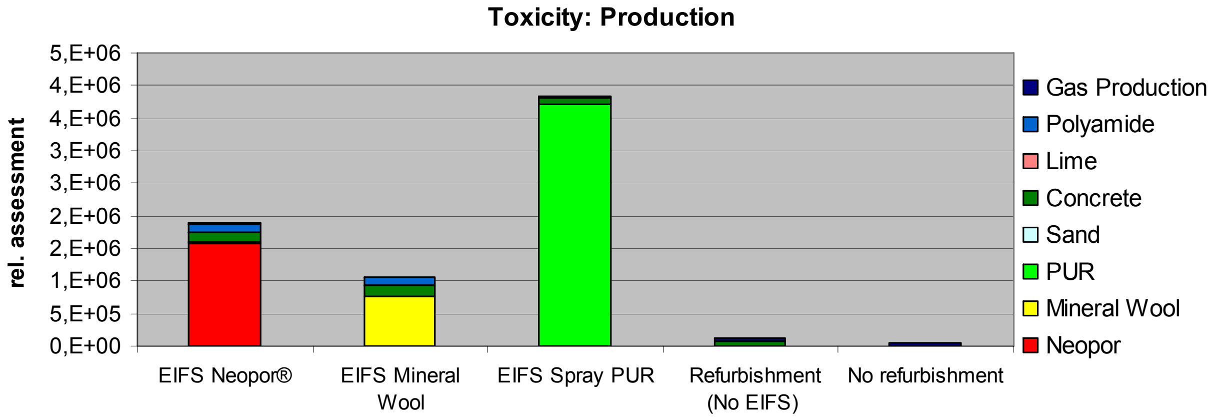
Environmental Categories
Risk Potential

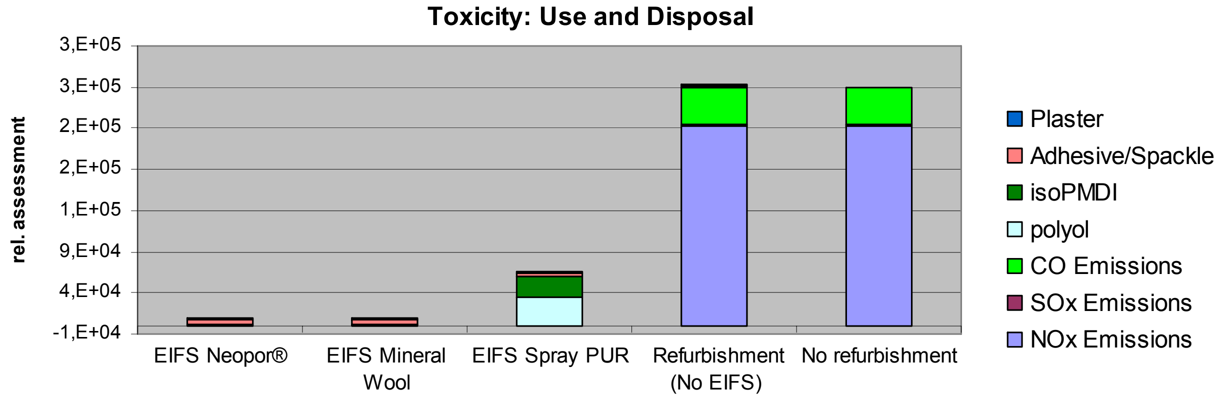




- Extraction of gas and construction (refurbishment site) are the activities with higher statistical values for working accidents and occupational diseases
- The risk is evaluated separately for the production of raw materials (weighting 30%) and their transport and use at construction site (weighting 70%)

Environmental Categories
Toxicity Potential



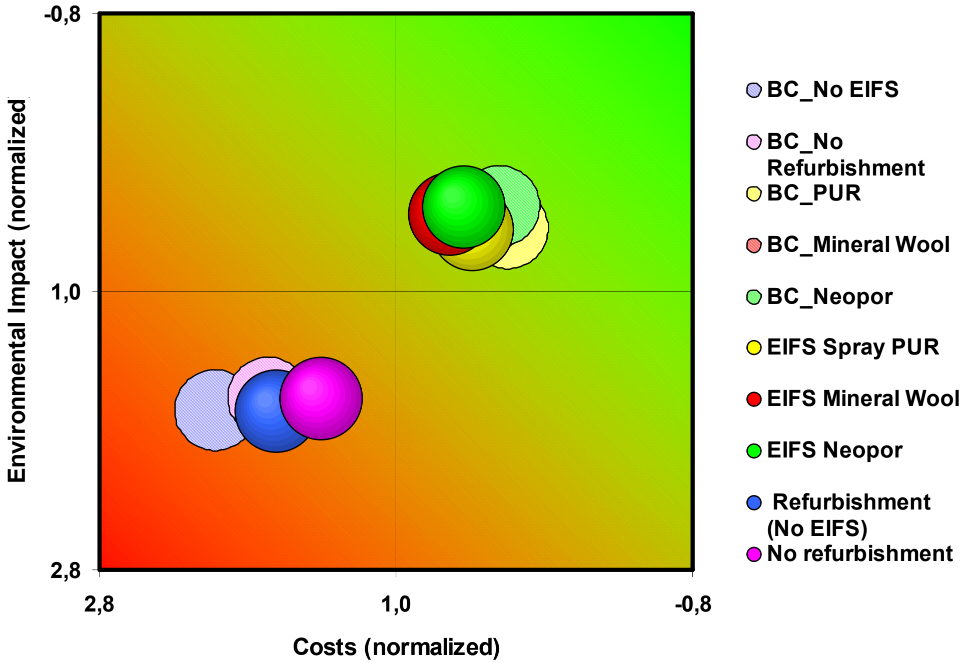


- The toxicity score for the alternatives is calculated separately for production phase and use/disposal phase
- The scores for the two phases are weighted respectively 30% and 70% due to different safety standards
- In the production phase the insulating materials have the highest scores (especially PUR), in the use phase toxic emissions from heating (NOx, CO) have the highest score

