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Longitudinal prediction of the operational energy use of buildings

Pieter de Wilde [a,*], Wei Tian [a], Godfried Augenbroe [b]

[a] School of Architecture, Design and Environment, University of Plymouth, Plymouth, United Kingdom
[b] College of Architecture, Georgia Institute of Technology, Atlanta, USA

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ABSTRACT

Thus far most studies of operational energy use of buildings fail to take a longitudinal view, or in other words, do not take into account how operational energy use changes during the lifetime of a building. However, such a view is important when predicting the impact of climate change, or for long term energy accounting purposes. This article presents an approach to deliver a longitudinal prediction of operational energy use. The work is based on the review of deterioration in thermal performance, building maintenance effects, and future climate change. The key issues are to estimate the service life expectancy and thermal performance degradation of building components while building maintenance and changing weather conditions are considered at the same time. Two examples are presented to demonstrate the application of the deterministic and stochastic approaches, respectively. The work concludes that longitudinal prediction of operational energy use is feasible, but the prediction will depend largely on the availability of extensive and reliable monitoring data. This premise is not met in most current buildings.

1. Introduction

The operational energy use of buildings (the energy used for heating, cooling, ventilation, provision of domestic hot water, lighting, and appliances) is the main focus of energy efficiency measures. More recently the building science community has started to balance this operational energy with the embodied energy invested in creating new buildings [1–3]. Thus far most assessments consider operational energy use to be constant over the building life cycle [1,2,4]. However, this is unlikely to hold true in real life [5]: the thermal performance of building components will be degrading over time[6], environmental conditions are subject to climate change, and internal loads will vary due to changes in building occupancy and when new technologies and appliances enter the market. As buildings become more efficient, these changes in energy performance during the building life cycle become more important factors in long term energy accounting methods. Furthermore, studies in for instance the field of adaptation of buildings to changing climate conditions require a longitudinal view of building performance rather than just an initial assessment.

The longitudinal thermal performance of a building will be affected by organizational and physical change processes affecting building occupancy, facility use properties of building elements, climatic conditions, and building maintenance processes and policies. Information is becoming available to estimate the magnitude of these changes, for instance in the areas of properties of building components over time [7–9], maintenance processes [10], and climate change [11,12]. Other factors, like occupancy changes, are likely to remain hard to predict and will result in the need to accommodate uncertainties and risk when planning for the future. Note that embodied energy can be responsible for a considerable proportion (up to 45%) of the total energy for low energy buildings [3] but this topic is considered to be beyond the scope of this research.

The purpose of this article is to propose a methodology for predicting the longitudinal thermal performance of buildings, specifically taking into account degradation in thermal performance of building components and changes in weather conditions.

Firstly it reviews the current state-of-the-art in building component service life expectancy, degradation of building component thermal performance, building maintenance, and changing environmental conditions (climate change). Based on this review, a methodology is suggested to predict the likely change of thermal performance over the building life cycle. Two simple case studies are presented to demonstrate how the operational energy use is expected to change over its service life by using the deterministic and probabilistic methods, respectively.

2. Service life expectancy of building components

This section reviews the service life expectancy of building components. For new or existing buildings, it is necessary to predict

* Corresponding author. Tel.: +44 1752 586115; fax: +44 1752 586003.
E-mail address: pieter.dewilde@plymouth.ac.uk (P. de Wilde).

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