A Comparative Life Cycle Assessment of Building Insulation Products made of Stone Wool, Paper Wool and Flax

Part 1: Background, Goal and Scope, Life Cycle Inventory, Impact Assessment and Interpretation

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Preamble. Insulation of buildings is an important technology for saving heating energy and for a sustainable development. The results of a comparative LCA study of three insulation products applied for roof insulation are summarised in two parts. The products selected are based on HT stone wool representing traditional products - flax representing crop grown products and paper wool representing recycled products, respectively. Although the three materials have vastly different life cycles, they yet fulfill the same function; the methodology used should be of general interest.

Part 1 of the paper contains the project background, the goal and scope definition and three life cycle assessments for the three individual products, with a detailed inventory analysis, impact assessment, sensitivity analysis and interpretation. The actual comparison of the results from the three individual life cycle assessments is presented in Part 2. An attempt is made to answer the question of whether the biological products flax and paper wool are more environmentally preferable than the mineral product stone wool representing more traditional insulation materials.

In general, paper wool has the lowest global and regional environmental impacts, and flax insulation the highest, with stone wool falling in between. A notable exception is the total energy use, where stone wool has the lowest consumption followed by cellulose and flax. The study also addresses occupational health issues using an approach similar to that for risk assessment. Here, the less biopersistent HT stone wool products are seen to be the safest alternatives, because of a low potential for exposure, sufficient animal testing, and the obvious absence of carcinogenic properties.

It must be recognised that insulation of buildings saves more than 100 times the environmental impacts associated with the production and disposal of the products used for insulation. Compared to that and the inherent uncertainties in the LCA, the differences between the investigated products are of minor environmental significance. Therefore, the main conclusion demonstrated in the study is that the quality and fitness of an insulation product is the most important aspect in the life cycle of insulation materials.

Abstract

Insulation of buildings in order to save heating energy is an important technology for enabling sustainable development. This paper summarises the results of a comparative LCA study according to ISO 14040 standard series of HT stone wool, flax representing crop grown products and paper wool representing recycled products applied for roof insulation. As the three materials have vastly different lifecycles, yet fulfill the same function cycles, the methodology used should be of general interest. Part 1 consists of the project background, goal and scope definition, a detailed life cycle inventory analysis with sensitivity analysis, impact assessment and interpretation. The actual comparison of the results from the life cycle assessments of the three products, in which an attempt is made to answer the question of whether the biological products flax and paper wool are more environmentally preferable than the mineral product stone wool representing more traditional insulation materials, is discussed in Part 2.

Keywords: Building insulation; case study; flax; goal and scope; LCA; LCI; paper wool; stone wool

1 Background

Insulation of buildings is a major sustainable technology to save heating energy and thereby contributing to conservation of energy resources and lowering of associated burdens of air pollution from the combustion of fossil fuels.

In 1995-96, an average household in the EU used about 50,000 MJ for heating purposes, corresponding to about 68% of the total energy consumption in the households, and 40% of the total energy consumption in EU. Portuguese households have the lowest consumption for heating purposes (10,000 MJ or 29% of total), while Luxembourg has the highest consumption (122,000 MJ or 73% of total). In countries like Belgium, Germany and Austria, more than 75% of the energy consumption in households is used for heating purposes [1].

For many years, a few materials have dominated the European market for insulation products, with the majority of the market covered by mineral wool (glass wool and stone wool). Polymer-based materials like expanded polystyrene (EPS), extruded polystyrene (XPS) and polyurethane (PUR) have also been used and, during the recent years, a number of 'new' materials have emerged on the market.
It is difficult to obtain a precise overview of the total European market as well as the individual shares of the materials. The West European market is characterised by a larger mineral wool market share in the north, whereas plastic foam insulation has a higher market share in the south. The Western Europe building insulation market in 1994 of a value of approximately 3.3 billion euros has been estimated to [2]:

- Mineral wool: Glass 27%
- Mineral wool: Stone 30%
- Foam plastics 40%
- Other materials 3%

2 Introduction

Many people believe that the emerging insulation products based on biological resources (cellulose), such as flax and paper wool, are much more environmentally friendly than a product based on natural mineral resources such as stone wool. This belief may, however, be unfounded. For a proper judgement it is necessary to compare the products and their impacts over the full life cycle. In two parts, this paper summarises the results of a comparative life cycle assessment (LCA) for the following three insulation products for attics:

- HT Stone wool insulation product based on natural minerals and recycled post-production waste materials. Binder and impregnation oil are added to achieve requested and desired technical properties.
- Flax insulation product based on flax grown in Europe. Polyester, diammonium hydrogen phosphate and borax are added to achieve the requested and desired technical properties.
- Paper wool insulation product based on shredded newsprint paper. Aluminium hydroxide, borax and/or boric acid are added to achieve the requested and desired technical properties.

The full study will be printed and be publicly available on the website: www.dk-teknik.dk.

A number of LCA-studies of insulation products have already been performed. The best-known ones are probably the documents with a life cycle screening of the environmental impacts as a basis for development of eco-label criteria for the European eco-labelling scheme [3,4]. These reports are, however, of varying quality for the single materials, simply because the information necessary to produce a consistent overview of good quality was not available at the time of the study.

Many producers have established life cycle assessments for their own products, often relating to a specific application. Although the studies are more recent than the eco-labelling studies, they still use basic information of relatively old age. For example, the first BUWAL-studies from 1991 are a key source of information in many reports. Some of these studies were not published in open literature and do not reflect the progress in LCA-methodology that has been achieved since the publication of the ISO 14040 standard series (ISO 14040–14043).

It is concluded from the survey of the available literature, that only a small part is relevant for a discussion of the findings in the present study. In practice, the most relevant report was an (unpublished) LCA of stone wool conducted by Rockwool Limited, U.K., in 1998 using a LCA method and data that fulfil the requirements in the ISO 14040 standard series to a very large extent [5]. The results published in that report have been compared with those from the present study, which is primarily based on Danish production of stone wool with a slightly different production process, thereby giving an indication of the representativity of either study. For flax and paper wool insulation, a Danish report from the Building Research Institute was used to focus the data collection and data treatment [6]. However, the documentation and presentation of the results in the Danish report are different and do not give sufficient opportunity for a proper comparison between the results.

3 Goal and Scope Definition

The objective of the LCA is a cradle to grave assessment of three products used for insulation of a roof taking into consideration their very different life cycles by using the best available data on the European level. The products are based on the three materials stone wool, flax and paper wool, respectively. The study aimed for compliance with the ISO 14040 series of LCA standards.

3.1 Fitness for use

The main purpose of insulation materials is to decrease the heat loss from buildings and save energy and costs. During the lifetime of a building the energy savings will be considerable and far higher than the energy consumption during the production of the material. The three insulation materials studied are fit for use but they have different basic properties, and in the practical application in the building the durability and performance during building life may also be different. Some important characteristics are as follows:

- The insulation material must fit and fill out the construction spaces without air gaps, and ideally, it should remain unchanged in all three dimensions during the building lifetime.
- The material must be stable to moisture and resistant to biological attack.
- The fire properties of insulation materials are vital. The classification and labelling in the present Danish building regulations are:
  - Stone wool with label 'A1' and 'A2' (non-combustible),
  - Paper wool with expected label 'B-E' depending on amount, type and content of flame retardant,
  - Flax with expected label 'C-E' depending on amount, type and content of flame retardant.

3.2 Functional unit

The functional unit is defined in the ISO 14040 standard as 'the quantified performance of a product system for use as a reference unit in a life cycle assessment study'. With respect to thermal insulation products, the thermal resistance $R_t$ measured in m$^2$K/W, has been generally accepted as a mean-