Review Report

Refurbishment of an existing detached house in Germany using an External Thermal Insulation Composite System based on Neopor® or Styropor®

Gap Assessment & Critical Review of BASF Eco-efficiency Analysis

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30 July 2013

INTRODUCTION

Background & Objectives

The subject of this gap assessment and critical review is the Eco-efficiency study **on the refurbishment of an existing detached house in Germany using an External Thermal Insulation Composite System based on Neopor® or Styropor®.** Background and motivation for the study is the calculation of the **avoided GHG emissions** when using insulation for existing buildings.

The analysis was conducted using the Eco-efficiency methodology, developed by *BASF* as a life cycle tool. The use of life cycle inventory data and the assessment of environmental impact categories are performed in accordance with the applicable international standards on Life Cycle Assessment (LCA) ISO 14040/44. Some further elements of the Eco-efficiency Analysis (EEA) are not covered by this ISO standard, but are performed in accordance with the externally validated and published Eco-efficiency methodology.

As part of the quality assurance and to ensure credibility of Eco-efficiency studies, *BASF* desires a critical review of each study by independent experts. This work provides a gap assessment against the applicable ISO standards and a critical review of the data and models.

The objectives of this gap assessment and peer review are to –

- Ascertain whether the LCA elements of the EEA meet the ISO 14040/44 standard in terms of methodological compliance and formal requirements. Additionally, the elements beyond the scope of the ISO standards will be checked against the published Eco-efficiency methodology. Suggestions on improvement options were given to the practitioner.
- Conduct a base-level critical review of the subject matter, providing an appraisal of data sources, life cycle models, assumptions, and calculations in terms of technical plausibility, transparency and appropriateness.

Scope of this Gap Assessment and Critical Review

The critical review is based on the report in ppt format:

“Refurbishment of an existing detached house in Germany using External Thermal Insulation Composite Systems based on Neopor® or Styropor®.”,

from July 2013 written by ZZS/SE, Sustainability Evaluation, Ludwigshafen, Germany (Dr. Nicola Paczkowski).

The references of the CF study are the standards

- ISO 14040 (2006): Environmental Management Life Cycle Assessment – Principles and Framework
- ISO 14044 (2006): Environmental Management Life Cycle Assessment – Requirements and Guidelines

The objectives of this gap assessment and critical review are the same as for the critical review process in accordance with ISO 14044, 6.1, i.e. ensuring that –

- the methods used to carry out the LCA are in line with ISO 14040–44;
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretation reflects the limitations identified and the goal of the study; and
- the study report is transparent and consistent.

The review statement is only valid for this specific report.

The EEA compares several product systems in terms of environmental and economic performance. The results are primarily intended for business decision makers, but can also be disclosed to the public. For publicly disclosed comparative assertions about environmental performance based upon Life Cycle Assessment (LCA), the applicable standard ISO 14040/44 foresees a critical review by a panel of independent experts able to represent interested parties. This was beyond the scope of this gap assessment and critical review. This gap assessment is rather intended to verify where the applied LCA methods are in accordance with ISO.

The special aspect of this EEA review is that the Eco-efficiency study was conducted to provide a case example for the document *“Guidelines from the Chemical Industry for accounting and reporting GHG emissions avoided along the value chain based on comparative studies"*, developed by ICCA and the Chemical Sector Group of the WBCSD. So, the EEA method is used as a vehicle in this case to calculate the avoided GHG emissions of the chemical product “EPS insulation”. The case example itself and the related report are not part of the critical review.

The commissioner and practitioner of the EEA adopted the good practice of having the EEA, specifically the LCA portion, reviewed by an external and independent expert. As a quality assurance of procedures, data and models, the purpose of this gap assessment and critical review was to ensure that the classification, characterisation, normalisation, grouping and weighting elements are sufficient and are documented in such a way that enables the life cycle interpretation phase of the LCA to be carried out [ISO 14040, 7.3.1].