Scenario 1
Higher Costs for EIFS

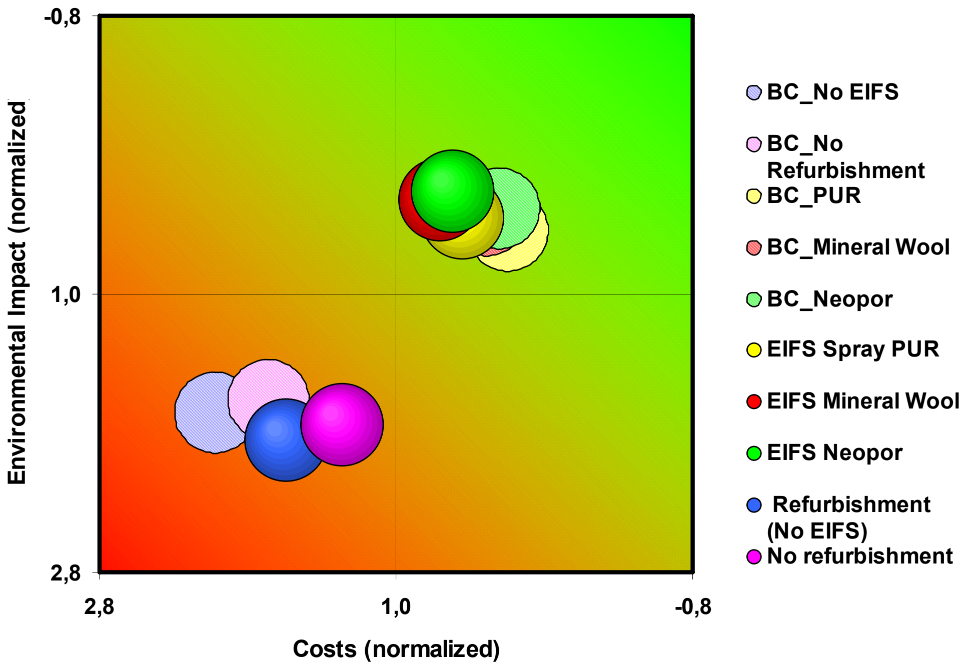
- In this scenario higher prices for EIFS systems have been considered accounting for regional and supplier variations

- The cost difference between the alternatives decreases but the EIFS system are still more cost-effective and more eco-efficient



Scenario 2
Lower Increase of Gas Price

- In this scenario a lower increase of gas price per year is assumed compared to the base case: 2 % (inflation-adjusted)
- The cost difference between the alternatives decreases but the EIFS system are still more cost-effective and more eco-efficient



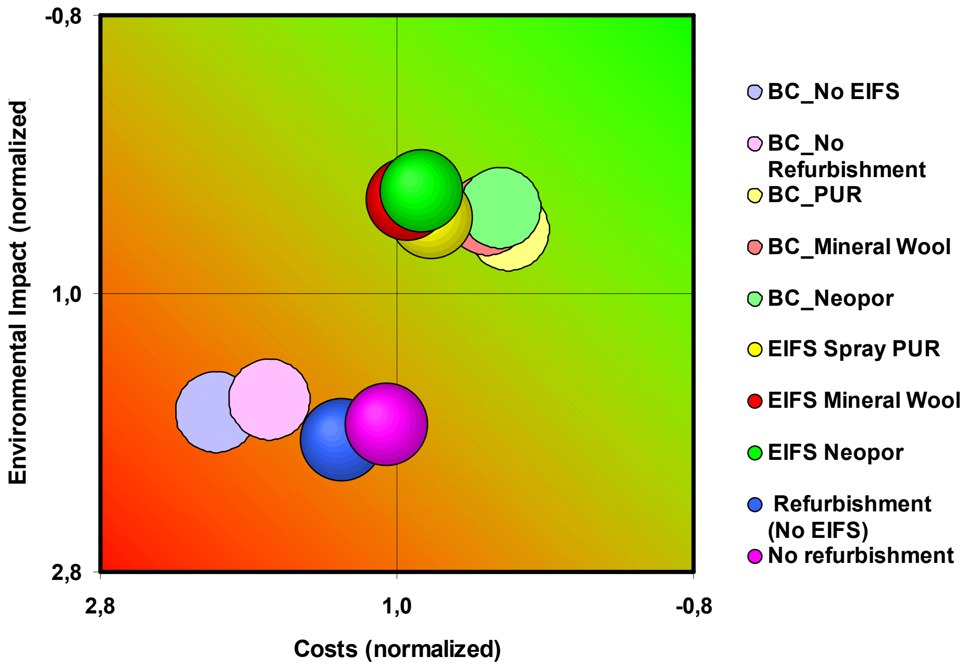
Scenario 3
EIFS Worst Case

- In this scenario the worst conditions for EIFS alternatives are combined together (scenarios 1 and 2):

  lower increase of gas price per year (2 %, inflation-adjusted)

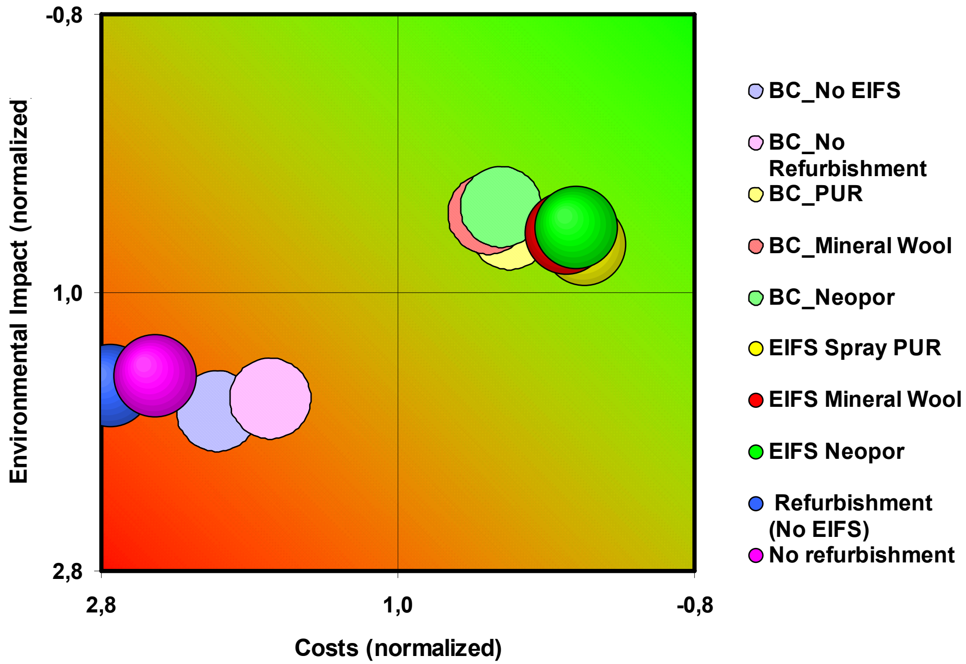
  higher prices for EIFS systems

- The cost difference between the alternatives decreases: the EIFS alternatives become only slightly more cost-effective than other alternatives but are still clearly more eco-efficient



