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Uncertainty and sensitivity analysis of building performance using probabilistic climate projections: A UK case study

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ABSTRACT

This study explores the uncertainties and sensitivities in the prediction of the thermal performance of buildings under climate change. This type of analysis is key to the assessment of the adaptability and resilience of buildings to changing climate conditions. The paper presents a comprehensive overview of the key methodological steps needed for a probabilistic prediction of building performance in the long term future (50 to 80 years). The approach propagates uncertainties in climate change predictions as well as the uncertainties related to interventions in building fabric and systems.

A case study focussing on an air-conditioned university building at the campus of the authors is presented in order to demonstrate the methodology. This employs the most recent probabilistic climate change projections for the United Kingdom (UKCP09 dataset) and takes into account facility management uncertainties when exploring uncertainties in the prediction of heating energy, cooling energy, and carbon emissions.

1. Introduction

In the UK, buildings account directly or indirectly for approximately 40% of national carbon emissions [1]. This is a major constituent of the human-driven greenhouse gas emissions, which are increasingly tied to global warming [2]. Reciprocally, building thermal performance is directly affected by changing weather conditions. Hence it is important to make sure buildings remain thermally comfortable, while being energy efficient and employing low carbon technologies.

The impact of climate change on building thermal performance and the adaptation of buildings to changing environmental conditions have become active research areas [3–20]. CIBSE TM 36 provides a comprehensive analysis of energy use and overheating in different types of buildings by using climate projections for the UK released in the 2002 (UKCIP02) [4]. Research by Guan [5], studying the impact of climate change on air-conditioned buildings in Australia, indicates that under the 2070 high emissions scenario a 28–59% increase of cooling capacity will be needed to maintain thermal comfort conditions. De Wilde and Tian [6] have implemented a probabilistic method and sensitivity analysis to identify the key variables affecting the thermal performance of a mixed-mode office building in Birmingham, UK. Coley and Kershaw [7] propose "climate change amplification coefficients" to correlate indoor air temperature to predicted weather conditions. More research has been carried out based on different climate change scenarios in different countries, such as Canada [8], the Netherlands [9], New Zealand [10], Portugal [11], Slovenia [12], Switzerland [13,14], the United Arab Emirates [15], and the UK [16,17]. Some research takes a wider view and compares the trends in building behaviour in a range of different climate zones [18–20]. However, most of this existing work on the impact of climate change on building thermal performance is deterministic in nature. Furthermore, any application of sensitivity analysis in building performance simulation (the main methodology for predicting future building behaviour) is mostly focussed on local sensitivity analysis (one-factor-at-a-time). At the same time meteorological research progresses quickly. In the UK, a new set of climate change projections (UKCP09) was released in June 2009 [2]. This new dataset is the first to attach probabilities to different levels of future climate change. However, this new data is also a challenge to the building science disciple due to its complexity. At the same time it also provides an opportunity to further analyse building behaviour under climate change by using (sampling-based) Monte Carlo approaches. This is a commonly used method for estimating the impact of uncertainty in inputs on a corresponding uncertainty in outputs [21,22]. There are many sources of uncertainty in building energy simulation, such as weather conditions, physical properties of building materials, internal heat gains [23–26], and accordingly the sampling-based methods are very suitable for research on impact and adaptation to climate change in the built environment [6].

This study explores the uncertainties and sensitivities in the prediction of the thermal performance of buildings under climate change. It presents a comprehensive overview of the key methodological steps needed for a probabilistic prediction of building performance

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