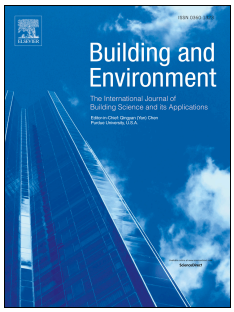
Accepted Manuscript



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PII: S0360-1323(16)30198-6

DOI: 10.1016/j.buildenv.2016.05.040

Reference: BAE 4514

To appear in: *Building and Environment*

Received Date: 6 March 2016

Revised Date: 19 May 2016

Accepted Date: 30 May 2016

Please cite this article as: Chastas P, Theodosiou T, Bikas D, Embodied energy in residential buildings-towards the nearly zero energy building: A literature review, *Building and Environment* (2016), doi: 10.1016/j.buildenv.2016.05.040.

Embodied energy in residential buildings-Towards the nearly zero energy building: A literature review

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This literature review addresses the Life Cycle Energy Analysis (LCEA) of residential buildings. As the fluctuation in the choice of functional units, boundaries of the system, life cycle inventory (LCI) methods, metrics and impact indicators complicated the potential comparability, the guidelines of Product Category Rule (PCR) 2014:02 for buildings were applied for the normalization procedure. Even though PCR provided a clear statement of the boundaries and a complete presentation of the results, uncertainty deriving from the LCI methods and the omissions in the system boundaries indicates that further standardization is needed. The sample consisted of 90 LCEA case studies of conventional, passive, low energy and nearly zero energy residential buildings (nZEB). Additional analysis identified an underestimation between case studies that use process instead of hybrid analysis, as the average value of embodied energy in hybrid analysis appears to be 3,92 times higher than in process analysis case studies. The highest value of embodied energy for a nZEB case study quantified with process analysis appears to be lower than all the input-output hybrid case studies. A revised definition, according to current trends and requirements in energy efficiency regulations, was also provided as an update of their consistency in time. Operating energy appeared to dominate in life cycle energy of residential buildings in the past. The results of this review show an increasing share of embodied energy in the transaction from conventional to passive, low energy and nZEB, despite the reduction in the total life cycle energy that could reach up to 50%. The share of embodied energy dominates, mainly in low energy and nearly zero energy buildings, with a share of 26%-57% and 74%-100% respectively. In passive buildings, the share of embodied energy varies within a range between 11% and 33% that reaches the embodied energy limits of both a conventional and a low energy building. The use of renewable energy sources (RES) in a passive house, for the production of electricity, classifies it in the range of embodied energy of a nZEB. A significant gap of 17% in the share of embodied energy, between the nearly zero and the most energy efficient building examined in the current review, is identified. This difference appears to be more important for the conventional and passive buildings, indicating the relative significance of embodied energy through time and towards the nZEB. Furthermore, if uncertainty and the underestimation of embodied energy deriving by process analysis were considered this gap could be different. The increase of embodied energy in buildings, indicates that a whole life cycle energy analysis may be needed in the methodological framework of current energy efficiency regulations.

Keywords: LCEA, residential buildings, embodied energy, nZEB, PCR, LCI