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From the building level energy performance assessment to the national level: How are uncertainties handled in building stock models

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Abstract

A considerable share of greenhouse gas (GHG) emissions is caused by the energy consumption for space heating and cooling in residential buildings. In Germany for instance about one third of the end energy consumption is accounted to space heating and cooling of buildings. Consequently, efforts to increase energy efficiency and substitute non-renewable energy with renewables are high. To explore the technical, economic and social effects of environmental mitigation strategies in order to increase energy efficiency in the building stock various models are used. Many of these models have to deal with the challenges of how to estimate energy demand levels. Derived from the recent development in this field researchers, planners and politicians are increasingly relying on energy models with integrated energy performance rating for environmental policy and strategy evaluation. However, energy assessments suffer from the common barriers of data access and data granularity. Therefore the approaches of energy building stock models comprise a mixture and variety of methods and have limits, which will be addressed in this contribution. The goal is to show how uncertainty is considered in existing models. This contribution provides general overview and key takeaways from the insight into different models and methodologies on the different levels of detail of building stock models.

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Keywords: Building stock models; energy modelling; uncertainty; uncertainty management; built environment

1. Introduction

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Many countries aim at pioneering in energy system transition and cutting greenhouse gases emission. In Germany the officially reported end-energy consumption reveals that the building stock is responsible for nearly 38 % of the heating related end-energy consumption [1].

In order to develop such plans, systematic and comprehensible approaches are much-needed to show the efficiency and reduction potentials, depict development paths and disclose low hanging performance fruits. Complying with this demand many models for assessing buildings energy demand evolved (see Sections 3 and 5). Furthermore, the private and commercial interest to be informed about buildings' energy demand and consumption is increasing steadily. This is especially observable in an increasing demand and integration of energy related consulting services such as the calculation of performance ratings for assisting tenants and owners of buildings in decision making. Consequently, understanding the energy consumption of buildings is a current field of interest and research. Additionally, this development indicates that the results of models in this field should be easily and quickly comprehensible.

A key element which the models, studies, strategies and services have in common is the energy performance assessment of buildings. Depending on their scope and aim, most of the models have to deal with the challenges of processing data from different sources and on different levels of detail in order to receive informative and valid results. Therefore and in order to minimize the effects of incomplete and uncertain data, combinations of different approaches and techniques are utilised.

An important issue is the quality and conclusiveness of the models' results in supporting and informing end-users[2†] who typically are policy or decision makers. Since numerous reviews about the existence of models (see Section 3) have been written, this contribution does not aim at elaborating the current portfolio of building stock models. Instead, it focuses on how shortcomings in building stock models on different scales are dealt with. Particularly, the objective of this paper is to list the various methodologies of how building stock models assess the energy demand resulting from space heating in building stocks and especially on how results are ensured to be plausible. The results of this study are presented in condensed form.

2. Objective and method

The objective of this study is to provide an insight into how a multiplicity of building stock energy models deals with uncertainty in building stock models for energy related assessments. An extensive literature research on building stock models revealed that many models, reviews and much literature exist. The most relevant reviews of building stock models are presented in the next section and Table 1. In this work, an investigation of existing models was conducted and those which considered uncertainty explicitly were selected for further analysis (27 of 72). In this analysis, an uncertainty classification framework was applied on the 27 models. The main focus of this investigation are uncertainties which afflict the models' results and how the modellers deal with different shortcomings. On this account modelling techniques and basic model descriptions are presented only briefly. In the following sections the comparison and analysis framework is set.

3. Overview of reviews of building stock models

Several authors have developed models (Tables 2,3,4) and others have written comprehensive reviews of building stock models for energy system modelling (Table 1). Since these reviews provide extensive insight into different aspects of numerous models, only the most important findings are summarised. Swan & Ugursal [3] and Kavgic et al. [4] addressed fundamental characteristics of building stock models in their reviews. They identified two distinct modelling techniques: bottom-up and top-down modelling. In few words, bottom-up models represent models which are based on building physics (of subsets or individual buildings of a building stock) and top-down models build on economic theory, aggregated and statistical data. Top-down models can be further differentiated into technolog-

[1] compared to base year: 2008

[2] Frequently, end-users were not involved in the development of these models.