# What is a "Natural Insulation Material"? Assessment Model Based on the Life Cycle

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## Abstract

So far, strategies to reduce the environmental impact of buildings focused on lowering the energy needs. Improving the characteristics of the building leads to a lower heating energy demand but also needs more construction materials to be used, especially insulation and airtightness materials. In the Walloon Region, a system of financial subsidies for envelope insulation has been implemented. In addition to the basic subsidy, an additional one of 3€/m² is granted if a «natural insulation material» is used. « Natural insulation material » is currently defined by the Ministerial Decree of the Walloon Government as a material containing 85% or more fibers originating from plants or animals, or cellulose.

The present contribution aims to analyse and improve this current definition. The authors show that a pertinent choice cannot only be based on raw materials composition but must refer to many other criteria, taking into account the whole life cycle of the material. An assessment model and a weighting of the criteria were developed and tested on 39 generic materials based on the data coming from available database and scientific literature.

## Introduction

In the Belgian building sector, during the last ten years, a will to significantly reduce the building heating energy requirement has appeared. It is undoubtedly related to the increasing price of fossil fuels but also increased awareness of some environmental impacts such as climate change, natural resources depletion and biodiversity decrease. Reduction of heating energy requirement in Belgian houses is essentially reached by higher performance of the envelope, and more specifically by higher insulation and airtightness.

With the objective of promoting the renovation of low energy houses, the Walloon Government, has implemented a system of financial subsidies for building envelope insulation. Based on a mandatory energy audit, this system offers subsidies from 10€/m² to 30€/m² of insulated area, according to the type of walls and the insulation system (outside, inside...). Moreover, an additional subsidy of 3€/m² is granted if a «natural insulation material» is used. « Natural insulation material » has been defined by the Ministerial Decree of the Walloon Government voted on March 2010 and adapted on January 2011 as insulation material containing 85% or more fibers originating from plants or animals, or cellulose.

Nevertheless, when improving the energy performance of houses more materials and components are applied. The environmental impact of building materials becomes then proportionally very important in the context of very well insulated buildings. Environmental impact of building could be currently assessed by a lot of LCA tools, over its lifespan, taking into account the building materials, components and systems. But none of those tools presents specific analysis on the "natural character" of building products, considering the nature and characteristics of materials used, the processing undergone by raw materials, the additives used for implementation, the emission of pollutants during the life and treatment opportunities at the end of life. On the other hand, "natural" insulation material based on plant or animal fibers have more and more success though they are not as thermally efficient as minerals or synthetic insulation materials. But do these insulation materials actually have a lower environmental and health impact due to their raw materials?

The paper presents a proposal that the authors submitted to Walloon Government, showing that this definition still does not guarantee a pertinent choice of materials. The authors showed that some insulation with mineral base could also be regarded as « natural ». This pertinent choice cannot be only based on raw materials composition but must refer to many other criteria, taking into account the whole life cycle of the material.

This paper introduces an assessment and a weighting model tested on 39 generic insulation materials. Firstly, the paper describes the life cycle steps and considered criteria, the data collection and the boundaries of the study. The assessment model and the weighting are subsequently presented. Finally the results of the study are discussed.

## METHOD

### Goal and scope of the research

Regarding the current definition, the goal of this study is to assess the "natural "character of insulation materials over the whole life cycle and to propose to the Walloon Government a more accurate definition of "natural insulation material".

Two steps were proposed but the paper only presents the second one (more complete): the Decree definition will be refined through a set of criteria based on the insulation material life cycle. This definition involves a full analysis of the environmental and health impacts of the proposed materials and a requirement on their treatment at the end of life. The "natural" insulation material is defined as <u>*a material coming from nature, without any impact on nature nor health and returning to nature.*</u>

The environmental impact were calculated for 1m² of insulation layer with an equivalent thermal resistance R = 2 m²K/W. This value is the minimum required by the Walloon Decree to obtain the basic subsidy for wall and floor insulation. For roof insulation, the Decree requires a value $R \geq 3.5$ m²K/W.

### Life cycle analysis and selection of criteria

The authors have divided the life cycle of material into five steps. For each step, some criteria were selected:

→ **Raw material (non-energy resources):** some raw materials provide the insulating character; others are additives that provide additional properties. Each of those materials is characterized by its nature, its place of extraction, its environmental impact (culture, extraction); its health impact (hazardous matters), its availability and its intrinsic qualities.

