USE OF LIFE CYCLE ASSESSMENT IN VIEW OF ECO-DESIGN FOR A GLASS-WOOL PROCESS

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ABSTRACT

The Life Cycle Analysis (LCA) methodology has been used to study glass wool production by Knauf Insulation in order to publish Environmental Product Declarations (EPD) and to initiate eco-design programs. The process has been modeled in GaBi v5 with industrial data. In this study, the impact on climate change has been study with more accuracy. The production step is the most impactful in this latter category. A detailed study underlines the importance of the natural gas production and combustion. The extraction and transport or raw materials for the wool also have a significant impact. A comparison between tow production plants underlines the importance of waste generation. The vegetal based binder production allows an impact reduction since carbon dioxide is captured from the atmosphere during the plant growth used for its production. But, the end of life of the binder generates methane emission. Then, if the entire life cycle is considered, the binder contributes to climate change.

Some process improvements have been studied in details. In the first scenario, less waste is generated. It allows a reduction of the climate change by 3% when the entire life cycle is considered. Nine other impact categories, with the ReCiPe methodology, have also been considered. Reducing the waste production is useful for all impact categories and more in the impact categories where the influence of raw material is higher (climate change, fossil depletion, particulate matter formation and terrestrial acidification). In the second scenario, a change in the energy mix for the electricity production is assumed: the French mix is totally replaced by photovoltaics. If the entire life cycle is considered, the climate change is reduced by 6 %. Nevertheless, when other impacts categories are considered, the results are dependent of the category. The impact categories where the decrease is highest are ionising radiation (95 %) and ozone depletion (96 %). Whereas, in some categories, the impacts become higher such as for terrestrial ecotoxicity (211 %) and metal depletion (567 %). The European normalisation underlines that the use of photovoltaic allows an impact reduction in the 3 categories with the highest impact.

In conclusion, the LCA is a powerful tool for eco-design because it allows a better understanding of the environmental impact and help to prevent impact transfers from an impact category to another or between life cycle steps. Moreover, the LCA quantifies environmental performances which is useful for communication.

INTRODUCTION

Taking into account that the environmental aspects have become unavoidable in the building sector. Knauf Insulation, a building insulation manufacturer, has begun to evaluate the environmental impacts of its processes. The Life Cycle Analysis (LCA) methodology is used in this view. Indeed, LCA deals with the environmental aspects and potential impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, and end-of-life. In this type of environmental assessment the energy and material fluxes for the entire life-cycle are surveyed and analysed, with special attention to possible environmental hazards or human health problems.

We present an analysis of glass wool production which has been realized in order to publish Environmental Product Declarations (EPD) and to initiate eco-design programs. The process has been modelled in GaBi v5 with industrial data. The studied materials are produced by Knauf Insulation, and are manufactured in 2 factories, one in France and one in Belgium. In order to study the environmental impacts of almost all the glass-wool products, variable parameters, such as, product thickness, have been introduced. We first describe the production system before introducing the LCA methodology and presenting our model.

We show how this model can help in eco-design by focusing on the global warming potential, and highlight, for one of the factories, the production steps that have the most impact. Finally, we discuss possibilities for reducing this impact and how this affects other impact indicators.

THE PRODUCTION PROCESS

The raw materials for glass wool are sand, limestone and soda ash, as well as recycled off-cuts from the production process, borax and sodium carbonate. They are first weighed and mixed. Knauf Insulation also uses a large amount of recycled glass (cullet) in its production, over 60% in both plants, even though a small amount of sand is always necessary to ensure good properties. The mix is sent to a furnace at very high temperature (1350°C). The furnace is heated by a combination of two heating techniques: oxycombustion and electricity. Therefore, two sources of energy are used: natural gas and electricity, in combination with oxygen.

Secondly, the melted material is fiberized and the binder is added, a process called forming. Knauf Insulation uses a special binder with ECOSE Technology, a new and formaldehyde-free binder. The wool fibres are collected, by suction on a metallic conveyor belt. Then the mattress goes through the curing oven where the distance between 2 chains (similar metallic conveyors) gives the thickness of the product.

