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Embodied energy and operational energy evaluation in tall buildings according to different typologies of façade

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Abstract

Although recent studies demonstrate the importance of including the Embodied Energy (EE) in building analysis, only the Operational Energy (OE) is currently taken into account in building energy demand calculation method.
In particular, the EE plays an important role in tall buildings evaluation, because the energy demand increases with building height. Aim of this study was to assess the Embodied Energy in evaluation of different types of tall building façade systems performances along with the Operational Energy, pointing out the importance of taking into account both these aspects.
Within the research activity here presented, 8 glazed envelope typologies, in 5 different climate zones, have been evaluated.

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Keywords: Operational Energy; Embodied Energy; Tall Building; Façade.

1. Introduction

In building energy analysis, the Embodied Energy (EE) is usually not included [1-2-3]. Such exclusion is due to magnitude recognized to Operational Energy (OE), assumed as more significant over the long term. Instead, the

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state-of-the-art recognizes a certain energy impact caused by raw materials extraction as well as by energy consumptions for some building products (i.e. aluminum and steel alloys) [4-5-6].

The findings have revealed 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 [7] the importance of the EE as indicator in the building energy analysis.

In most cases, the use of materials with high energy value, as glass and aluminum, makes the building envelope a main subsystem in global energy demand of EE. Several research studies carried out by Council on Tall Buildings and Urban Habitat (CTBUH) estimate the energy required for façade system equal to 20% of the total EE.

Nomenclature

Ucw	curtain wall thermal transmittance
EE	Embodied Energy
EEi	Initial Embodied Energy
OE	Operational Energy
NRA	Net Rentable Area
CFA	Conditioned Floor Area
UFA	Unconditioned Floor Area
GFA	Gross Floor Area
PED	Primary Energy Demand

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 [8], and the IEA, Evaluation of Embodied Energy and CO2eq for Building Constructions, Annex 57 [9].

The EE is defined as the amount of non-renewable primary energy required for the extraction of raw materials, their transformation into semi-finished and finished products (initial EE), the replacement processes (recurring EE) and the disposal processes (end-of-life EE).

The energy measures in the various stages of a products life are often related to a “cradle-to-grave” approach [4]. The importance to assess a building over its life cycle refers to the need to implement closed-loop cycles in the construction sectors. The “cradle-to-grave” approach (or, consistent with circular economy principles, the “cradle-to-cradle” approach) is recommended for a proper and full energy assessment. Although that, most of the EE databases [10-11-12] refer to manufacturing and construction stages, while recurring and end-of-life EE are generally considered negligible [13-14].

Due to the data limitations to performing the EE of products over their life cycle, in the case study herein presented, the EE has been calculated taking into account in a first phase the “cradle-to-gate” and has been assumed as the Primary Energy Demand (PED) until the product leaves the factory gate.

The values of EE have been calculated using the IREEA (Initial and Recurring Embodied Energy Assessment) worksheet tool [15]. This tool is based on the Swiss SIA 2032 [16] technical specification (Grey Energy of Buildings) and its functioning was tested by Master of Science’s students enrolled at Politecnico di Torino, Course of Sustainable Architecture. The evaluation refers only to building envelope components. A period of up to 25 years has been examined for EE calculation, considering the energy demand for building envelope maintenance as negligible. The IREEA database refers to Italian data. Such data were used for every analyzed climate zones.

The OE is defined as the annual amount of non-renewable primary energy required for use during the life of a building. OE refers to Primary Energy Demand (PED) for heating, ventilation, cooling, hot-water production and for