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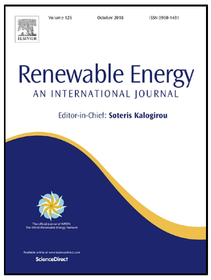

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Optimisation of heating, cooling and lighting energy performance of modular buildings in respect to location's climatic specifics

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Abstract:

Off-site construction can represent a potential solution for worldwide mass housing demand and has gained a lot of attention during the refugee crisis in Europe. In particular, modular construction is one of the most cost effective off-site methods for various types of buildings. Its characteristics are cost effectiveness, quality control and quick on-site assembly. The design challenge is to join the stated advantages with operational sustainability, which is susceptible to climate-determined and energy efficient design. Therefore, the purpose of this paper was to systematically evaluate energy and visual (daylight) efficiency of singular prefabricated modular unit. In order to emphasise the relevance of local climate, modular unit model was analysed at five different locations, monitoring cooling, heating and lighting energy use. Results showed similarities and differences between the analysed locations and implemented design measures. The conducted analysis included variation of orientation, window to wall ratio, window distribution, envelope thermal transmittance and glazing characteristics. Surprisingly, the results indicate substantial impact of artificial lighting on the total energy use. Therefore, emphasizing a direct connection to the Spatial Daylight Autonomy (*sDA*) values of the modular units. With *sDA* values below 50%, lighting can represent up to half of the total energy use.

Keywords: off-site construction; modular buildings; sustainable buildings; climate-determined design; energy performance; daylight performance

1 Introduction

Buildings come in different shapes and sizes as well as types, primarily they are designed in order to facilitate to investor's demands. However, as society evolved the energy use in buildings increased due to the higher comfort demands and relatively low prices of energy from non-renewable sources. In recent decades, it became evident that such high-energy use of buildings has a substantial impact on the environment and economy therefore building designers and other stakeholders started to search for more energy efficient building solutions. Simultaneously, legislation actions [1,2] taken over the last few decades in the EU and other parts of the world as well have been geared towards limiting building energy use through prescribed maximum allowed use. Such actions have a substantial impact on the EU building stock. Further on, if no actions toward building sustainability would be taken, the energy demand would rise by 50% till 2050 [3]. Which is unacceptable simply because: "*We do not inherit the Earth from our Ancestors, we borrow it from our Children*" [4]. Additionally, high energy use, primarily of non-renewable energy sources, causes an increase of building environmental impact and is at its present rate unsustainable [5]. On the other hand, rapid growth of global human population causes intensified urbanisation [6] and with it a demand for new buildings. According to UN-HABITANT [7] it is estimated that in the absence of serious action, additional 1 billion people will live in urban slums till 2030. According to Gupta et al. [2] the light at the end of the tunnel, is sustainable building design with a short term goal of improved building energy efficiency (e.g. using passive design techniques) and a long term goal of using sustainability as primary building design criterion supported by creative research. This push towards sustainable buildings is also evident in the increase of research in the field of building sustainability [2, 8–11], with researchers and designers focusing on building energy