The mattress is passed through a natural gas oven at 250°C in order to cure the binder. After cooling, the mattress is cut to correct width and length and packed.

METHODOLOGY

1. Life Cycle Analysis

a. Methodology

The LCA methodology evaluates and quantifies the environmental impacts for every stage of a product's life. The ISO 14040 and 14044 norms [1, 2] provide the general guidance for performing an LCA. There are four interdependent stages: (1) goal and scope definition, (2) Life Cycle Inventory (LCI), (3) impacts assessment, and (4) results interpretation. During the first stage the functional unit and the system boundary are determined. In the second stage, the full life cycle is decomposed into elementary steps and for each step the energy and material balances are performed. All the environmental impacts are evaluated in the third stage: for each flow from the LCI, a specific characterisation factor determines its impact in the studied impact category. A specific score is finally obtained for each impact category studied. Normalisation can also be used. In this case, the results are expressed in relation to a reference, such as the mean impact of a European citizen. This can help in determining the categories that have the most impact, although normalisation should be used with caution.

European ILCD handbook [3] offers precise advice in order to perform an LCA.

b. ReCiPe methodology and climate change

As an example, the climate change category is studied from an eco-design perspective, using the ReCiPe methodology. This methodology was created in 2000 and provides two levels of analysis, however in this case only one, the MidPoint level, is used. It is the base level for the characterisation and it quantifies the impact in each category. The ReCiPe methodology has 18 impact categories in the MidPoint level but we consider only a few in this study [4].

Impact on climate change, i.e. greenhouse gas emissions, is systematically expressed in CO_2-equivalent. The ReCiPe methodology combines a set of characterisation factors to determine this impact. Some processes have an inverse effect on this impact, as they allow for the capture of carbon dioxide through photosynthesis. This captured CO_2 is generally released at the end of life of the product, resulting in a zero balance on the climate change impact. However in the studied system, some of the carbon released at the end of life is in the form of methane, a gas that has a different characterisation factor from CO_2. Therefore, we adjust the balance by taking into account the CO_2 captured from atmosphere by photosynthesis as a negative contribution to climate change but we also take into account the carbon emission as both CO_2 and CH_4 at the end of life of the product.

2. The model

The system boundaries are raw materials extraction and product end of life, and the functional unit is the production of the thermal isolation function on 1 m^2 during its life expectancy, i.e. 50 years (the product is supposed to stay in place during the entire building life). Nevertheless, the impacts of the usage of the insulation system during its use are not included, as they are strongly depend on parameters such as construction systems, climate data, etc. Moreover, the use phase is not relevant for eco-design view as the producer can not influence on it. Therefore, 4 different steps are considered: production, transport, installation and end of life. Of course, these steps can be divided in substeps, such as, in production, electricity generation or raw material extraction.

The model, developed in GaBi v5, uses industrial data for the plants, and a commercial database [5] with certain extensions for the remaining processes. It is able to characterise the majority of the products thanks to adjustable parameters (thickness, length, etc.). Both factories work on similar pathways but the production and transport steps are divided in two branches, one for each factory, in order to take into account the small differences between them, although, we focus here on one plant, which we name plant A, the other being plant B.

A standard product, glass mineral wool roll, is chosen as example.

RESULTS

1. The Climate Change

Production is the step that most affects climate change, at 74 %, while end of life is at 14 %, and the remaining steps, transport and installation, contribute respectively to 8 and 9 %. The production step, in light of its impact, is studied in detail in the following section.

a. Production

Climate change is principally influenced, in the production step, by CO_2 emissions from the plant, as shown in figure 1. These emissions are caused by raw material decarbonisation and natural gas combustion. The latter contributes to 80 % of total emissions. Furthermore, natural gas also contributes to climate change through its production, therefore the most effective solution for reducing the impact of the production step is to reduce the use of natural gas. Higher energy efficiency or other energy sources can be considered.

