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Reducing the total life cycle energy demand of recent residential buildings in Lebanon

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A B S T R A C T

Buildings require a substantive amount of energy for their operation. Recent studies have found that indirect requirements, such as the embodied energy associated with their construction and the transport-related energy of their users can be even more significant. A complete life cycle energy analysis of buildings in a Mediterranean context has seldom been undertaken.

This paper relies on a multi-scale life cycle energy analysis framework to determine the energy use profile of recent residential buildings in Lebanon by taking into account embodied, operational and user transport energy requirements. It studies a representative case study building in Sehaileh, a suburb of the capital Beirut, over 50 years and identifies the most effective ways to reduce energy use across the different life cycle stages and scales of the built environment.

Results show that the life cycle energy demand is dominated by transport energy (49%) followed by operational (33%) and embodied (18%) requirements. The main ways to reduce this life cycle energy demand comprise relocating jobs outside of the capital, putting in place an adequate public transport network, improving town planning to favour pedestrians and rely on gas or renewable energy sources instead of electricity when possible, notably for domestic hot water.

1. Introduction

The construction and operation of buildings require significant amounts of energy and are responsible for huge environmental impacts [1]. A growing number of studies is investigating the life cycle environmental impact of buildings (often in terms of energy use only) [2,3] or neighbourhoods in order to reduce them. These studies have covered a wide geographical range including Australia [4–6], Belgium [7,8], China [9], Finland [10,11], Italy [12,13], Sweden [14,15], Switzerland and the USA [16], the UK [17] and other locations. However, there is currently no study assessing the total life cycle energy demand of buildings in Lebanon despite the unprecedented number of new construction on its soil in recent years.

Lebanon has witnessed a construction boom, notably during the 2008–2011 period of relative stability. During this time, a large number of residential buildings have been erected, notably in Mount Lebanon, a district surrounding the capital Beirut. Mount Lebanon represented on average 62% of the new residential buildings' floor area during this period [18]. According to the same source, nearly 22.5 million square metres of residential buildings have been built between 2008 and 2012, the majority being low to medium rise apartment buildings (four to eight stories). Assuming an average apartment gross floor area of 160 m^2 (based on the average apartment size in recent buildings), this equates to ~140,000 apartment units, far more than the actual need for residential units. There is therefore a mismatch between supply and local demand. Also, a substantial share of this housing stock consists of large, luxurious apartments with a price tag well above the average local residents' means. For this reason, a significant share of these apartment units is bought by Lebanese expatriates and, to a lesser extent, foreigners, especially Arab nationals. This explains why up to 50% of these apartment buildings can remain unoccupied. The construction of such a housing stock in a short period of time and the operation of the occupied units can have great environmental repercussions, notably in terms of energy use.

Most studies about the energy efficiency of the building stock across the world focus on their operational energy, notably in terms

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of thermal efficiency. A clear indicator of this trend is the emergence of policies aimed at improving the thermal efficiency of buildings, such as the EPBD (European Directive for the Energy Performance of Buildings) [19]. In Lebanon, such directives do not exist, but other instruments have recently been implemented to favour thermal performance. The most notable of these incentives is the law regarding the construction of double concrete walls (with an air blade) and the use of double glazing. A developer or client that uses double walls and double glazing does not take the thickness of the building envelope in the allowed constructible area. Therefore, the developer or client can benefit from a larger area for resale or use. This incentive is behind the notable increase in the use of double walls and double glazing in new residential buildings in Lebanon. Yet, the additional use of materials is not considered. The additional energy required to produce these materials might counterbalance the savings in terms of heating and cooling energy demand. The embodied energy in building materials, which is the energy required to produce these materials, across their entire supply chain, needs to be taken into account for a comprehensive assessment [20].

At a different scale of the built environment, land scarcity and increasing plots and property prices are pushing residential developments further away from the capital Beirut, the major working, administrative, social and cultural hub of Lebanon. Moreover, the very inefficient and unregulated public transport system, relying solely on road vehicles (shared taxis, small vans, buses) leaves the dominant majority of the Lebanese population with no choice but to rely on private cars for mobility. These two factors are responsible for larger travel distances and an increased energy use for transport which needs to be taken into account to provide an overall picture of the energy demand [21].