  *<u>Criteria:</u> nature of resources (main and additional raw material), geographical origin (main raw material), resource availability (main and additional raw material), impact of culture, farming or mining on the environment (main raw material), natural resistance (main raw material), environmental impact (additional raw material), impact on worker's health (additional raw material)*

→ **Production process:** the production process can involve different types of processing: change of t°, form, physical or chemical state. The energy used and the environmental impact are assessed.

*<u>Criteria:</u> type of transformation, embodied energy (total and Non Renewable Energy), environmental impact (Global Warming Potential, Acidification Potential, Photochemical Ozone Creation Potential)*

→ **Implementation process:** according to the type of assembly, the material can be reused or recycled, or not. Some insulating materials are implemented with an additive: glue or binder. This additive must also be evaluated. The implementation of the building materials may cause nuisances to workers, due to the texture of the material, its emission or its additives (toxic substances).

*<u>Criteria</u>: reversibility of assemblies, additive required for assembly, noxiousness related to the implementation*

→ **Life in use:** most of toxic emissions occur when materials are handled or in direct contact with the indoor air. Moisture in the building is a significant health problem. It can promote mould growth, degradation of surface materials and a decrease of the indoor air quality.

*<u>Criteria</u>: pollutants emission, hazardous substances, humidity and thermal inertia*

→ **End of life / elimination:** some materials are reusable, some may be used in a new cycle of production, while others are destined to be incinerated or landfilled. The ability of a material to be recycled or treated is not enough: the recycling or the treatment must really exist and perform (market demand). The lifespan of material is also important to assess the number of replacements needed on the buildings lifespan.

*<u>Criteria</u>: type of treatment/elimination, existing treatment processes, material lifespan*

### Data collection and collaboration with manufacturers

Unlike other European countries, Belgium does not have database related to the environmental impact of construction materials. Considering the difficulty of obtaining complete and valid data for all insulation products, the authors have used several databases [9 to 16]. These databases have been established by independent organizations and are based on life cycle analysis.

To assess the health impact, the authors have considered the "hazard phrases (EUHxxx)" of each of the components present in the insulation material, according to the Regulation CLP on the classification, labelling and packaging of substances and mixtures but also precautions according to the risks incurred by workers during the implementation. These are indicated in precautionary statements issued by manufacturers of substances, according to the Regulation CLP.

Moreover, the authors developed a direct cooperation with manufacturers of insulation materials. The aim was firstly to collect data on materials, secondly to initiate a substantive debate on the topic of natural insulation. An online questionnaire was implemented in December 2010. Manufacturers were invited to complete it in order to make available the necessary data. This approach has been well received by most manufacturers, but only a few gave complete information.

### Systems boundaries

Due to the lack of relevant data, some insulation materials such as straw, reeds, duck feathers and seashells were not included in the study.

Due to the time allotted to this study, the authors have voluntarily limited the quantitative criteria of environmental impact to a "cradle to gate" scheme taking into account only embodied energy, Global Warming Potential, Acidification Potential and Photochemical Ozone Creation Potential. Other criteria are more qualitative, except the availability of resources, moisture behaviour and thermal inertia of insulation material. In the assessment model, the authors have also considered others certifications or environmental labels such as Natureplus, FSC, PEFC, Der Blaue Engel, Öko Plus AG.

### Performance evaluation and weighting

With the objective of defining insulation material as “natural” or not following the previously detailed definition, the evaluation of criteria needs to be done, in a quantitative manner, on the five steps of life cycle. To compare the criteria that are expressed with completely different units, the authors developed a weighting system that is divided into three levels: first, each criterium is evaluated individually, then the criteria of a single stage are weighted, and finally the five phases of the life cycle are weighted together. For the individual evaluation (according to each criterium), the authors have proposed to work with a scale of 1 to 5. This choice of weighting makes the definition of categories sufficiently accurate but also simple to understand:

| Weighting | Qualitative criteria | **Quantitative criteria:** the limit values between levels (X1, X2…) are determined by dividing the difference between worst and best value on the market. |
|---|---|---|
| **1** | Very bad | from [**worst value** on market] to X1 [unit]; |
| **2** | Bad | from X1 to X2 [unit]; |
| **3** | Average/ neutral | from X2 to X3 [unit] –including **average value**; |
| **4** | Good | from X3 to X4 [unit]; |
| **5** | Very good | from X4 to [**best value** on market] [unit]. |

*Table 1: Weighting system for each criterium*

## RESULTS

The authors have worked on a baseline scenario and five specific scenarios, each testing a different version of “natural insulation material” definition : (0) Baseline scenario, (1) “Main raw material” Scenario, (2) “Additional raw material” Scenario, (3) “Environmental impact on the all life cycle” Scenario, (4) “Insulation material close to nature” Scenario, and (5) “Production with a low environmental impact” Scenario. A last scenario was defined to quantify the impact on health. Due to the lack of available data and information - the classification and labeling of chemicals being done on voluntary basis until December 2010 - the authors chose not to include it in the study.