The influence of electricity is low because the French grid electricity is considered, in which nearly 90 % is produced by nuclear and hydroelectricity, sources that have a small global warning potential.

The negative contribution of the binder is due to the capture of CO_2 during photosynthesis by the plants used in the binder raw material. Nevertheless, the absorbed carbon is released at the end of life of the product as CO_2 and CH_4. As the impact factor for climate change of methane is higher than for carbon dioxide, when the entire life cycle is considered, the binder has a non-zero contribution (see figure 2).

The extraction and transport of raw materials for wool also play an important role, more so in plant A compared to plant B for the same product (50% more impact). This difference is due to plant waste efficiency: in plant A, more waste is generated, so more raw materials are used for the same amount of product. Working on plant efficiency in plant A can therefore reduce the impact on climate change. This case is further studied in the next section. Moreover, in plant B, most of the wastes are valorised as co-products, while in plant A the wastes are mainly disposed of in landfills.

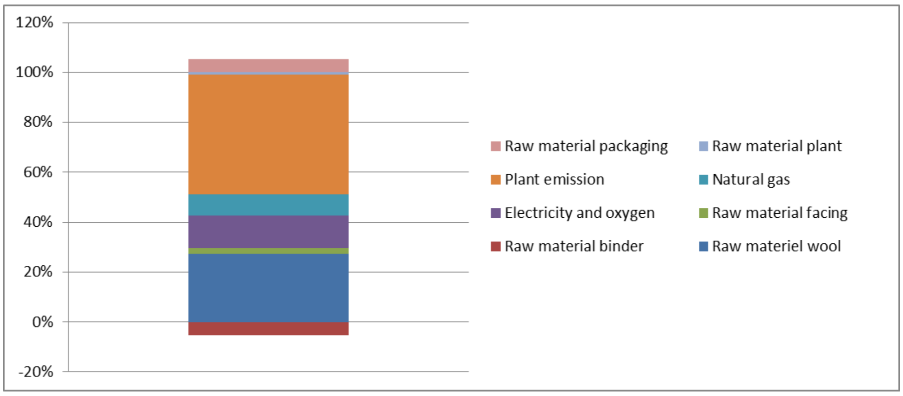

Figure 1: Climate change for the production step

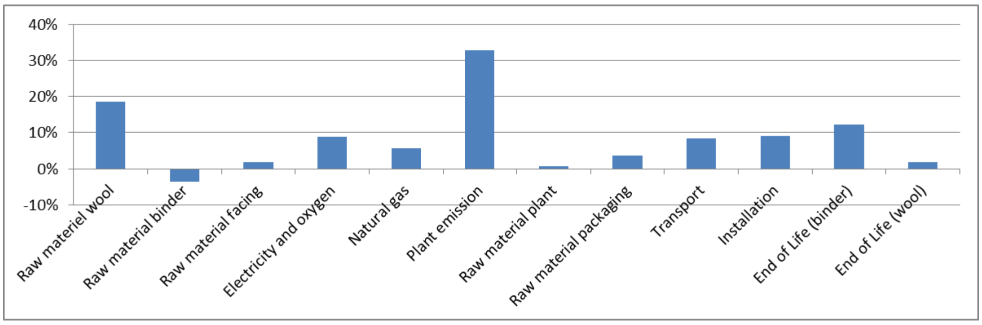

Figure 2: Climate change for the entire life cycle.

2. Eco-design

a. Line waste efficiency

As shown before, the plant A efficiency is smaller than the plant B. If we suppose that plant A generates exactly the same amount of waste as plant B, for a given product. Then the impact on climate change, presented in figure 3, is 4% lower than the base case. The impact of raw materials, as well as the positive aspect of the binder, are reduced, although to a lesser extent for the latter. If the entire life cycle is considered, the climate change is reduced by 3%.

