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An assessment tool for the energy, economic and environmental evaluation of thermal insulation solutions

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ABSTRACT

The paper discusses an assessment tool, used for the energy, economic and environmental evaluation of Thermal Insulation Solutions (TIS). The results of the assessment undertaken with this tool can take the form of a simple rating system in order to enable users to perform comprehensive comparisons amongst various building materials and TIS. A ranking expressed by A, B and C classes is used for energy, environmental and economic parameters. By evaluating the materials, the tool supports the users to make decisions, depending on preferences or priorities such as the energy efficiency achieved, the total cost and the environmental performance. The assessment tool is applied for the double cavity wall and the External Thermal Insulation Composite Systems (ETICS) as they are used throughout Europe, both in new constructions and in the renovation of existing buildings.

1. Introduction

Sustainability is increasingly becoming an issue of importance and practical significance for the construction sector, as the environmental concern related to buildings is rising amongst the public and, in that sense, also amongst prospective buyers of buildings. At the same time, from a methodological point of view, the scope of environmental evaluation is widening, marking an evolution from a single criterion consideration, like the energy performance of buildings, towards a full integration of all aspects emerging during the lifetime of a building and its elements. Many of the parameters to be considered are intrinsically linked to the life quality which determines the inhabitants' physical health, productivity and emotional wellbeing. It becomes therefore clear, that "Sustainable Buildings" is a broad, multi-criteria subject related to three basic interlinked parameters:

- economics, as a building stands for an entire economic and productive branch;
- environmental issues, both direct ones, as those caused by land use, construction processes, demolition and waste management, and indirect or discreet ones, like those resulting from mining, materials' supply and transportation;
- social parameters based on human's need for comfort and "good living", which leads to the acceptance of some building solutions and the rejection of others.

The tool discussed in this paper aims at the examination of those parameters and the determination of the energy, environmental and economic efficiency of the most common building materials and TIS, taking the Greek sector as an example.

2. Energy, economic and environmental figures of the European building sector

There were some 196 million dwellings in EU27 in 2006, about 80% of which are concentrated in five counties: 18.6% in Germany, 13.8% in Italy, 10.8% in Spain, 6.5% in Poland and 3.5% in the Netherlands. The core business of construction activities is the residential sector, with a turnover of 642 millions € in 2005, which is nearly half (47.7%) of the total construction output, that reached 1,308 millions €. The worth of new residential constructions reached 322 millions € outpacing slightly that of renovation (302 millions €).

Still, the volume of renovation activities is significant. It accounts for 36% of the building sector's turnover, with 23.1% being allotted to residential buildings and 13.2% to commercial and office buildings. The smallest sub-sector, that of civil engineering and infrastructure projects, accounts for 276 millions € and a respective share of 21% [1].

Overall the construction market in Europe increased on average by 1.7% annually between 1996 and 2000, compared to an average annual growth in GDP of 2.6%. Thus GDP growth has on average exceeded construction output growth by almost 1 percentage point. However, growth in the European construction branch had begun to slow down, even before the 2008 financial crisis, as the

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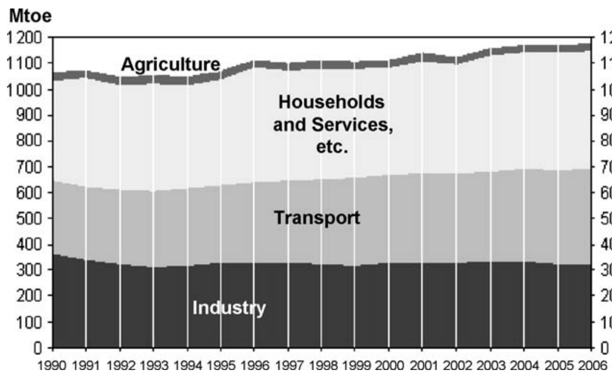

Fig. 1. Final energy consumption, EU27, 2005 [3].

increase rate of new residential constructions in 2005 was +0.7% compared to +4.4% in 2004 [2].