Procedures and Structure of this Report

The gap assessment and critical review were conducted as follows:

- BASF provided DEKRA with the EEA report and accompanying MS Excel calculation sheet - 17 May 2013;
- DEKRA conducted the gap assessment on the above mentioned documents – 12+14 June 2013;
- BASF and DEKRA met in order to discuss comments and resolve open questions - 17 June 2013;
- BASF updated the EEA report and the accompanying MS Excel calculation sheet - 23 July 2013
- DEKRA submitted the critical review report to BASF - 30 July 2013

The gap assessment is intended for internal use by *BASF* and contains suggestions for the practitioner about the possible improvement of the study. These suggestions use the following colour code ("traffic lights system") in order to designate areas of improvement; page references are given in brackets:

l Critical issue – needs to be addressed to achieve ISO compliance, or could otherwise impinge on success of the study.

l Optional improvement – should be considered to fulfil formal aspects of ISO compliant reporting and to facilitate critical review, or could otherwise enhance the study.

l Pass – compliant with ISO, suggestions are entirely optional.

m Exemption – issue outside the scope of ISO, suggestions are hints from a peer review perspective.

The critical review summary comprising the appraisal of the technical merits of the study is meant for communication with the target audience of the EEA.

CRITICAL REVIEW GAP ASSESSMENT

General Aspects

Background and Motivation

The background and motivation for the EEA study is to provide a case example for the calculation of avoided GHG emission based on a document developed by ICCA and the Chemical Sector Group of the WBCSD.

Due to that fact, the EEA is performed with limitations which are described in a transparent way in the report and summarised in the following:

- The focus is on the chemical product only, e.g. no other insulation material like mineral wool considered;
- The study does not intend to assess all technical options to fulfil the defined user benefit which is "Living in an existing, detached house in Germany at an average room temperature of 19°C for 40 years";
- The focus is just on one particular aspect for refurbishment of existing houses à insulation with EPS-based systems of the exterior walls;
- All other building components (roof, windows, heating system, etc.) remain unchanged for all alternatives under study;
- The study does not include a complete analysis, i.e. the construction and disposal of the house are omitted (but addressed in a scenario).

However, the study provides a full range analysis of environmental and economic impacts as foreseen by the BASF Eco-efficiency methodology.

The simplified approach of the EEA is clearly stated and explained, so the motivation in this specific context is plausible and can be supported by the reviewers.

Commissioner, Practitioner and Stakeholders of this EEA

The commissioner, practitioner and stakeholders of this study are provided.

- Commissioner: BASF SE;
- Practitioner: BASF SE, Sustainability Evaluation;
- Stakeholders include LCA practitioners, sustainability managers, and the interested public.

Date of Report

The report is dated 23 July 2013.

ISO 14040/44 Compliance Statement

It is stated that the LCA-related parts of the EEA have been conducted following the ISO 14040/44 standards. Additional elements go beyond the ISO standard (e.g. cost calculation, Eco-efficiency portfolio) and are performed in accordance with the externally validated and published Eco-efficiency methodology.

Definition of Goal and Scope

Goal Definition

The goal and scope of the study are limited based on the described limitations due to the background and motivation of the performed work.

The **goal** is to compare the environmental and economic performance of an existing detached house without refurbishment with the same house refurbished with an external thermal insulation composite system for the exterior walls in two alternatives - based on Neopor and Styropor - otherwise no changes are considered with regards to any other building components over a 40 year lifetime.

The goal is to only demonstrate the contribution of the chemical insulation material as one singular element of a holistic and complex concept of a building refurbishment.

The **intended use** of this EEA is to apply the GWP results as a case example for calculating the avoided GHG emissions explicitly due to the application of chemical insulation products (done in a separate report) and to externally communicate the results of the EEA overall to LCA practitioners, sustainability managers, and the interested public (with the help of the MS power point slides on which the review is based).

One of the main topics during the review process and at the face-to-face review meeting was to clearly state the simplified approach of the EEA study and to explain the resulting limitations. In the report it is clarified that the applied approach does not reflect the current practice for refurbishment of existing buildings and thus limits the general conclusiveness of the study. This is done to ensure the credibility of the results and to make sure that the study is as robust as possible.