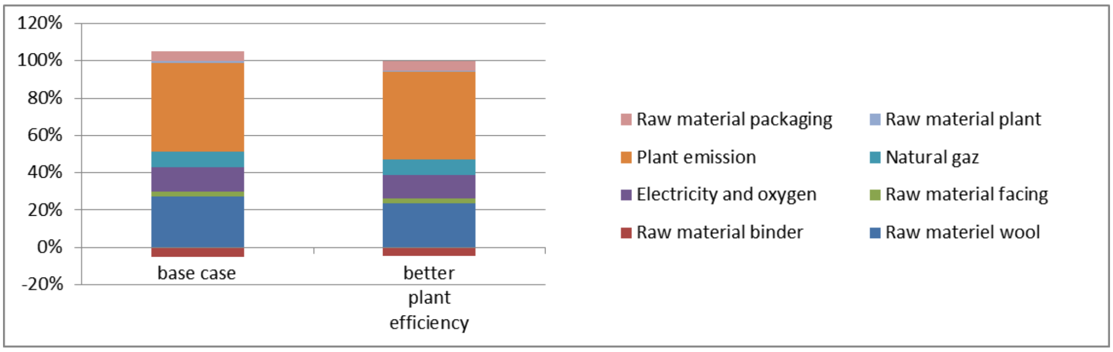

Figure 3: Climate change – Comparison between a case where the line efficiency of plant A is identical to plant B and the base case (total base case = 100 %).

The impact of this change of waste production in 9 other impacts categories is also determined using the ReCiPe methodology. The results for the base case are presented in figure 4. The impact of raw material extraction and transport is highest in climate change, fossil depletion, particulate matter formation and terrestrial acidification, therefore the influence of plant efficiency is most noticeable in these categories (see figure 5).

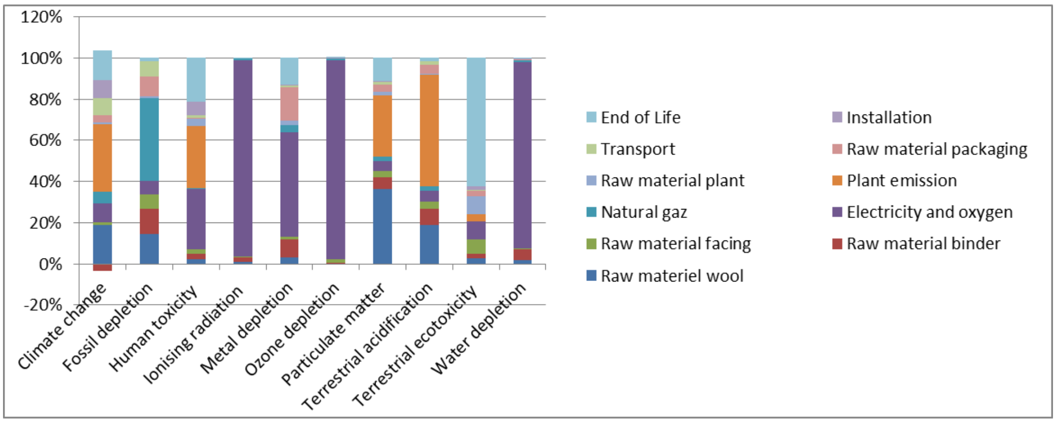

Figure 4: ReCiPe - characterisation in relative percentage - Base case.