Considering the aggregate electrical and thermal energy consumption, buildings in Europe account for one third of the total energy related CO_2 emissions [3,4], a figure that is higher for some countries, depending on the electrical energy production and final energy sources used. In 2005 the final energy consumption in the EU-27 member states reached 1,168 Mtoe or 2.04 toe per capita [5,6] [Fig. 1].

Given the long life-span of buildings, as they present a lifetime between 50 and more than 100 years, and the high number of existing buildings, it is clear that the largest potential for improving the energy performance lies in the existing building stock. About 70% of the residential buildings are over 30 years old and about 35% are more than 50 years old [7,8]. This is a very important fact, with respect to the existence and efficiency of thermal insulation of the buildings' envelopes, as the first legislative measures were introduced in the 1970s following the first energy crisis. Furthermore, it affects the efficiency of boilers and air conditioning systems which are becoming rapidly obsolete. This explains the emphasis given on renovation and upgrading of the existing building stock, which is becoming a priority for most European countries.

3. Methodology adopted for the assessment tool

For the assessment's tool development the basic concept adopted was the Life Cycle Thinking Concept and the main tool used to support this concept is the Life Cycle Analysis (LCA) methodology.

The importance of environment-related product information by means of LCA is in that sense broadly recognized and LCA is considered to be one of the tools to help achieving sustainable building practices. LCA offers a comprehensive analysis which links actions with environmental impacts. At the same time it provides quantitative and qualitative results and taking into consideration the link between system's functions and environmental impacts it is easy to identify the issues that need improvement [9].

Within the LCA framework, the following phases are examined:

- Inventory analysis: this stage deals with the input and output flows of all the procedures concerning the most common building's materials. The inputs and outputs flows contain data of materials and energy consumption.
- Impact assessment: at this phase the environmental load calculated from the inventory analysis is transformed into environmental impacts. The environmental impacts categories' examined include: climate change, acidification, eutrophication and photochemical oxidation.
- Use and application of results: at this phase and after having analysed the system, the crucial points are identified in order to focus on the procedures which need to be improved.
- Relation to other tools: the assessment tool created can be used in relation with management and environmental, systems and standards towards building certification.

Based on the methodology described above several tools have been developed in order to support the LCA methodology implementation on building materials, elements and systems, as well as on the building as a whole. Based on the extent of the systems' analysis and the ultimate goal of the study three evaluation levels have been formed.

The first evaluation level focuses on LCA implementation to materials in order to compare different products based on environmental criteria. Tools that form this category are Gabi, SimaPro, TEAM, etc. The second evaluation level consists of decision making support tools for the building as a whole, like Envest, Athena, Lisa, etc. Finally, the third evaluation level consists of methodologies such as BREEAM, LEED, etc. which are tools for the building's assessment.

4. Assessment tool's implementation on building materials and thermal insulation solutions

The assessment tool developed is an integrated evaluation model for building materials and is based on data derived mainly from the Greek building industry. Moreover, it constitutes a useful and practical decision making tool as it measures environmental, energy and economic performance on three major levels: building materials, TIS and building as a whole. In Fig. 2 are depicted the three evaluation levels included in the assessment tool.

4.1. First evaluation level—building materials

The first evaluation level concerns the building materials' integrated evaluation. Within this framework an extended database of the most common building materials used in Greek construction practice was developed. The database contains information about the following parameters:

- thermal and physical properties such as density, thermal conductivity, specific heat
- emissions from production, transportation and installation procedures such as CO_2 equivalent, SO_2 equivalent, PO_4 equivalent, C_2H_4 equivalent
- environmental impacts like climate change, acidification, eutrophication, and photochemical oxidation
- embodied energy
- cost

Data for thermal and physical properties were derived from Papadopoulos [10].

Necessary input data, namely raw materials and energy flows, were acquired through an extensive survey with the participation of major Greek building materials manufacturers. For the output data, namely emissions from production, transportation and installation at the inventory phase, the SimaPro LCA software was used, which is a life-cycle analysis model with embodied EcoInvent LCA database and cost–emission analysis system [11]. Cost of supply and installation of building materials is based on current market prices.

At the environmental impact assessment phase (normalization and weighting) two set of indicators were used, one derived from CML 2 baseline 2000 method [12] and the other from Eco Indicator 95 method [13].