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A state-of-art review of retrofit interventions in buildings towards nearly zero energy level

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Abstract

Unmistakably, buildings retrofitting brings the possibilities to reduce energy use and greenhouse gas emissions. However, selecting specific retrofit strategies is complex and requires careful planning. There are already various technics of buildings retrofitting towards nearly zero energy level. Therefore, the focal point in this paper is the review of relevant solutions and the effect of their corresponding consequences on building energy efficiency as well as recommending renewable energy technologies. Further investigation on the feasibility of adopting these technics for cold climates requires thorough studies to be carried out through experiments or numerical simulations.

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Keywords: Building areas; Retrofit intervention; Zero energy level; Energy efficiency

1. Introduction

It is known that buildings are the largest energy using sector in the world, and over one-third of total final energy use and an equally important source of carbon dioxide (CO_2) emissions are imputable to existing buildings [1,2].

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Therefore, it is vital to reduce the total energy use by means of energy efficiency improvements through retrofitting of existing buildings to achieve a nearly zero energy building (nZEB) level that will bring environmental, economic, social, and health benefits. Generally, a net zero energy building (ZEB) is a residential or commercial building with zero net energy use, meaning total amount of energy used by the building on an annual basis can be compensated by on-site production of energy via renewable energy technologies.

The nZEB has a very high energy performance. The low amount of energy required is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby, which the latter technically may mean existing district heating and cooling or any other technical system serving a group of buildings. It is important to emphasize that there are many definitions and ambition levels towards ZEB depending on the climate zone [1].

The energy efficiency retrofits for buildings towards a nZEB level are defined as actions that allow an upgrade of the building's energy and environmental performance to a higher standard than was originally planned [3]. An overview of potential retrofit strategies and retrofit actions which may improve performance figures can be categorized into three main strategies: (1) actions regarding building envelope and design aspects including insulation upgrades, air leakage reduction, improvement of doors and windows, control and exploitation of solar gain and daylight, etc.; (2) actions for building systems and installations including installation of high-effectively HVAC systems, improvement of electrical lighting systems, improvement of domestic appliances, installation of renewable energy, etc.; (3) actions associated with building services and management tools including monitor and control of building during operation, utilization of metering services, clock controls, sensors, etc. [4]. Thermo-active building systems for thermal stability and natural lighting for a better quality of illumination are also other operational examples of retrofit strategies [5,6]. The overall consequence of these retrofit strategies would be an energy efficient building with low greenhouse gas emission that is both comfortable for occupant and cost effective.

Another important factor in studying nZEB is climate of the region where retrofitting is performed. It's generally accepted that buildings in colder climates use more energy for heating than those in warmer climates use for heating of building space and air ventilation. So, it takes less energy to achieve indoor comfort in cooling-dominated climates as well as it's easier to build a nZEB, indicating differences in approach towards nZEB in cold and warm climates. For instance, while thick layers of insulation get most of the attention in cold climates, insulation needs less emphasis in warm climates [7].

This paper aims at providing an overview of retrofit technologies, strategies, and renewable energy systems applied to different areas of existing buildings as well as their energy performance and environmental effects, mainly for cold climate and partly for warm climate, to achieve a nZEB level. A thorough discussion on each level of building retrofitting is presented and some alternative solutions are also suggested.

The review research methodology considers the different scholarly studies mostly related to the potential of employing building retrofit interventions, with promising results in improving of two key parameters; building energy use and indoor environmental quality. The results are classified into three categories including the most popular and innovative interventions regarding building design, building envelope, and building system and services recognized in the literature as appropriate solutions to achieve a nZEB level. Finding are subsequently interpreted, and presented.

2. Retrofit interventions and performance criteria

The main criteria for efficiency and sustainable performance of retrofit measures in all building areas towards nZEB level include: (1) decreasing of energy use, (2) limited impact on global greenhouse gas emission, (3) improvement of indoor environmental quality, and (4) upgrading of functionality and architectural quality. Furthermore, the expected cost of a specific retrofit is key to its effective value. However, several of these criteria often appear to be in conflict, for example, energy use improvements versus architectural quality [4]. In some cases, retrofitting of building service and systems requires less cost investment while providing more environmental benefits than retrofit measures using renewable energy technologies [8]. Therefore, finding the optimum retrofit strategy is a complex procedure and needs to be critically investigated.