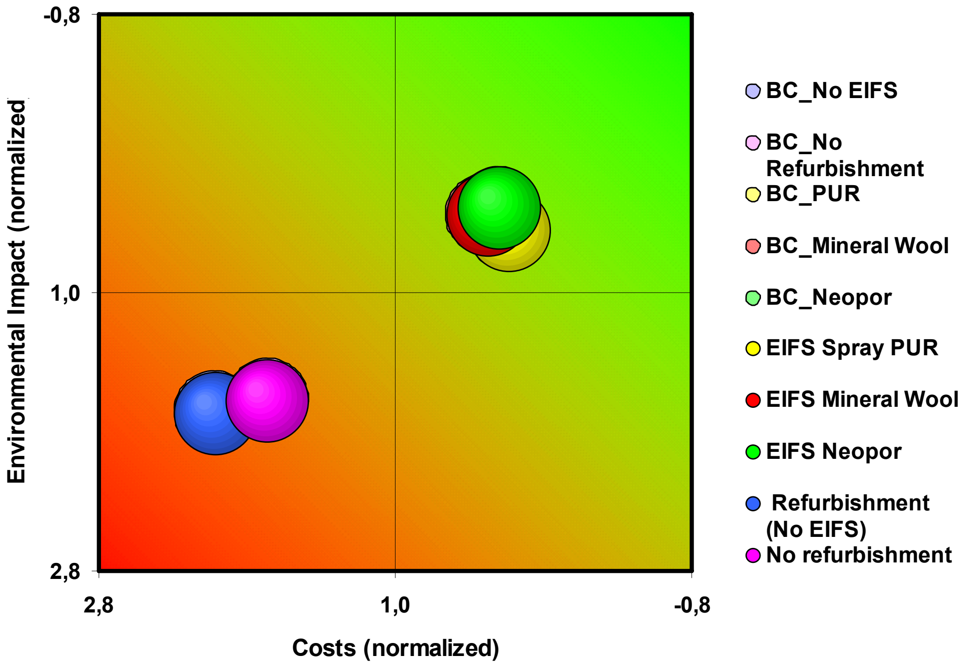
Scenario 4
Higher Increase of Gas Price

- In this scenario a higher increase of gas price per year is assumed compared to the base case: 10 % (inflation-adjusted)
- 10% increase is according to worst case estimates for energy prices increase
- The cost difference between the alternatives increases and the EIFS alternatives become even more cost-effective and more eco-efficient



Sensitivity Analysis
End of Life

- Recycling of mineral wool and building materials is assumed (95% of total materials), instead of landfilling
- No incineration of organic is material assumed
- The overall results do not change



Contact

- For more information on EIFS systems please contact:

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- For more information on the eco-efficiency analysis please contact:

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Appendix (A)

Input Data
Literature

BASF
The Chemical Company

Input Data
Refurbishment

BASF The Chemical Company

	Façade Refurbishment EIFS Neopor	Façade Refurbishment EIFS Mineral Wool	Façade Refurbishment EIFS PUR	Façade Refurbishment (No EIFS)	No Refurbishment	Unit
Façade Area	229	229	229	229	229	m²
U Value)	0,31	0,31	0,31	1,44	1,44	W/m² k
λ	032	040	028	—	—	W/mk
Thickness of insulating material	0,08	0,10	0,07	—	—	m
Losses of insulating materials	5	5	15	—	—	%
Density of insulating material	15	90	38	—	—	Kg/m³
Amount of mineral adhesive	4	4	0	—	—	kg/m²
Mineral Spackling paste	4	4	5	2	—	kg/m²
Mineral plaster	3	3	3	3	—	kg/m²
Transport	200	200	200	200	—	km
Average room temperature according to EnEV	19	19	19	19	19	°C
Gas use	43.353	43.353	43.353	69.716	69.716	Kwh/a

Input Data
Life Cycle Inventories

Material	Source	Details
Neopor	Boustead Programm	BASF
Mineral Wool	EPD	Rockwool
PUR	Elastogran, Boustead Programm	Deutschland
Polyamide	Hilti, Boustead Programm	General Data
Polyamide	Hilti, Boustead Programm	General Data
Plaster	Colfirmit, Boustead Programm	Mineralischer Putz
Spackling paste	Colfirmit, Boustead Programm	Mineralischer Spachtel
Reinforcement fabric	Colfirmit, Boustead Programm	Armierungsgewebe
Costs	Colfirmit, Elastogran, Luwoge, Hilti	Spez. Anwendung
Transport	Colfirmit, Boustead Programm	15 to LKW
Waste incineration	Boustead Programm	MVA Allgemein
Landfill	Boustead Programm	Deponie Allgemein
Gas use	Boustead Programm	Deutschland

Input Data
Energy Balace for House before Refurbishment (LUWOGE Consultant)

Energy losses:

Wärmeverluste in kWh/Monat												
Monat	**Jan**	**Feb**	**Mrz**	**Apr**	**Mai**	**Jun**	**Jul**	**Aug**	**Sep**	**Okt**	**Nov**	**Dez**
Transmissionswärmeverluste												
Transmissionsverluste	9343	7649	6858	4231	2808	1470	460	322	2049	4557	6369	8147
Wärmebrückenverluste	782	640	574	354	235	123	39	27	171	381	533	682
Summe	10125	8289	7432	4585	3043	1593	499	349	2220	4938	6902	8828
Lüftungswärmeverluste												
Lüftungsverluste	1989	1628	1460	901	598	313	98	69	436	970	1356	1734
reduzierte Wärmeverluste durch Nachtabschaltung, -senkung												
reduzierte Wärmeverluste	-1118	-883	-754	-454	-301	-158	-49	-35	-220	-489	-696	-930
Gesamtwärmeverluste												
Gesamtwärmeverluste	**10996**	**9034**	**8138**	**5032**	**3339**	**1748**	**547**	**383**	**2436**	**5418**	**7563**	**9632**