This goal definition and intended use can be considered appropriate under the given circumstances and respecting the described limitations. However, a “yellow” evaluation (possible improvement) is given due to those limitations in combination with the intended external communication.

Scope Definition

Details on the **temporal**, **geographical** and **technological reference** of the EEA study are given.

The scope definition is considered appropriate for this EEA study.

Functional Unit and Reference Flows

The **functional unit (FU)** (called “customer benefit” according to EEA methodology) of this EEA study is given as “living in an existing, detached house in Germany at an average room temperature of 19°C for 40 years”. The building under study is defined as a single family detached house. The dimensions and geometry of the buildings represents a detached house built in the 1960s.

This description of the customer benefit implies to investigate more technical options than the three alternatives considered in the EEA (non-insulated house and two variations of an external wall insulation system applied). Thus, it is necessary to state clearly the motivation for the limitations of the study and the narrow focus on chemical insulation materials for the walls.

So, the given FU is supported by the reviewers in combination with the already mentioned description of the limitations of the study.

Based on a suggestion of the reviewers, the equivalence of the alternatives is addressed in the report. The report states that the equivalence of all alternatives is given concerning technical and functional aspects and that no additional services like ventilation systems for the insulated house are required to achieve equivalence. The reviewers support this position in this specific context as only one simplified aspect of building refurbishment is investigated.

Flow Diagram & System Boundaries

The **system boundaries** for all three alternatives under study are illustrated through process flow diagrams and are described in the report.

The constraint for the system boundaries is the omission of the construction and disposal phases of the house itself. The related premise is that these processes are identical for all alternatives and so can be ignored when comparing them. It is supported with a scenario calculation that the consideration of the construction and disposal phases of the house does not change the overall conclusion of the study.

Consequently, the system boundaries are appropriately chosen and consistent with the goal and scope of this EEA study.

Modelling

The three options under study were modelled mainly based on secondary data. Only the data for the heating energy demand during use phase were specifically calculated for the purpose and according to the set-up of this study. This data was combined with cradle-to-gate background data obtained from various databases. The modelling was carried out with the help of a tailored MS Excel spreadsheet.

All modelling assumptions and underlying data sources are outlined in the report and in the accompanying MS Excel spreadsheet which was made available to the reviewers.

Life Cycle Inventory (LCI) Analysis

Data collection and data sources

No primary data collection was done within the study for technical processes or products. However, a lot of data was gathered to set up the technical frame of the alternatives. Various literature sources which are considered as state-of-the-art and reliable by the reviewers are used and displayed in a transparent manner (e.g. German Energy Savings Regulation EnEV 2009, Basis für Hochrechnungen mit der deutschen Gebäudetopologie des IWU - Instituts für Wohnen und Umwelt, Darmstadt, 2011). The procedure of setting up the technical parameters of the alternatives is well described and understandable. Technical parameters which were defined are e.g.

- Geometry of the building;
- U-values of the exterior walls for all alternatives;
- U-values for all other building components for all alternatives;
- Parameters for heating system (energy efficiency, mix of energy carriers).

The U-value for the existing, non-insulated house is calculated based on statistics of actual U-values of existing houses in Germany which are up to 150 years old. A weighted average (based on living are in m^2) is calculated for both the U-value of the exterior wall and the heating system in place (mix of energy carriers and energy efficiencies, also based on statistics). This approach refers to the named ICCA document giving guidance on how to calculate the avoided GHG emissions. The document suggests a comparison to the weighted average based on the shares of all currently implemented technologies, including the share of already refurbished houses with wall insulation in this case which represents about 20% of the total living area in Germany (referred to building data before 2011).

Since this averaging creates a theoretical case which is not realistic and not directly comparable to actual existing houses, the report shows two extreme and realistic cases in the scenarios following a suggestion by the reviewers. A best case with low U-value (but non-insulated) based on the existing buildings statistic, using a state-of-the-art heating system and a worst case with high U-value, using a typical heating system applied in the 1980s. This gives a realistic range of possible energy and cost savings due to the application of chemical insulation products depending on the respective base case which completes the results based on the averaged base case.

