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Life cycle analysis in refurbishment of the buildings as intervention practices in energy saving

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ABSTRACT

This paper presents the energy savings in refurbishment of the buildings using Life Cycle Assessment at material level by comparing three insulation materials that offer higher thermal performance and greater environmental sustainability. The comparison is made on products having the same insulation performance (*U*-value). After the enumeration of intervention practices for energy saving in buildings, the Life Cycle Assessment methodology in refurbishment of the buildings is applied at material level using Life Cycle Inventory to transform material volume input into impact on the environment as output. The Life Cycle Assessment (LCA) was carried out according to the requirements of the Environmental Product Declaration (EPD). After assessing the building performance before and after isolation, the "embodied energy", which comes from the materials manufacturing as phases of the refurbishment of the buildings, was determinate and compared with the operational energy of the building.

This LCA methodology in refurbishment of the buildings at material level was evaluated for Expanded Polystyrene (EPS), Extruded Polystyrene (XPS) and Rigid polyurethane (PUR) insulation products. This methodology has been used on a building in Galati, Romania (School No. 9). A spider diagram was used to represent the criteria in a consistent, graphical way in relative units. The extreme values for a given criteria indicate the poor performance of the insulation material.

Finally, the assessment of the building performance before and after using the insulation and the determination of the "embodied energy" compared to the operational energy of the building resulted in a 55% energy saving in the use stage of the building after refurbishment.

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1. Introduction

The refurbishment of buildings begins by choosing energy efficiency measures (EEM). The evaluation and prioritization of EEM depends on the chosen criteria. The most commonly used criterion is economical evaluation (money or cost). For assessing energy saving measures using only economic criteria it is necessary to define three attributes: pay-back period, net present value (NPV) and internal rate of return (IRR). These attributes of the economic criteria are most popular [1]; the list of economic criteria is extended payback period evaluating depreciation of the building and ratio of savings and investment [2].

Another criteria for evaluation of EEM is energy efficiency and energy saving. It is related to the economic criteria, because without the energy savings there will be no financial benefit of implementation of EEM. The energy efficiency criteria often are used together with criteria of environmental impact. Environmental and energy efficiency criteria are usually met within a life cycle analysis (LCA) [3,4]. The LCA evaluation together with energy efficiency enables the analysis of the EEM related to energy savings.

Energy efficiency has a major role to play in economically, environmentally and socially sustainable energy policies. Energy savings are among the fastest, highest impacting and most cost-effective ways of reducing greenhouse gases (GHG) emissions. Over the years, the European Union has introduced a number of directives, regulations and initiatives to encourage and support Member States, regional authorities, individuals and other interested parties to increase energy efficiency in different sectors, including buildings, transport and products. The span of policies has yet to change our combined thinking, capacity and ambition to capture significant savings. Although everyone agrees with the importance of saving energy, it has enjoyed little high level political attention. As such we are a long way from achieving the indicative 20% energy savings target by 2020. From the European Union's point of view, the energy efficiency directive (EED) [5] is a part of a

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Nomenclature

LCA	life cycle assessment
EPS	expanded polystyrene
XPS	extruded polystyrene
PUR	rigid polyurethane
EEM	energy efficiency measures
GHG	green house gases
EPD	environmental product declaration
U-value [W/m^2 K]	thermal transmittance
R-value [m^2 K/W]	thermal resistance
UA_{ref} [W/°K]	heat loss coefficient
λ	thermal conductivity of the material
HDD	heating degree day
CDD	cooling degree day
GWP	global warming potential
AP	acidification potential
EP	eutrification potential
POCP	photochemical ozone creation potential
AEE	annualized embodied energy
AEU	annual energy use

comprehensive set of legislation which also comprises efficiency in buildings (EPBD Directive) [6], efficiency in products (appliances, lighting, ICT, motors), energy labeling, eco-design, energy start [7], all serving the purpose of implementing the Energy Efficiency Plan 2011 [8]. Moreover, since the Commission in its communications affirmed that the Union is not on track with its targets, there was a need to update the legal framework for energy efficiency.