Energy inputs (without heating):

Wärmegewinne in kWh/Monat												
Monat	**Jan**	**Feb**	**Mrz**	**Apr**	**Mai**	**Jun**	**Jul**	**Aug**	**Sep**	**Okt**	**Nov**	**Dez**
Interne Wärmegewinne												
Interne Wärmegewinne	867	783	867	839	867	839	867	867	839	867	839	867
Solare Wärmegewinne												
Fenster N 90°	35	53	86	157	205	242	253	177	118	84	44	25
Fenster W 90°	47	63	101	230	249	276	296	218	165	97	51	28
Fenster S 90°	142	139	202	336	301	318	342	283	282	205	132	84
Fenster O 90°	47	63	101	230	249	276	296	218	165	97	51	28
Solare Wärmegewinne	272	319	490	952	1004	1112	1187	897	730	482	279	166
Gesamtwärmegewinne in kWh/Monat												
Gesamtwärmegewinne	**1139**	**1102**	**1356**	**1790**	**1870**	**1951**	**2054**	**1764**	**1569**	**1349**	**1118**	**1032**

Input Data
Energy Balace for House before Refurnishment (LUWOGE consultant)

Energy Balance:

Heizwärmebedarf in kWh/Monat												
Monat	**Jan**	**Feb**	**Mrz**	**Apr**	**Mai**	**Jun**	**Jul**	**Aug**	**Sep**	**Okt**	**Nov**	**Dez**
Ausnutzungsgrad Gewinne	1,000	1,000	0,999	0,988	0,949	0,748	0,265	0,217	0,925	0,996	0,999	1,000
Heizwärmebedarf	**9857**	**7933**	**6783**	**3264**	**1563**	**290**	**3**	**1**	**985**	**4075**	**6445**	**8600**
Heizgrenztemperatur in °C und Heiztage												
Heizgrenztemperatur	17,49	17,38	17,20	16,54	16,51	16,32	16,27	16,66	16,85	17,21	17,46	17,63
mittl. Außentemperatur:	-1,30	0,60	4,10	9,50	12,90	15,70	18,00	18,30	14,40	9,10	4,70	1,30
Heiztage	**31,0**	**28,0**	**31,0**	**30,0**	**31,0**	**22,9**	**0,0**	**3,5**	**30,0**	**31,0**	**30,0**	**31,0**

Input Data
Energy Need for House after EIFS Refurbishment (LUWOGE consultant)

Heating Requirements Q_h:	kWh/a
No Refurbishment	49797
EIFS Neopor	30966
EIFS PU	30966
EIFS Mineral Wool	30966

Appendix (B)

Methodology

BASF
The Chemical Company

The Eco-Efficiency Portfolio According to BASF

BASF The Chemical Company

Reference:
P. Saling, A. Kicherer et al, Int. J. LCA **7** (4), 203-218, (2002)

- BASF has developed the eco-efficiency portfolio to allow a clear illustration of eco-efficiency.
- The overall cost calculation and the calculation of the ecology fingerprint constitute independent calculations of the economic and environmental considerations of a complete system with different alternatives. Since ecology and economy are equally important in a sustainability study, a system can compensate for weaknesses in one area by good performance in the other. Alternatives whose sums of ecological and economic performance are equal are considered to be equally eco-efficient.
- The values obtained from the ecology fingerprint are multiplied by weighting factors (description of fingerprint and weighting factors can be found on subsequent pages) and added up in order to determine the environmental impact of each alternative. The various environmental impact values are normalized by the mean environmental impact and plotted on the eco-efficiency portfolio.

The Ecology Fingerprint According to BASF

BASF The Chemical Company

- The impact categories are normalized (and, in the case of emissions and material consumption, also weighted) and plotted on the ecology fingerprint. This plot shows the ecological advantages and disadvantages of the alternatives relative to one another. The alternative with a value of one is the least favorable alternative in that category; the closer an alternative is to zero, the better its performance.
- The axes are independent of each other so that an alternative which is, for example, favorable in terms of energy consumption may be less favorable in terms of emissions.
- Using the ecology fingerprint, it is possible to find the areas in which improvements are necessary in order to optimize the whole system effectively.

Determination of Energy Consumption

The impact category energy consumption is based on the consumption of primary energy over the whole life cycle. The sum of fossil fuels before production and of the renewable energy before harvest or use is shown. Thus conversion losses from the generation of electricity and steam are taken into account. In the case of BASF processes, company-specific data is used. In the case of non-BASF processes, the UCPTE data set [1] is used. However, consideration of specific scenarios for the production of electricity and steam are possible, e.g. for site comparisons.

The energy consumption figures are assigned to the individual types of energy carriers. The consumption of the various forms of primary energy is taken into account in the consumption of raw materials.
In the category of “energy consumption”, there is no further conversion to specific impact categories. The energy consumption values are normalized so that the least favorable alternative assigned a value of 1; the other alternatives are arranged on an axis ranging from 0 to 1. The performance in all other environmental impact categories are compared in this manner.

In order to calculate the total energy requirement the lower calorific value of the primary energy equivalent is used. The following forms of energy are taken into account: coal, oil, gas, lignite, nuclear energy, hydraulic power, biomass and others.

[1] West European Electricity Coordination System
(UNION POUR LA COORDINATION DE LA PRODUCTION ET DU TRANSPORT DE L`ÉLÉCTRICITÉ)

Determination of Material Consumption

The mass of raw materials necessary for each alternative is determined. The individual materials are then weighted according by a factor incorporating the life span and the fractional consumption of that material [2].

In the case of renewable raw materials, sustainable farming is assumed. Therefore, the resource that has been removed has been replenished in the period under consideration. This means an endless life span and thus a weighting factor of zero. Of course, in the case of renewable raw materials from non-sustainable farming (e.g. rainforest clearance), an appropriate (non-zero) weighting factor is used for the calculation.

