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Impact of building envelope and mechanical component degradation on the whole building performance: a review paper

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Abstract

During the building operation phase, it is recognized that the performance of building envelope elements and energy supply systems drops with time. This performance degradation usually leads to lower energy efficiency and higher life cycle costs than predicted in the early design phase. This paper quantitatively reviews the impacts of this deterioration on the whole building performance. From the findings of the reviewed literature, it can be concluded that the whole building performance is very sensitive to several deterioration factors, particularly the performance degradation of the heating, ventilation and air conditioning (HVAC) system. The impact on the whole building performance mostly ranges from 20% to 30% over 20 years, according to the reviewed studies.

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Keywords: Building ageing; Energy performance; Efficiency; Degradation; Deterioration; Decline

1. Introduction

With the building sector accounting for approximately 40% of the energy demand in the European Union (EU) and 32% in the world [1], particular focus has been placed by both the scientific community and politicians on the energy performance of buildings. As a result, continuous efforts are being made to reduce the buildings' energy use. In order to achieve that, the energy efficiency needs to be increased by implementing energy saving measures (ESMs) and

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renewable energy technologies (RETs), such as highly energy efficient fixtures and photovoltaic panels respectively [2].

For a successful implementation of such measures and technologies, the building has to be designed with a high level of quality. The energy balance that needs to be solved during this design process can be influenced by a variety of uncertainty sources. Some of these sources have already been examined to a satisfactory level, with examples including the probability of a component failure [3] or the impact of climate change on future considerations [4, 5]. There are however others that are yet to be put under thorough examination, one of them being the ageing of buildings and their components.

It can be observed that the energy performance of both building envelope elements and energy supply systems drops as a result of natural ageing or even because of mismanagement and poor maintenance [6]. This leads to lower energy efficiency and higher life cycle costs. The term that can be used to best describe this phenomenon is "performance degradation". The effects of this degradation are generally not taken into consideration, neither by conventional simulation models nor by existing optimization concepts [2, 7, 8].

The paper first provides an overview of studies that deal with the impacts of this performance degradation on the whole building performance. As a next step, the degradation rates of building envelope elements (mainly insulation) and mechanical components (e.g. heat pumps) are demonstrated. In this way, conclusions are drawn regarding the suitability of the reviewed literature for use in future assessments of the energy performance of buildings.

Nomenclature

ESMs	energy saving measures
RETs	renewable energy technologies
HVAC	heating, ventilation and air conditioning
NREL	national renewable energy laboratory
DX	direct expansion
GSHP	ground-source heat pump
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
LTTR	long term thermal resistance

2. Degradation impact on whole building

As stated, the performance deterioration that every building element undergoes with time is generally neglected when assessing the energy performance of buildings. Nevertheless, some studies that examine the effects of degradation on the energy performance of buildings over time have been carried out [6, 9, 10]. In [6] and [9] the effects of both climate change and building ageing on the performance of reference buildings are investigated by conducting simulations. In [6], the IDA ICE model is used to simulate the performance of a library building in Turin, Italy, while in [9] the simulations of a supermarket in Plymouth, UK are carried out with EnergyPlus V 5.0. Magnuson [10] examines the impact of heating, ventilation and air conditioning (HVAC) component degradation on two buildings of the University of Kansas in Lawrence, Kansas, USA. Here, other factors, such as embodied energy, are also taken into account. Waddicor et al. [6] and Magnuson [10] use deterministic models to predict performance degradation, whereas Wilde et al. [9] implement both a deterministic and a stochastic approach. Regardless of the followed concept, the conclusion in all three studies is that the energy performance of a building is very sensitive to its ageing and particularly to the degradation of HVAC components.

Table 1. Overview of whole building impact of degradation

Source	Building type	Considered for degradation?		Impact on building energy consumption		
		Insulation	HVAC	HVAC (incl. electricity and refrigeration)	Other electricity	Total
Derived from [6]	Commercial (library)	Yes	Yes	+32%	0	+23%
Derived from [9]	Commercial (supermarket)	Yes	Yes	+ 9%	0	N.A