The scenarios were tested using an excel tool and a list of 39 generic materials. Most of insulation materials were analysed in various forms or products: rigid or semi-rigid panels, mattress or roll and in bulk. The list was compiled based on manufacturer’s technical information and on the reference [1] for the following values: embodied energy, NRE, GWP, AP and POCP.

For all scenarios, the authors have proposed to consider the score of 3.5 as the minimum to achieve in order that insulation material could be regarded as “natural”. A score of 3 corresponds to a neutral result (average value), but a score higher than 3.5 seems too severe. It is clear that this threshold should be chosen according to the accuracy with which the values obtained by insulation materials have been determined.

| WEIGHTING FACTORS | Scen (0) | Scen (1) | Scen (2) | Scen (3) | Scen (4) | Scen (5) |
|---|---|---|---|---|---|---|
| **RESOURCES** | | | | | | |
| MAIN RAW MATERIAL | **1** | **1** | **0** | **1** | **1** | **0** |
| Nature of resource | 0 | 0 | 0 | 0 | 1 | 0 |
| Resource availability | 1 | 1 | 1 | 1 | 0 | 1 |
| Impact on environment | 1 | 1 | 1 | 1 | 0 | 1 |
| Natural resistance | 1 | 1 | 1 | 1 | 0 | 1 |
| Geographical origin | 1 | 1 | 1 | 1 | 0 | 1 |
| ADDITIONAL RAW MATERIAL | **1** | **0** | **1** | **1** | **1** | **0** |
| Nature of resource | 0 | 0 | 0 | 0 | 1 | 0 |
| Resource availability | 1 | 1 | 1 | 1 | 0 | 1 |
| Impact on environment | 1 | 1 | 1 | 1 | 0 | 1 |
| **PRODUCTION PROCESS** | **1** | **0** | **0** | **1** | **1** | **1** |
| Nbr of transformation places | 0 | 0 | 0 | 0 | 0 | 0 |
| Transportation | 1 | 1 | 1 | 1 | 0 | 0 |
| Production process | 1 | 1 | 1 | 1 | 1 | 0 |
| Embodied energy (total) | 1 | 1 | 1 | 1 | 0 | 1 |
| %NRE | 1 | 1 | 1 | 1 | 0 | 1 |
| GWP | 1 | 1 | 1 | 1 | 0 | 1 |
| AP | 1 | 1 | 1 | 1 | 0 | 1 |
| PCOP | 1 | 1 | 1 | 1 | 0 | 1 |
| **IMPLEMENTATION** | **1** | **0** | **0** | **1** | **1** | **0** |
| Reversibility of assembly | 1 | 1 | 1 | 1 | 1 | 1 |
| Toxicity of additive | 0 | 0 | 0 | 0 | 0 | 0 |
| Protection required | 1 | 1 | 1 | 0 | 0 | 1 |
| **LIFE (USE) IN BUILDING** | **1** | **0** | **1** | **0** | **0** | **0** |
| Oral toxicity | 1 | 1 | 1 | 1 | 1 | 1 |
| Ocular toxicity | 1 | 1 | 1 | 1 | 1 | 1 |
| Dermal toxicity | 1 | 1 | 1 | 1 | 1 | 1 |
| Respiratory toxicity | 1 | 1 | 1 | 1 | 1 | 1 |
| Specific organ toxicity | 1 | 1 | 1 | 1 | 1 | 1 |
| **END OF LIFE** | **1** | **0** | **0** | **1** | **1** | **0** |
| Possible treatment | 1 | 1 | 1 | 1 | 1 | 1 |
| Existing treatment system | 0 | 0 | 0 | 0 | 0 | 0 |
| Lifespan | 0 | 0 | 0 | 0 | 0 | 0 |
| **MIN. to be considered as "natural"** | **3,5** | **3,5** | **3,5** | **3,5** | **3,5** | **3,5** |
| **Nbr of accepted products (tot 39)** | **29** | **26** | **29** | **32** | **24** | **20** |
| | **74%** | **67%** | **74%** | **82%** | **62%** | **51%** |