High energy consumption can be correlated with low materials consumption if renewable raw materials such as wood or hydraulic power are used. What therefore appears to be double counting of raw material and energy consumption does not occur with these two categories.

[2] U.S. Geological Survey, Mineral Commodity Summaries, 1997; Römpp Chemie Lexikon, Thieme, Stuttgart; Institut für Weltwirtschaft, Kiel; D. Hargreaves et al, World Index of Resources and population, Dartmouth Publishing, 1994; World Resources, Guide to the Global Environment, Oxford 1996; Deutsches Institut für Wirtschaftsforschung, Berlin

Determination of Air Emissions

Air emissions of different gases are recorded separately and added up over the whole life cycle. In most processes, the emission of carbon dioxide is the largest air emission. This emission is typically followed (in terms of quantity) by emissions of sulfur and nitrogen oxides as well as N_2O and hydrocarbons. All emissions occurring during the life cycle are considered, for example for the generation and use of electricity as a source of energy. As a rule, these impact the manufacturing process through the consumption of sources of primary energy.

The effect of these air emissions in the environment varies depending on the type of gas. In order to take account of this, the various emission quantities are linked to scientifically determined assessment factors [3]. Using this method, the emissions of 21 kg of carbon dioxide have the same greenhouse effect as 1 kg of methane. These so-called impact categories are used for each emission. Some emissions, for example the emission of methane, play a role in several impact categories. The impact categories that are taken into consideration in the eco-efficiency analysis are the global warming potential, photochemical ozone creation potential (summer smog), acidification potential (acid rain) and ozone depletion potential.

[3] UBA Texts 23/95

Procedure for Assessing Water Emissions

The assessment of water pollution is carried out by means of the “critical volume” model. For selected pollutants that enter the water, the theoretical water volume affected by the emission up to the statutory limit value (critical load) is determined. The volumes calculated for each pollutant are added up to yield the “critical volume”.

The factors for calculating the critical volume are shown in the table. The requirements that are made on sewage at the entry point into surface water, listed in the appendices to the German Waste Water Regulation (AbwV), are the basis for the factors.

These limit values are generally based on the relevance of the emitted substance for the environment; in some cases, technical issues were taken into account in establishing the statute. In spite of this restriction, BASF uses this method for several reasons:

- existence of complete database for most of the emissions
- recognition of the Waste Water Regulation and broad acceptance of the associated limit values

parameter	*Appendix to Waste Water Regulation (AbwV)*	requirement on waste water (mg/l)	factors for calculating ‚critical volumes’ (l/mg)
COD	*Nr. 1*	75	1/75
BOD_5	*Nr. 1*	15	1/15
N-total	*Nr. 1*	13	1/13
NH_4-N	*Nr. 1*	10	1/10
P-total	*Nr. 1*	1	1
AOX	*Nr. 9*	1	1
heavy metals	*Nr. 9*	∅ 1	1
HC	*Nr. 45*	2	½

COD: chemical oxygen demand; BOD_5: biochemical oxygen demand;. N-total: total nitrogen. NH_4-N: ammonium-nitrogen; P-total: total phosphorus; AOX: adsorbable organic halides; heavy metals: sum of copper, nickel, lead, mercury etc; HC: sum of hydrocarbons.

Determination of Solid Waste

BASF The Chemical Company

The results of the material balance on solid waste emissions are summarized into four waste categories: municipal waste, chemical (special) waste, construction waste and mining waste. Due to lack of other assessment criteria, the average costs (normalized) for the treatment or disposal of each type of waste are used as weighting factors to form the overall impact potential. Production residues that are incinerated are considered in the overall calculation by including the incineration energy and the emissions that occur during incineration.

Assessment of the Area Use

BASF
The Chemical Company

Area is not consumed like a raw material but, depending on the type, scope and intensity of the use, is changed so radically that it is impaired or even destroyed in its ability to perform tits natural function. Apart from the direct loss of fertile soil, there are a series of subsequent effects, for example cutting into ecosystems, loss of living space for flora and fauna, etc.
Area necessary to fulfill the customer benefit is considered for each alternative. The area requirement is assessed by weighting according to principal type of use and in relation to the relevance of the area requirement. Since virtually all the countryside in Europe is cultivated, the origins of the areas are not important. For special questions (e.g. conversion of rainforest to plantations), there is no difficulty in extending the consideration of the area requirement in this direction.
The life cycle consists of construction, operation and demolition and is put in relation to the overall capacity of the system. In the case of non-renewable resources, the recultivation time is taken into account.

	area type		assessment factor
0	natural	unaffected ecosystems	0
I	close to nature	forestry use, forest areas and bio-agriculture close to nature	1
II	semi-natural	semi-natural agricultural use, green area	1.5
III	remote from nature	agricultural use and arable cropping remote from nature	2.3
IV	sealed	sealed and impaired area, industrial area	5.1
V	sealed & separating	traffic areas that split up ecosystems (roads, railwys and waterways)	7.6

Assessment of the Area Use: Examples

	amount	area II	area III	area IV	area V
materials		m2a	m2a	m2a	m2a
platinum post-enrichment	100 kg	-24990.00	21680.00	2647.42	665.28
aluminum 0% recycled	100 kg	-49.59	45.39	3.43	0.91
polypropylene	100 kg	-20.56	18.63	1.84	0.09
cement	100 kg	-0.84	0.69	0.09	0.07
energy					
unleaded gasoline post-refinery	t	-97.77	86.05	11.26	0.48
electricity- West Germany mix	GJ	-9667.00	9374.00	260.77	32.45

	alternative 1			alternative 2		
	numerical value	factor	numerical value	numerical value	factor	numerical value
area II	4	1.5	6	2	1.5	3
area III	10	2.3	23	5	2.3	11.5
area IV	0.6	5.1	3.1	0.6	5.1	3.1
area V	0.1	7.6	0.8	1.2	7.6	9.1
sum			32.9			26.7