Therefore, the scope of the energy efficiency directive (EED) is to carry on the "overall objective of the energy efficiency target of saving 20% of the Union's primary energy consumption by 2020" (Preamble, point 10) by establishing a "common framework of measures for the promotion of energy efficiency within the Union"(Article 1, Para. 1). Moreover, the Directive "lays down rules designed to remove barriers in the energy market and overcome market failures" (Article 1, Para. 1). It addresses security of supply by reducing the primary energy consumption through energy efficiency, which also contributes to the reduction of greenhouse gas emission addressing sustainability and ultimately, by removing market barrier it addresses the competitiveness in the internal market.

The energy performance of buildings directive (EPBD) focuses on energy efficiency in buildings as they "account for 40% of total energy consumption in the Union" and growing. Therefore they must have a share too in reducing both the energy imports and GHG emissions. The EPBD Directive is meant to promote and improve the energy performances of buildings, as defined by Article 2 (4), "within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness". To this end, an energy performance certificate (EPC), as defined by Article 2 (12) is issued, allowing the "owners or tenants of the building or building unit to compare and assess its energy performance" when "offered for sale or for rent". To translate into practice the provisions of this Directive, EN standard [9] states that "the energy performance of a building" is represented by an overall indicator energy performance (EP). A standard calculated energy indicator requires the collection of data on the building (insulation, heating system, etc.), which will be useful for giving advice on the improvement of its energy performance. The overall indicator is related to the total floor area "A" in order to facilitate the comparison of the energy performance between buildings. The type of dimensions used to calculate "A" is not standardized yet because there are many different conventions in the member states. Therefore internal dimensions, external dimensions and overall internal dimensions may still be used. In addition, the EN standard indicates that the energy performance certificate may contain energy classes. The performance scale shall range from "A" (buildings of highest energy performance) to "G" (buildings of lowest energy performance).

2. The energy saving of buildings

Different terms are used, often with little precision or accuracy, to express targets in the area of energy efficiency policy. The definitions provided in the energy efficiency directive try to establish a clear relation between 'energy savings' and 'energy efficiency'. The following definitions from Article 2 of the EED are worth recalling as they are relevant:

'*Energy efficiency'* expresses the ratio of output of performance, service, goods or energy to input of energy (Article 2.4).

'*Energy savings'* means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency improvement measure, whilst ensuring normalization for external conditions that affect energy consumption (Article 2.5).Specifically, *energy savings are defined as the result of improvements of energy efficiency*. *Savings are measured as the difference in energy consumption before and after the efficiency improvement has taken place.* Two types of energy are given in the directive, namely:

'*Primary energy consumption'* referring to the gross inland consumption, excluding non-energy uses (Article 2.2).

'Final energy consumption' meaning all energy supplied to industry, transport, households, services and agriculture. It excludes deliveries to the energy transformation sector and the energy industries themselves (Article 2.3).

Using these definitions, for a binding energy savings target as an absolute amount of energy saved, it is necessary to be achieved principally through efficiency improvements that will result in a reduction of energy consumption compared to a baseline.

As a result, it is acknowledged that every product or process goes through various phases or stages in its life. Each stage is composed of a number of activities. For industrial products, these stages can be broadly defined as material acquisition, manufacturing, use and maintenance and end-of-life. In case of buildings, these stages are more specifically delineated as: materials manufacturing, construction, use and maintenance and end of life.

In this context, the life cycle analysis (LCA) is an instrument to check all ways of resource consumption via products as well as during the construction, use and after the use of the building (Fig. 1).

Generally in LCA, products life stages are discriminated into before-use stages (Table 1) comprising the raw material acquisition, transports and manufacturing, the use stage and the end-of-life stage (or after-use stage).

For buildings, the life cycle environmental impacts are often dominated by energy consumption during use phase. It has been

Fig. 1. Building life cycle stages according to the pr-EN 15643 of CEN TC 350.

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