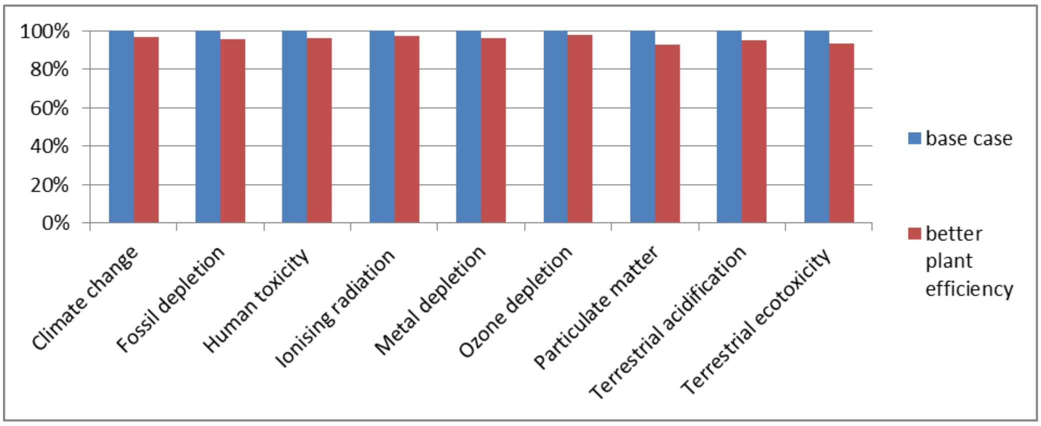

Figure 5: ReCiPe – Comparison between a case where the line efficiency of plant A is identical to plant B and the base case (total base case = 100 %).

b. Electricity mix

As the development of alternative electricity sources is promoted by several European governments, we examine, as an example, the influence of a switch to photovoltaic electricity instead of the French mix. A combination of photovoltaic panel types is used based on the share of different photovoltaic technologies installed in Europe in 2008: Mono-silicon (47.7 %), Multi-silicon (38.3 %), Cadmium-telluride (6.4 %), Amorphous-silicon (5.1 %), Ribbon-silicon (1.5) and Copper-indium-gallium-diselenide (1 %). No storage system is considered and the entire electricity consumption of plant A is assumed to be photovoltaic. Obviously, the only difference in the climate change impact category is related to electricity production. Its impact is reduced by 74 %, which results in a reduction for the entire life cycle of 6 %.

The influence on other impact categories is shown on figure 6. Fossil depletion decreases only by 4% for the whole life cycle. The impact categories where the decrease is highest are ionising radiation (95 %) because the French grid mix uses a lot of nuclear electricity, and ozone depletion (96 %). In the last category, the influence of electricity stays high (25 %), but for ionising radiation, the electricity part becomes negligible (see figure 7). In other categories however, photovoltaics have a stronger impact, especially in terrestrial ecotoxicity (211 %) and metal depletion (567 %). In the first, when in the base case the influence of electricity was small, figure 7 shows that with photovoltaics it becomes the most important factor (91 %).

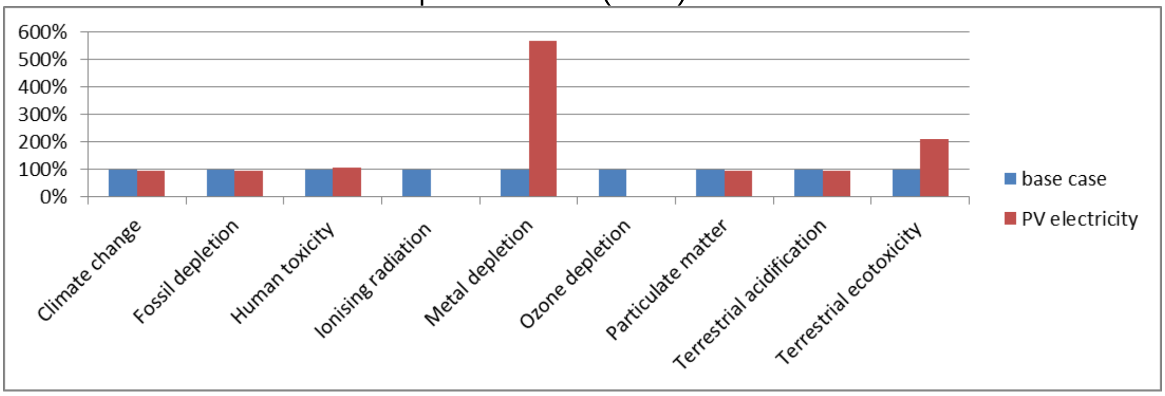

Figure 6: ReCiPe – Plant A - Comparison between a case where the electricity is provided by photovoltaic panels and the base case (total base case = 100 %).