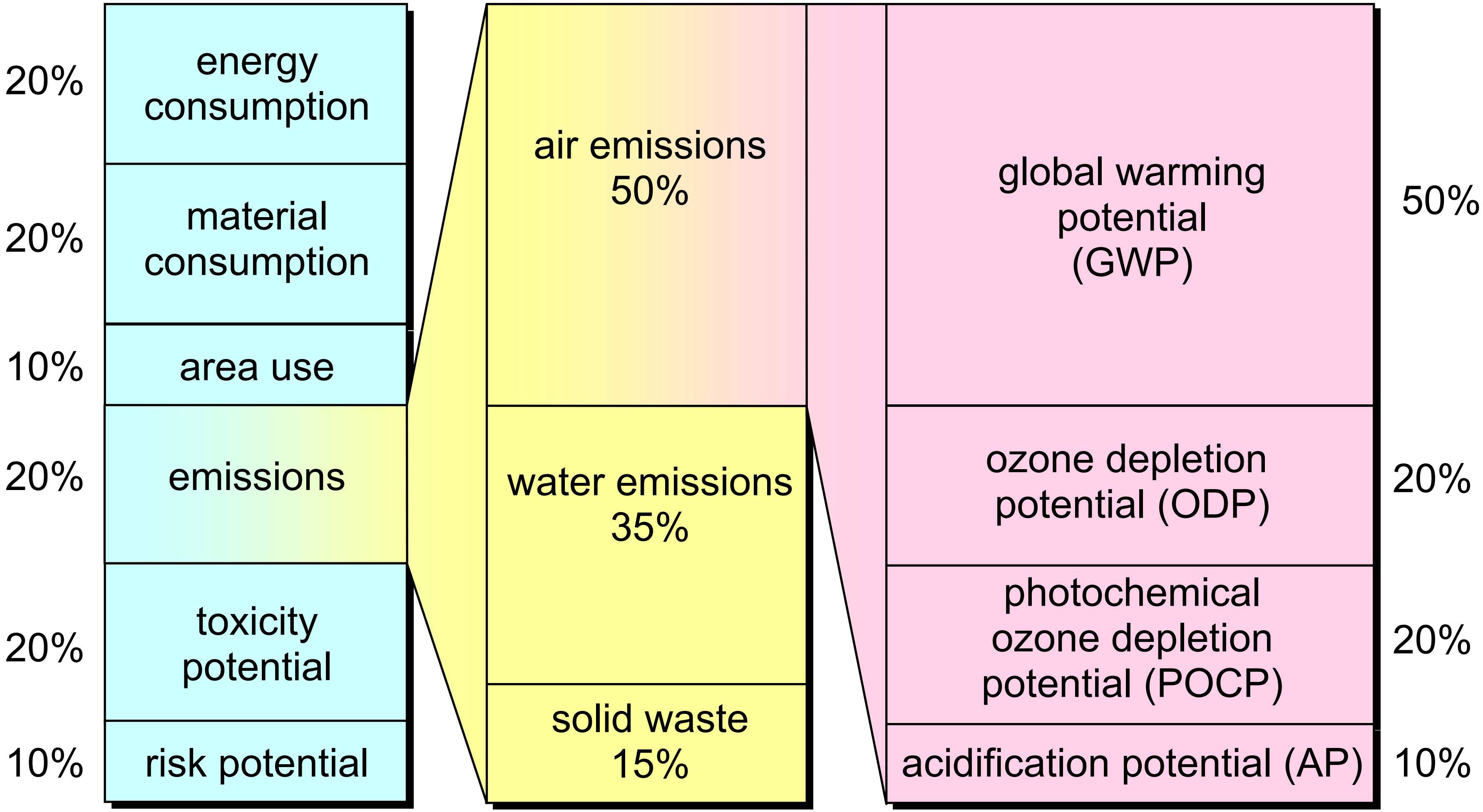
The numerical values are weighted and added up.
Then the normalization is carried out as well as the determination of the relevance.

Determination of the Overall Environmental Impact

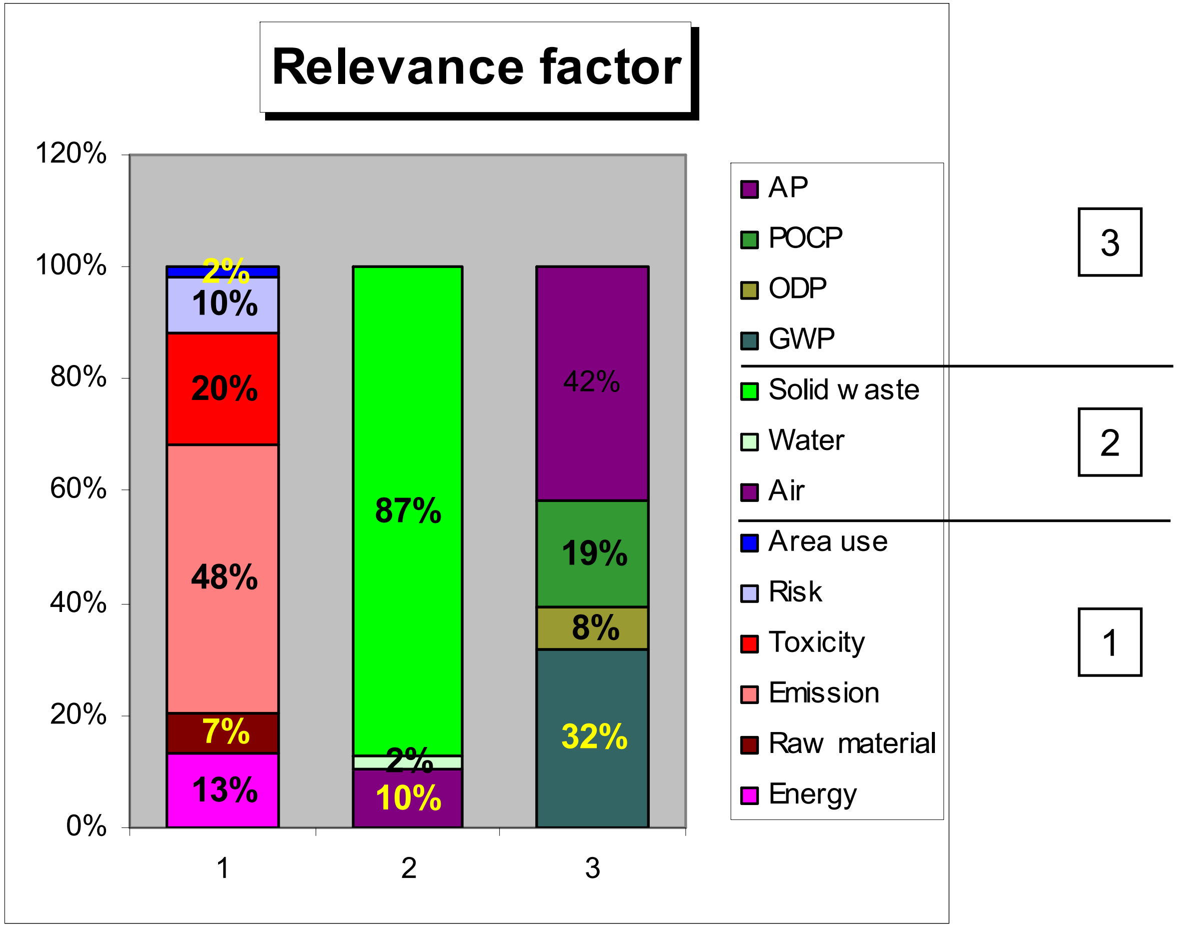
The values obtained in the material balance and impact estimate (greenhouse potential, ozone depletion potential, photochemical ozone formation potential, acidification potential, water emissions, solid waste, energy consumption, raw material consumption and area requirement) are aggregated with weighting factors to yield an overall environmental impact value. The weighting factors consist of the following:

- a *societal factor:*
  What value does society attach to the reduction of the individual potentials?
- a *relevance factor*:
  What is the fractional contribution of the specific emission (or consumption) to the overall countrywide emissions?

Determination of Environmental Impact: Societal Weighting Factors

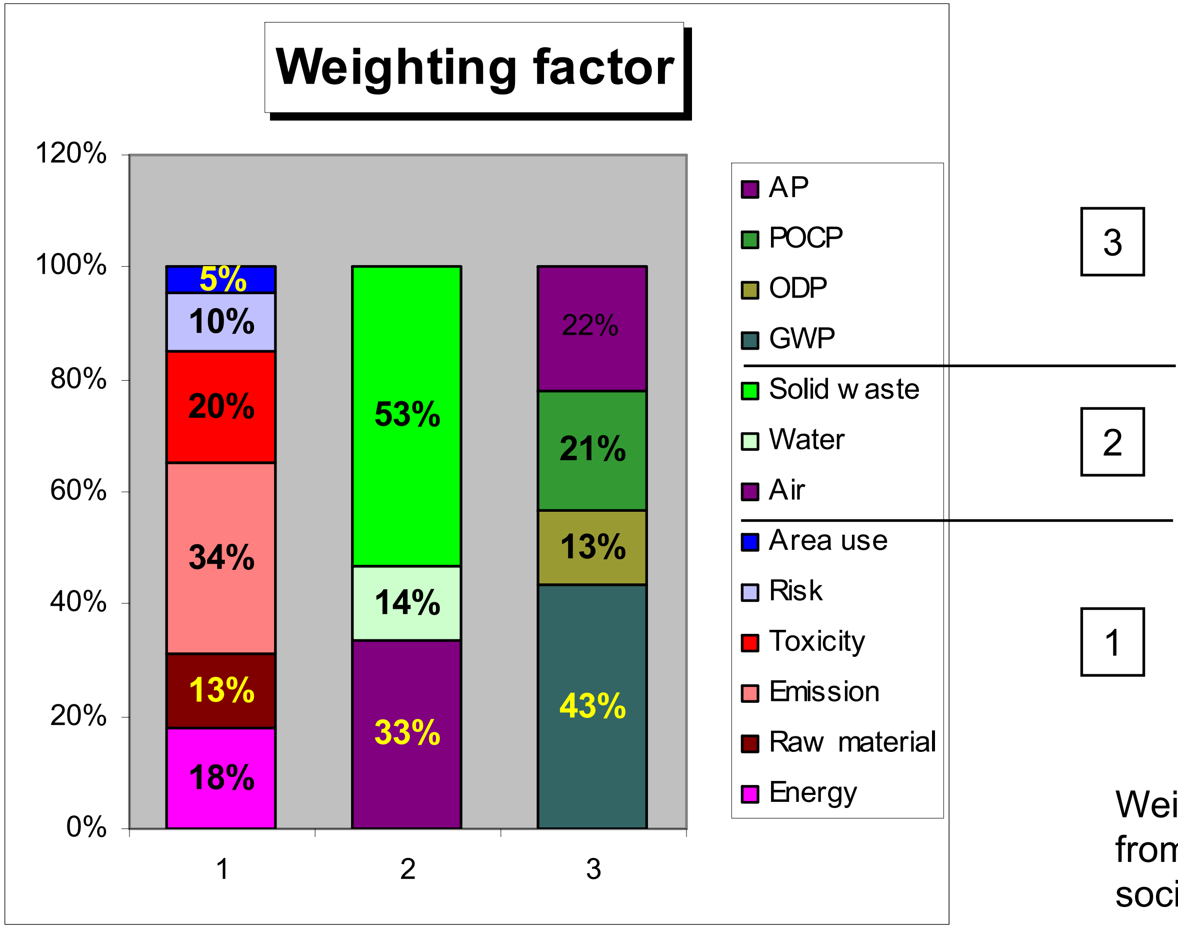


Relevance Factors



BIP relevance factor
0.37

Weighting Factors



Weighting factors are derived from relevance factors and societal factors.

Determination of the Toxicity Potential

BASF The Chemical Company

Reference: R. Landsiedel, P. Saling, Int. J. LCA **7** (5), 261-268, (2002)

- The toxicity potential is determined using an assessment method developed by BASF based on the R-phrases of the Hazardous Substances Regulation Act (GefStoffV). In cooperation with toxicologists numerical values ranging between 0 and 1000 were assigned to each R-phrase (or combinations thereof) according to their risk potential. For example, the classification R 26/27 (very toxic) is worth 750 points and the considerably less critical category R 35 (corrosive), 300 points (see example on next page). These R-phrase-based values are determined for all intermediate and final products that are used during the life cycle of each alternative, taking into account likelihood of human exposure.
- The calculated index figures are multiplied by the amounts of substances used and and added up to yield the overall toxicity potential over the life cycle.
- In the production category, only the actual R-phrases of a substance are considered. In contrast, in the production phase, the R-phrases of the pre-chain are evaluated as well as of the substance being produced.
- The results of these assessments are expressed in dimensionless toxicity units which can be compared with one another by normalizing and weighting the various life span phases.
- Only potential toxicity values are calculated. In order to be able to assess an actual risk to humans, additional calculations on the exposure of humans, uptake of the substance, etc., are needed.

