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Embodied energy versus operational energy in a nearly zero energy building case study

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Abstract

Currently in the NZEB energy demand calculation method the Embodied Energy is not included, despite the state-of-the-art recognizes a relevant energy impact caused by raw materials extraction as well as components manufacturing, product final assembly and transportation. Aim of this study was to assess the Embodied Energy in a NZEB case study along with the Operational Energy, pointing out the importance of taking into account both these aspects since the earliest design stage.
Within the research activity here presented, for accounting the EE, a worksheet was developed and implemented with over 65 materials taken from a database carried out by the authors, in order to encourage designers to properly manage these issues.

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Keywords: Nearly Zero Energy Building; Operational Energy; Embodied Energy; Design Tool

1. Introduction

In recent years a consistent legislative framework aimed at significantly improving the energy efficiency of European building stock, i.e. the Energy Performance of Buildings Directive (EPBD) [1], the Energy Efficiency Directive (EED) [2] and the Renewable Energy Directive (RED) [3], has been set out.

Particularly relevant is the EPBD Recast stating that new buildings occupied by public authorities and properties have to be Nearly Zero Energy Buildings (NZEBs) by December 31, 2018 and that new buildings have to be NZEBs by December 31, 2020. International Standards and National Building Codes are thus required to duly take into account these goals, identifying commonly agreed definitions and methodologies to estimate the building energy analysis. Both these aspects are not yet standardized and this un-ambiguity represents one of the most important

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issue to be faced. According to the EPBD Recast a NZEB is a building that has a very high energy performance with nearly zero or very low amount of energy required to be covered - to a very significant level - by energy from renewable sources, including renewable energy produced on-site or nearby.

Usually in the NZEB calculation method the Embodied Energy (EE) is not included. Such exclusion is due magnitude recognized to Operational Energy (OE) assumed as more significant over the long term, despite the state-of-the-art recognize a certain energy impact caused by raw materials extraction as well as by energy consumptions for some building products (e.g. aluminum and steel alloys) [4-5-6].

A literature based discovery method was adopted to analyze 38 research works consisting of 206 cases. The study compares the EE with Operational Energy OE of buildings [5]. The findings reveal that most EE calculations were based on different stages of life cycles for the energy analysis in buildings. As a result the comparison was often problematic. So far the impact of EE of the construction materials is frequently ignored since the life cycle energy analysis of buildings is a complex process. Furthermore, methods and tools for calculations can vary widely and the data availability is rather partial.

On the whole, scientific literature shows the need for appropriate analysis metrics and weighting systems to properly characterize NZEB and the importance of the EE as indicator in the building energy analysis.

The aim of this study was to assess if EE is a valuable indicator that should be included in building energy analysis along with OE and if they can be both taken into account at an early design stage.

Within the research activity here presented, for accounting the EE, a worksheet was developed and implemented with over 65 materials taken from a database carried out by the authors, in order to encourage designers to properly consider these issues.

Nomenclature

BIM	Building Information Modeling
CFA	Conditioned Floor Area
EE	Embodied Energy
EEi	Initial Embodied Energy
EEr	Recurring Embodied Energy
HDD	Heating Degree Days
IFC	Industry Foundation Classes
LCA	Life Cycle Assessments
NZEB	Nearly Zero Energy Building
OE	Operational Energy
PED	Primary Energy Demand
REER	Renewable Embodied Energy Ratio
RER	Renewable Energy Ratio
UFA	Unconditioned Floor Area

2. Definitions and methodology

The EE and OE assessment here presented was carried out considering the International Energy Agency (IEA), Solar Heating & Cooling Program, Task 40, Annex 52 [7], and the IEA, Evaluation of Embodied Energy and $CO2_{eq}$ for Building Constructions, Annex 57 [8].

They provide the following definitions concerning a building throughout its life:

- Initial EE i.e. the primary energy demand required for off-site and on-site building processes including raw materials extraction, components manufacturing, products final assembly and transportation.
- Recurring EE i.e. the primary energy demand required in refurbishing and maintaining the building over its life cycle.