The U-values of the insulated alternatives follow the requirements of the German ENEV 2009 for renovated houses in combination with the requirements of the KfW Bankengruppe loan and subsidy program which is a frequently used loan program in Germany for refurbishment of buildings. This U-value defines the construction of the insulation system including e.g. thickness of the insulation layer.

The calculation of the heating energy demand of the alternatives – which is the decisive and crucial resulting parameter based on the set up of the technical frame as described above – is done by an expert consultancy in real estate, a subsidiary of

BASF SE and performed with the help of an expert software system. The resulting heating energy demands for the alternatives are considered as solid and valid by the reviewers.

Note: even though the set-up of the technical frame (parameters of the building components) is considered appropriate and solid as given in the study, the influence of the base case definition (non-insulated house) on the overall results is high and leads to a certain volatility of the results. There are a number of freedom degrees when defining the base case, so this includes a certain degree of subjectivity. The influence of the decisions made needs to be checked intensively in scenario analyses which is done in the study and addressed later in the review report.

The data used for modelling of the insulation systems, the energy carriers, the End-of-Life, the transportation etc. are cradle-to-gate background data. In some cases the age of the used background data is problematic (e.g. some datasets are more than 10 years old) and the data is sourced from different LCA databases with most likely inconsistent system boundaries. This limits to a certain degree the reliability of the results of this EEA study.

However, since most of the older data are used for all alternatives and the main purpose is to compare the different options, the lack of recent background data does not weigh too heavily and the main focus is not on the absolute but the relative Eco-efficiency of the different building options.

Note: Nevertheless, the quality of the study could be improved by using more up-to-date and consistent background data.

In the course of this critical review, spot checks were conducted to verify the validity of the LCI data with respect to the goal and scope of the study.

Cut-off and Assumptions

All relevant assumptions are documented in the report and also noted in the MS Excel spreadsheet. The assumptions were explained and justified in the review meeting and it can be verified that they are adequately chosen.

The most relevant assumption is the definition of the service life. A service life of 40 years for the external thermal insulation system was chosen in accordance with the assessment system for sustainable buildings, developed by the German Federal Ministry of Transport, Building and Urban Development (BMVBS) in collaboration with the German Sustainable Building Council (DGNB), following a suggestion by the reviewers.

Classic cut-off rules are not applicable as no primary data collection is done in this study. Otherwise, all relevant input and output flows are considered in the defined system boundary.

Allocation

There are no allocation issues associated with this study.

Data Quality Criteria Requirements

The data are complete and reproducible as far as possible. The consistency of the applied background data is partly not given as described above. The data for setting up the technical frame of the building are good and representative for Germany.

As a result, the overall data quality in this study is good and sufficient.

Life Cycle Impact Assessment (LCIA)

The life cycle impact assessment was conducted in accordance with ISO 14040/44, considering a range of impact categories, such as primary energy demand, global warming potential, acidification potential, photochemical ozone creation potential, ozone depletion potential etc.

In accordance with the published Eco-efficiency methodology, the classification of LCI entries in some cases uses sum parameters or substance groups, such as chlorinated hydrocarbons, and averaged characterisation factors. Some of the characterisation models are proprietary developments of *BASF*, documented in peer-reviewed publications[1], for instance the impact category resource depletion comprises both scarcity and range of coverage of deposits. This review included spot checks of these models.

Methodology

The following impact categories have been considered: energy consumption; resource depletion; land use; air emissions (GWP, ODP, POCP, AP); water emissions and solid wastes; toxicity potential; and risk potential. The selection of impact categories is made according to the *BASF* EEA method.

The respective impact assessment methods applied are in accordance with the *BASF* EEA: characterisation factors are provided separately in a table, e.g. for air emissions.

We recommend regularly reviewing these characterisation factors and possibly using secondary sources, such as *CML*. This would facilitate updating the whole impact assessment module and staying in line with the state-of-the-art.

