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ScienceDirect
Energy and Buildings 40 (2008) 1–10
ENERGY and BUILDINGS
www.elsevier.com/locate/enbuild

Building energy performance: A LCA case study of kenaf-fibres insulation board

Fulvio Ardente, Marco Beccali, Maurizio Cellura, Marina Mistretta *

Dipartimento di Ricerche Energetiche e Ambientali, Università di Palermo, Viale delle Scienze, 90128 Palermo, Italy

Received 11 April 2006; received in revised form 7 July 2006; accepted 15 December 2006

Abstract

The paper presents a life cycle assessment of a kenaf-fibre insulation board following the international standards of the ISO 14040 series. Each life-cycle step has been checked, from kenaf production and board manufacture by an Italian firm, to use and disposal.

The aim is to assess the board eco-profile and to compare, on the basis of a life-cycle approach, the energy and environmental benefits and drawbacks related to its employment into a typical residential dwelling. A comparison among various insulating materials has been carried out.

The study focuses also on processes and input materials which cause the main environmental impacts of the product, and points out critical issues and the life-cycle steps with the highest improvement potentials.

Keywords: LCA; Bio-building materials; Sustainable building

1. Introduction

According to the 2003/87/CE Directive the EU has introduced a scheme for greenhouse gas trading in the Community. The emission trading scheme [ETS] covers about a third of the total greenhouse emissions in the UE-25, deriving from installations as combustion plants, mineral oil refining, coke ovens, iron and steel plants, cement, glass, brick, ceramics, pulp and paper [1].

The building sector, as well as the transport one, is not taken into account by the ETS, although the high energy demand and the long useful life of buildings involve a relevant share in the EU energy balance and in the CO_2 emissions scenario. In fact this sector accounts for about 40% of energy use and greenhouse gas emissions [2]. On average, one-third of energy end-use is consumed for heating, cooling, lighting, appliances and general services in residential, commercial and public buildings. In 2000, an average household in the EU used about 52,000 MJ for heating purposes, corresponding to about 77% of the total average energy consumption per household (67,450 MJ) [3].

The above figures point out the EU need to reduce the building energy consumption, both for advancing in the fulfilment of Kyoto Protocol targets and for reducing its energy dependency. Therefore, the national allocation plan (NAP), in which each member state establishes how the emission rates have to be allocated for the periods 2005–2007 and 2008–2012, should be prepared involving also the building sector. Such a NAP should agree with the Kyoto Protocol target of reduction of the greenhouse emissions and with the final goal to stabilize the air greenhouse gas concentrations at safe levels [2].

The relevant weight of the building sector in the energy balance of each UE country involves the need of regulation and market mechanisms, like the energy certification, to structure the application of energy assessment in the building sector. The Directive 2002/91/CE, in advancement of the action lines showed in the Directive 93/76/CEE for the building sector, establishes a general framework in which the building energy assessment should be implemented [4,5]. The EU member states have to establish minimum energy performance standards and energy certification schemes that allow to drive the building sector to higher energy performance levels, promoting measures of energy efficiency (bioclimatic architecture standards, passive heating and cooling, renewable sources integration, etc.).

* Corresponding author. Tel.: + 39 91 236139; fax: +39 91 484425.
E-mail address: mistretta@dream.unipa.it (M. Mistretta).

0378-7788/$ – see front matter
doi:10.1016/j.enbuild.2006.12.009

2. The relevance of thermal insulation in the building energy performance

Currently, the total energy consumption of an average Italian household is about 78,219 MJ/year, of which the 80% (62,575 MJ/year) is used for heating and the remaining 20% is used for lighting and appliances, hot water supply, and cooking [6]. In such a context, an appropriate planning for building energy saving should need rational criteria of energy assessment to quantify energy consumption during design, construction and operating time, and suitable strategies and measures to increase building energy performance, such as the reduction of fossil fuels consumption, the growth of renewable energy use, and the energy-efficient conversion [7].

The use of thermal insulation materials in building walls and roofs is the most relevant tool to improve energy performance, reducing the resources consumption and the associated environmental burdens arising from the combustion of fossil fuels. Furthermore, the use of thermal insulation materials reduces the heat losses from buildings, involving considerable energy and cost savings for air conditioning and heating during the building lifetime [8].

The European market of insulation materials is still dominated by two groups of products, which are classified according to their chemical or physical structure [9]:

- mineral or inorganic fibrous materials, namely glass wool and stone wool, which account for 60% of the market;
- organic foamy materials, like expanded polystyrene (EPS), extruded polystyrene (XPS) and the less widespread polyurethane (PUR), which account for about 30% of the market;
- other materials, as combined materials (wood-wool, gypsum-foam) and new technology materials (transparent and dynamic materials), which account for about 10% [10].

Inorganic fibrous materials are expected to play the main role in the next decade, with a production growth of more than 5%, whilst the organic foams will probably have a lower production growth [11].

In spite of that, innovative insulation products have recently emerged on the market. They are based on biological resources and therefore are called biomaterials.

3. Biomaterials requirements in sustainable buildings

Each building product involves environmental impacts in its life-cycle, due to the resources consumption and pollutant releases during the resources extraction, the product manufacturing and use, and the products' end-of-life (collection/sorting, reuse, recycling, and waste disposal) [12].

The use of building biomaterials involves the following environmental benefits during the whole life-cycle [13,14]:

- reduction of resource consumption;
- energy saving and less environmental impacts;
- recovery, re-use and recycling of the products before the final disposal.

There is an increasing interest in using agricultural fibres for building components, either to complement or replace wood, in combination with wood fibres or other materials.

Such interest, associated to the political engagement to control CO_2 emissions, can help the spread of biomass crops in the next years.

In the following it is showed the eco-profile of a thermo-insulating board based on a biomaterial, called "kenaf-fibre".

4. Case study: kenaf-fibre board

4.1. Goal and scope definition

The main goal of the study is to define the energy and environmental profile of an insulation product based on a natural fibre composite material. The analysis is carried out according to the Life Cycle Assessment (LCA) standards of the series ISO 14040 [15–18].

4.2. Kenaf properties

The assessed product is a fibre reinforced composite made by kenaf vegetable fibres which are incorporated in a polyester matrix. Kenaf (*Hibiscus cannabinus*) is a herbaceous annual plant that grows very quickly under a wide range of weather condition. It grows more than 3 m in 3 months even in moderate ambient conditions [19]. Kenaf is cultivated in Italy and other Mediterranean countries and mainly used in the thermal insulation field and in the pulp production.

Kenaf has been actively cultivated in recent years essentially for the following reasons [20]:

- it needs few treatments during the growth as, for example, low quantities of chemical fertilizers;
- kenaf absorbs CO_2 at a significantly high rate.

Kenaf exhibits low density, non-abrasiveness during processing, high specific mechanical properties, and biodegradability. Recently, kenaf has been used as a raw material alternative to the wood in pulp and paper industries, and in the textile industry [21].

Thermal conductivity and resistance are distinctive properties of an insulating board since they relate to the heat flow through a composite board. Thermal conductivity should remain unvaried in the board lifetime. However, it could increase depending on moisture and chemical and physical deterioration of the material. Therefore, the following basic properties are relevant in the insulation materials lifetime:

- durability, since the material must be stable to moisture and resistant to biological attack;
- ignition behaviour [22].

4.3. Functional unit

According to the ISO 14040 standard the functional unit (f.u.) is defined as the reference unit through which a system performance is quantified in a LCA.