Determination of the Toxicity Potential: Example

BASF
The Chemical Company

toxicity potential

- R 26/27 = 750 points, very toxic
- R 23/25 = 550 points, toxic
- R 20/22 = 400 points, harmful
- R 35 =300 points, corrosive
- R 38 =100 points, irritating

calculation

substance 1, R 26/27, 750 points
prechain: 0 P
total 750 P

use: 0.5 kg
factor:
0.5*750 = 375 P

substance 2, R 35, 300 points
prechain: 0 P
total 300 P

use: 0.5 kg
Factor:
0.5*300 = 150 P

substance 3, R 20/22, 400 points
prechain: 375 P + 150 P= 525 P
total: 925 P

use: 400 points

production: 925 points

Determination of the Risk Potential

- The risk potential in the eco-efficiency analysis is established using expert judgement. The focus is always on the severity of potential damage that an operation can cause, multiplied by its probability.
- In the risk potential category, different types the damage can be considered. For example, possible damage due to physical reactions (explosion or fire hazards and transportation risks), impurities in the product, incorrect handling, incorrect storage, etc may be included.
- The criteria of the risk potential are variable and may be different in each study, because they are adapted to the circumstances and special features of the particular alternatives. The number of risk categories may vary.
- Data on accidents in various industries or in various occupations may be included, for example safety data on various types of reactions in the chemical industry.
- All aspects of the complete life cycle are included in the assessment.
- Risk potentials are calculated values. In order to be able to estimate a risk actually occurring to a human, additional calculations and estimates are required.

Appendix (C)

Glossary

BASF
The Chemical Company

Glossary of Abbreviations and Technical Terms I

AOX: abbr. for adsorbable organic halogen, a category of water emissions

AP: abbr. for acidification potential or acid rain. In this impact category, the effects of air emissions that lower the local pH values of soils and can thus e.g. cause forest death are taken into account.

BOD: abbr. for biological oxygen demand. This is a method for determining wastewater loads.

CB: abbr. for customer benefit. All impacts (costs, environment) are specific to this customer benefit which all alternatives being evaluated have to fulfill.

CH_4: abbr. for methane.

Cl^-: abbr. for chloride.

COD: abbr. for chemical oxygen demand. This is a method for determining wastewater. loads.

CO_2: abbr. for carbon dioxide.

critical volume: operand for assessing the extent to which wastewater is polluted by mathematically diluting the wastewater with fresh water until the allowed limit value is reached. This volume of fresh water that has been added is referred to as the critical volume.

municipal waste: waste that may be deposited on a normal household landfill.

emissions: emissions are categorized as emissions into air, water and soil. These broad groupings are further subdivided into more specific categories.

Glossary of Abbreviations and Technical Terms II

energy unit: energy is expressed in megajoules (MJ). 1 **MJ** is equivalent to 3.6 kilowatt hours (**kWh**).

feedstock: the energy content that is bound in the materials used and can be used e.g. in incineration processes.

GWP: abbr. for global warming potential, the greenhouse effect. This impact category takes into account the effects of air emissions that lead to global warming of the earth's surface.

hal. HC: abbr. for halogenated hydrocarbons.

halogenated NM VOC: abbr. for halogenated non-methane volatile hydrocarbons.

HC: abbr. for various hydrocarbons or hydrocarbon emissions into water.

HCl: abbr. for hydrogen chloride.

HM: abbr. for heavy metals.

impact potential: name of an operand that mathematically takes into account the impact of an emission on a defined compartment of the environment.

material consumption: in this category, the consumption of raw materials is considered along with worldwide consumption and remaining reserves. Thus, a raw material with smaller reserves or greater worlwide consumption rates is more critically weighted.

Glossary of Abbreviations and Technical Terms III

NH_3: abbr. for ammonia emissions.

NH_4^+: abbr. for emissions of ammonium into water.

NM VOC: abbr. for non-methane volatile organic compound.

N_2O: abbr. for N_2O emissions.

NO_x: abbr. for various nitrogen oxides.

normalization: in the eco-efficiency analysis, the worst performance in each ecological category is normalized to a value of one. Thus alternatives with better performance in that category will lie between zero and one on the ecological fingerprint.

ODP: abbr. for ozone depletion potential, damage to the ozone layer. This impact category takes into account the effects of air emissions that lead to the destruction of the ozone layer of the upper layers of air and thus to an increase in UV radiation.

PO_4^{3-}: abbr. for emissions of phosphate into water.

POCP: abbr. for photochemical ozone creation potential. This effect category takes into account the effects of local emissions that lead to an increase in ozone close to the ground and thus contribute to what is known as summer smog.

Glossary of Abbreviations and Technical Terms IV

BASF The Chemical Company

risk potential: impact category assessing the effects of risk factors over the complete life cycle. Risks such as transportation risks, dangers of explosion, dangers of accidents, etc. may be included

SO_x: abbr. for various sulfur dioxides.

SO_4^{2-}: abbr. for emissions of sulfates into water.

special waste: waste that has to be deposited on a special landfill.

system boundary: determines what aspects are considered in the study.

Glossary of abbreviations and technical terms V

Time span: The period for which a raw material is still available and can be used. The current use of the raw material in relation to what is currently known to be the amount that is still available and can be used industrially is the basis for the assessment.

Total N: Collective term for all water pollutants that contain nitrogen and that cannot be included in one of the other categories.

Toxicity potential: In this category, the effect of the substances involved is assessed with regard to their effect on human health. It relates solely to possible material effects in the whole life span. Further data have to be used to assess a direct risk.

The symbols have the following meanings: T+: very toxic; T: toxic; Xn: harmful; C: corrosive; Xi: irritating.