To date, most studies on the energy efficiency of the building stock in Lebanon focus solely on the operational energy aspect, e.g. Chedid and Ghajar [22] and Ruble and El Khoury [23]. The embodied energy is seldom mentioned [24], and rarely quantified. A study taking into account the transport energy demand of building occupants as well as embodied and operational requirements has not been found. There is therefore a pressing need for a comprehensive energy assessment of the growing building stock in Lebanon.

1.1. *Aim*

The aim of this paper is therefore to conduct a comprehensive energy analysis of recent low-rise residential buildings in Lebanon in order to determine their energy use profile and to identify the most appropriate means to reduce their energy demand.

1.2. *Scope*

This work focuses solely on energy, as Junilla [25] and Allacker [7] have proven that it is the most significant indicator regarding the environmental impact of buildings. In order to provide a comprehensive assessment, wide system boundaries are chosen, spanning the life cycle of the building across the different scales of the built environment. The embodied energy in building materials is taken into account as well as the energy required to replace them across the useful life of the building. The operational energy demand, in terms of heating, cooling, ventilation (if present), domestic hot water, appliances, lighting and cooking is considered. Energy requirements for user transportation are also within the system boundaries, in order to evaluate their significance and include the location and context of the building. The different energy demands taken into account are depicted in Fig. 1.

2. Method

Buildings are the constituting brick of the built environment. They can be seen as a combination of various materials and assemblies, generating indoor and outdoor spaces in which the occupants live. At a larger scale, these buildings generate the urban fabric. Whether for the production of building materials, their construction, the operation of buildings or at a larger scale the mobility of their occupants, a significant amount of energy is associated with buildings. In Europe, the operation of residential buildings is responsible for 26% of the final energy demand [26]. In

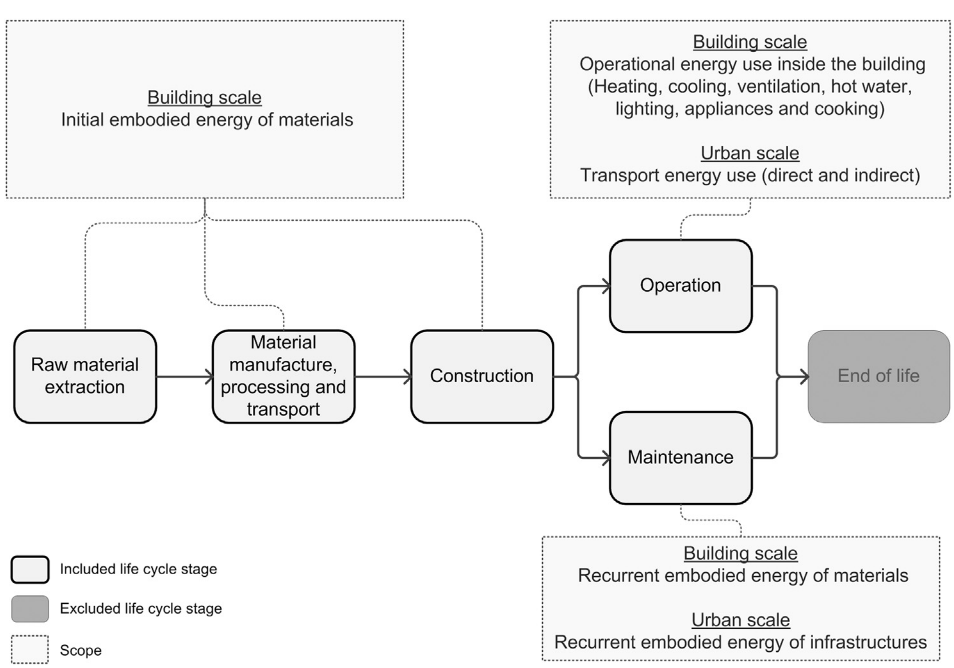

Fig. 1. System boundaries of the life cycle energy analysis framework.

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