| | |
|---|---|
| hemp with polyester (mattress) | 1 |
| hemp with starch (mattress) | 2 |
| hemp in bulk | 3 |
| flax with polyester (mattress) | 4 |
| flax with starch (mattress) | 5 |
| coconut with polyester | 6 |
| coconut with natural latex | 7 |
| wood fibers - wet process | 8 |
| wood fibers - dry process - polyester | 9 |
| wood fibers - dry process - parafin | 10 |
| wood fibers in bulk | 11 |
| cork - panel | 12 |
| cork in bulk | 13 |
| sheep wool with polyester | 14 |
| sheep wool with starch | 15 |
| sheep wool in bulk | 16 |
| cellulose - panel with polyester | 17 |
| cellulose - panel with polyester 2 | 18 |
| cellulose in bulk | 19 |
| rock wool 200kg/m³ | 20 |
| rock wool 20kg/m³ | 21 |
| rock wool without formaldehyde | 22 |
| glass wool | 23 |
| glass wool | 24 |
| glass wool | 25 |
| cellular glass - panel | 26 |
| cellular glass in bulk | 27 |
| cellular glass in bulk, recycled glass | 28 |
| expanded clay in bulk | 29 |
| perlite - panel | 30 |
| perlite in bulk | 31 |
| vermiculite - panel | 32 |
| vermuculite in bulk | 33 |
| expanded polystyrene | 34 |
| extruded polystyrene | 35 |
| polyurethane | 36 |
| expanded polystyrene | 37 |
| extruded polystyrene | 38 |
| polyurethane | 39 |

*Figure 1: Various scenarios, weighting factors and insulation materials analysed*

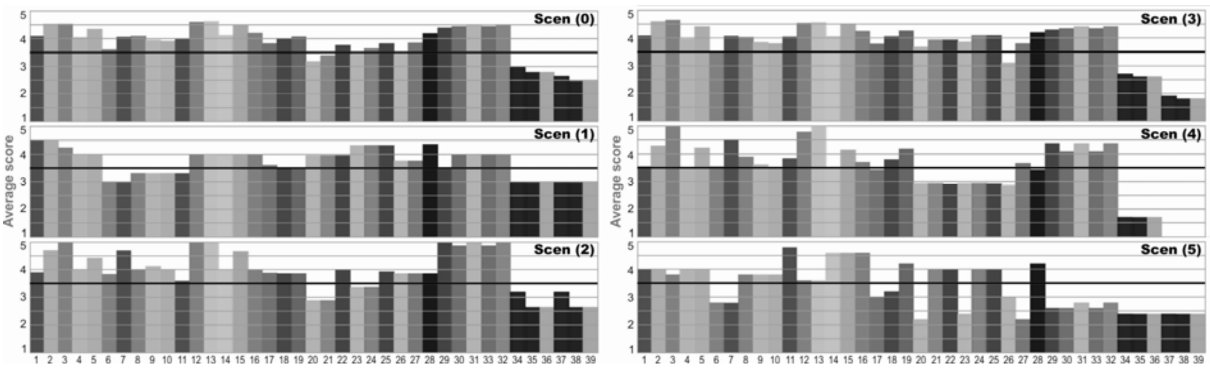


*Figure 2: Results obtained by all insulation materials according to each scenario*

## DISCUSSION

Considering the 6 scenarios as a whole defining the “natural” character of a insulation material, some conclusions can be drawn:

- Generally speaking, insulation material “in bulk”, based on plant, animal or mineral achieve good results (n°3,11,16,19, 27, 31);
- Synthetic insulation (n° 34 to 39) materials cannot be considered "natural" because they get a result between around 1.5 and 3 for all the scenario;
- Mineral-based insulation materials, that have not undergone chemical processing, such as expanded clay, perlite or vermiculite get a very good score (> 4) for all the scenario except the scenario 5;
- Results for mineral wool (n°20 to 25) fluctuate around 3.5 depending on the scenario. Generally wool without formaldehyde obtain higher scores;
- Insulation materials based on plant, animal and/or recycled fibers get higher scores (> 4) for all scenarios except the coconut fibers materials

The results obtained by the 39 analysed insulation materials show that it is insufficient to provide a subsidy for insulation based exclusively on the composition of the insulation material. For example, according to the definition of the Walloon Decree, insulation material like perlite or vermiculite is rejected. According to the new accurate definition, it is accepted. Integration of environmental and health impact in the material assessment, throughout the whole life cycle, is essential to ensure a sustainable renewal and improvement of the housing stock in Wallonia.

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