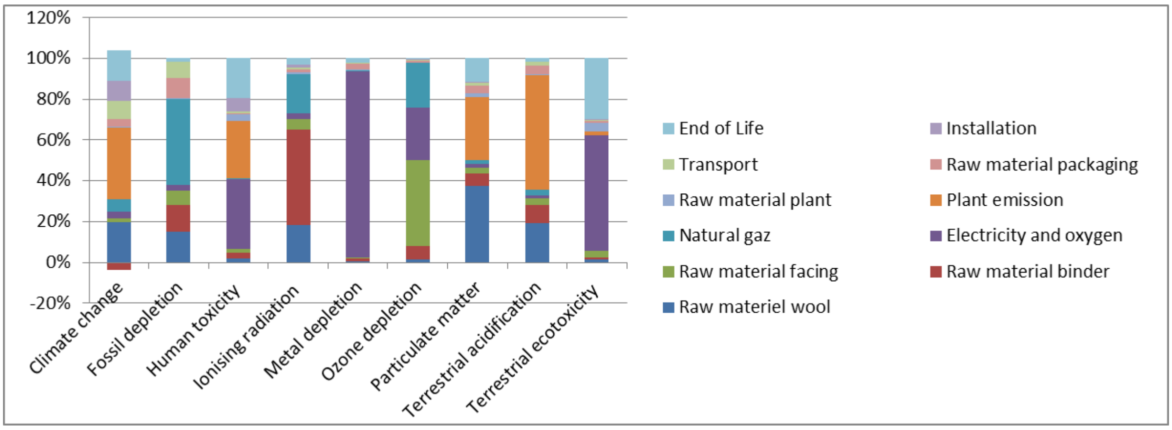

Figure 7: ReCiPe – Plant A - Electricity provided by photovoltaic panels.

European normalisation is used to better understand the impact of the use of photovoltaics (see table 1). The use of photovoltaic allows an impact reduction in the 3 categories with the highest impact (climate change, fossil depletion and ionising radiation). The score in terrestrial ecotoxicity, where photovoltaics has a higher impact than the base case, remains low, but a strong increase is noted in metal depletion.

Depending on the importance of each impact category, photovoltaic electricity is more or less environmentally-friendly. Nevertheless, the categories where the reduction is important are also the categories with the highest normalised scores, therefore overall it can be considered better for the environment.

Impact categories	Climate change	Fossil depletion	Human toxicity	Ionizing radiation	Metal depletion	Ozone depletion	Particulate matter	Terrestrial acidification	Terrestrial ecotoxicity
Points	4,77E+4	2,22E+3	2,53E+1	2,74E+3	6,75E+1	4,16E-10	8,88E-2	6,54E-1	3,23E-3

Table 1: ReCiPe – European normalisation - Base case.

CONCLUSIONS AND PERSPECTIVES

We have presented an example of the use of LCA in eco-design. Our model examines the entire life cycle of all glass wool products produced by Knauf Insulation. From this model, EPD and eco-design can be developed. LCA is a powerful tool for eco-design because it details the environmental impact of a product and quantifies potential improvements can be suggested. Moreover, LCA helps to avoid impact transfers from one category to another (as with the use of photovoltaic electricity in the present study) or between life cycle steps. Finally, LCA is the most exhaustive method to provide accurate environmental performance measures, which is useful in order to communicate with the public (marketing) or for internal communication (fixing objectives, etc.).

This study offers Knauf Insulation valuable insight on the impacts of its glass wool process on climate change and therefore will allow it to make more informed decisions. Other eco-design strategies can be studied, concerning changes in raw material, for example. Furthermore, when improvements are performed, the results of this study can be used as a reference for comparing and quantifying the new performances. Although it was not shown here, several other categories can be studied.

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