The scope of the *BASF* EEA methodology goes beyond ISO and cannot be verified other than against the published description of this method. For example, the single impact results follow ISO rules but the weighted aggregation into portfolio diagrams is not covered by ISO. The weighting and aggregation carries the risk of inaccuracy and misinterpretation:

- Averaged characterisation factors may distort the contributions of single substances to impact categories.
- Relevance factors and the critical volume method introduce references to ecological limits or thresholds, and therefore necessitate country-specific data and regular updates.

[1] Peter Saling *et al.*, Assessing the Environmental-Hazard Potential for Life Cycle Assessment, Eco-efficiency and SEEbalance, Int J LCA 2005, vol. 10(5), pp. 364–371.

- Societal factors and the critical volume method introduce references to political or societal priorities and thresholds, and are therefore also subject to change.

Each of these three levels of weighting and aggregation can influence the reliability of the results. As long as the *BASF* EEA is consistently applied, this potential issue is mitigated; but it may be desirable to increase the share of robust methodological building blocks that are state-of-the-art and commonly accepted, such as ISO and CML.

l Results

Classification and characterisation are accomplished by means of the *BASF* EEA tool. Results of the single environmental impact categories for the three alternatives are displayed in bar diagrams, accompanied by comments and the weighting factor each category contributes to the environmental fingerprint and the overall Eco-efficiency portfolio.

The trend of the overall results of the study are as expected: in all environmental result categories, the non-insulated house has the highest impacts, both houses with EPS insulation alternatives are on a comparable level with no significant performance differences. All result categories are dominated by the use phase (with omission of construction and EoL phases of the house itself).

The results are compared with the study of 2008 - BASF: “Eco-Efficiency Analysis, Refurbishment of Detached House (Germany)” - which has a comparable goal and scope. During the review meeting, the results were discussed and analysed in detail and all existing differences between the outcomes of the 2008 and the present study are plausible and explainable.

Hence, the robustness of the results can be considered to be very good. Plausibility checks (where possible) indicate that the data and calculations are accurate.

Other Life Cycle Aspects

m Toxicity and Occupational Risks

The assessment of toxicity and occupational risks was performed in accordance with the published Eco-efficiency methodology. Both procedures employ semi-quantitative scales that are proprietary developments of *BASF*, documented in peer-reviewed publications[2].

- **Toxicity potential**: due to the EEA methodology, toxicity always contributes 20% to the EEA results and consists of a human toxicity score (70%) and an ecological toxicity score (30%). The life cycle phases are differently weighted as follows: Production phase 20%, use phase 70% and disposal 10%. Through the different weighting of the life cycle phases, the impact of the production phase for the

[2] Robert Landsiedel and Peter Saling, Assessment of Toxicological Risks for Life Cycle Assessment and Eco-efficiency Analysis, Int J LCA 2002, vol. 7(5), pp. 261–268

chemicals is reduced in relation to the use phase since the results are shown in one aggregated graph.

Note: More transparency and better interpretation would be given for the Toxicity result with disaggregated, so un-weighted graphs showing the results of the different life cycle stages separately.

The results for this indicator are in line with the EEA method and deemed appropriate.

- **Risk potential:** in this EEA study, the risk potential contributes 7% to the EEA results. Due to the rough aggregation of statistical data on accidents and occupational diseases on a whole industry level, the levels of uncertainty associated with these results in this indicator can be considered to be rather high.

m Life Cycle Costs

The assessment of life cycle cost aspects is another key component in the framework of the EEA, but is beyond the scope of LCA in accordance with ISO 14040/44. Hence, this review can only conclude that the calculations are transparent.

The energy costs are current cost data and no inflation rate is considered (conservative approach since energy costs are the crucial parameters for the cost analysis). The cost result is as well dominated by the use phase. The difference in cost of the house alternatives is less significant compared to the difference in environmental performance.

Life Cycle Interpretation

l Analysis and Evaluation of Results

Critical assumptions and key parameters were examined by means of scenario analyses. The respective results do change to a certain extent the main outcomes or messages associated with the eco-efficiency of the house alternatives and thus show the volatility of the results depending on the definition of the base case, the non-insulated house.

A number of seven different scenarios are calculated in the study. The different scenarios challenge the stability of the results by varying different key parameters.

The advantage of the insulated house alternatives regarding environmental performance shrinks significantly if the base case of the non-insulated house has already a relatively low U-value (even without insulation) and an efficient heating system or the energy mix changes in the future to a low-carbon one based on renewable energy.

Scenario 7 calculates the influence of the consideration of construction and EoL phases of the house itself. Construction and disposal have a significant absolute impact on the results but they do not change the overall result trend taken the defined base case of the study (weighted averaged U-value for the walls) into account. The use phase remains still dominant (with exception of the result category "solid waste") although it is obvious that the use phase has a reduced impact the better the house is insulated.

The seven scenarios investigated in this EEA study provide further interesting insights into the Eco-efficiency of the house alternatives and demonstrate the dependency on the definition of the key parameters.

m Weighting and Aggregation of Results

The Eco-efficiency methodology involves weighting and aggregation into single environmental and economic indicators. While these steps are not in agreement with ISO 14040/44 for comparative LCA studies intended to be disclosed to the public, they may be appropriate in the framework of the Eco-efficiency Analysis and are justified in peer-reviewed publications.

l Conclusions

The conclusions drawn from both for the potential environmental impacts as well as for the eco-efficiency performance of the house alternatives under study reflect the results presented in the LCIA and the scenario analysis.

CRITICAL REVIEW SUMMARY

Subject of this critical review was the Eco-efficiency Analysis of three different alternatives of a single family detached house:

a) Non-insulated house;
b) Refurbished house with insulation at exterior walls (based on Neopor®);
c) Refurbished house with insulation at exterior walls (based on Styropor®).

The Eco-efficiency Analysis is a peer-reviewed and very sophisticated method. Its execution is supported by a professional LCA database and a well-developed software model.

The goal was to compare the environmental and economic performance of an existing detached house without refurbishment with the same house refurbished with an external thermal insulation composite system for the exterior walls in two alternatives, otherwise no changes are considered with regards to any other building components over a 40 year lifetime. The main motivation of the study is to serve as an example case for avoided GHG emissions of a chemical product.

So, the goal is to only demonstrate the contribution of the chemical insulation material as one singular element of a holistic and complex concept of a building refurbishment. Due to the reduced complexity of the subject, the general conclusiveness of the results is limited. The scope is a detached house built in the 1960s – in the base case, the construction and disposal of the house itself is neglected.

The critical review process included data quality checks. An appropriate and sufficient data quality can be stated. The review meeting and the review process as such was performed by BASF SE in an open, competent and very professional manner.

The key results are:

- Compared to the average condition of existing non-insulated houses in Germany, the application of insulation at exterior walls - following the ENEV 2009 and KfW Bankengruppe requirements – has a clear advantage regarding environmental and economic performance;
- The type of insulations materials does not affect the results;
- The use phase dominates the results;
- The choice of scope, whether the construction and disposal phase of the house itself is included or not, does not change the main conclusion of the study.

The abovementioned results and conclusions were plausibly and transparently derived from the data. The underlying life cycle models, assumptions, and calculations are transparent, detailed, well documented and appropriate.

The scenarios chosen helped to identify the high volatility of the results. The results of the scenarios demonstrate the dependency on the definition of the key parameters. For example, the reference case of a non-insulated house can be defined based on actual building and heating system data in a way that the environmental advantage of the insulation is not significant anymore.

One weakness of this Eco-efficiency study is the age and partly inconsistency of the database used for secondary datasets. Although updated datasets are unlikely to change the relative results for the house alternatives analysed, using more up-to-date and consistent background data sets would help to improve the overall accuracy of the LCA results.

Besides, the reviewers found the overall quality of the methodology and its execution to be adequate for the purposes of the study. The study is reported in a comprehensive manner including a transparent documentation of its scope and limitations.

Except where noted in the review with respect to weighting and aggregation, the LCA elements of the Eco-efficiency study were conducted in accordance with ISO 14040/44.

The Eco-efficiency Analysis – including portions beyond the scope of LCA according to ISO 14040/44 – 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 Eco-efficiency study 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.

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