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Adaptation of building envelope models for energy simulation at district scale

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Abstract

In order to reduce computational cost of district scale energy simulations, very simplified building envelope models are often used. However, the impacts induced by such simplifications, are not systematically validated, especially for instantaneous power demand, required for district energy network design and management, since those models are mainly designed for monthly or annual energy consumptions. This paper aims to analyse the impacts of usual envelope simplifications used at the district scale (such as conduction modelling, zoning, allocation of transmitted solar flux, controlled temperature modelling, etc.) on the building energy needs, and, consequently, to suggest relevant selections of adaptations according to the simulation focus, i.e. the temporal resolution.

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1. Introduction

District scale studies require simulations of hundreds of buildings, and modelling hundreds of buildings with a technologically explicit formulation for computing power demand over a year, can lead to prohibitive computational cost (even more if considering interactions between them, as longwave heat exchange or microclimate impacts).

In order to reduce simulation cost, simplified approaches are often used in city energy simulations. Since simulating the conductive heat transfer is the most expensive part of building energy simulations, envelope model is the main target of simplifications. In particular, many building envelope resistance-capacitance (RC) analogy models were developed for district scale building energy simulation platforms: Kämpf and Robinson model for CitySim [1], Berthou et al. model for Smart-E [2][3], Perez et al. model for DIMOSIM [4] and specific envelope models of the Modelica libraries BuildingSystems [5,6], AixLib [7], OpenIDEAS [8], and BuildSysPro [9]. Other platforms [10–14], adapted for annual or monthly energy calculation, use quasi-static models. Otherwise, mathematical reduction technics are also used [15,16].

Furthermore, implicit simplifications relying on modelling assumptions of the building energy model (BEM) are usually used, as monozone model, geometry and meteorological loads simplifications. These simplifications are also used because of lack of suited data at city scale (e.g. glazing ratio, fabrics and the local micro-climate).

Thereafter, the term *adaptation* is used rather than *simplification* because the modifications (simplifications/adaptations) are performed with respect to a specific goal in order to reduce the computational cost and/or the number of parameters; the model is adapted to the outputs of the simulation which we need to focus on. This paper studies the impact of common adaptations used in BEM on the simulated building energy needs (heating and cooling) in order to determine which adaptations could be relevant with respect to the simulation goal. Power needs, at least hourly estimated, are particularly focused on since adaptations are usually validated with respect to annual or monthly energy consumption but not to power needs.

For this purpose, the paper is structured as follows: a first part (Sec. 2) details the methodology retained for the adaptation impact analysis; then, the estimated impacts are presented and analysed (Sec. 3); finally, the last part (Sec. 4) draws conclusions and perspectives.

2. Methodology

Two kinds of adaptations are studied: the first one relies on the level of discretization of the conductive heat transfer model, the second on usual modelling adaptations of BEMs.

The impact of each adaptation is analysed by comparing the power simulation results of the adapted model with the results of the un-adapted model. In order to do so, we focus on the time series differences between the two power curves. Two indicators are computed in order to analyse this time series: the mean and the absolute maximum (referred to *max.* in the following), in order to respectively discriminate impacts on annual energy needs (long term), and on power needs (estimated over a time step period). The rectified mean (*r. mean*), mean of the absolute values, is used as a second complementary indicator for quantification of long term period impacts without compensating effects between positive and negative differences.

The methodology is applied to a generic 10 m cubic building oriented towards the cardinal directions. Its characteristics is based on the French TABULA typology [17] for 'multi-family house built before 1915' category, as this category represents a key part of the French building stock. In addition, the case of an efficient-energy renovated building is also studied, in order to highlight the effects of the envelope performance on the impacts of the adaptations. Thereafter, *Init.* refers to the initial building according to the typology, whereas *Perf.* refers to the renovated building.

The models are built using the BuildSysPro Modelica library developed by EDF R&D [9] and simulated with Dymola for a whole year. A solver with an adaptive step size algorithm is used, but the output interval is set to 1 hour in order to match with the hourly Meteonorm weather data from the city of Lyon in France which is used. The setpoint temperatures are respectively 19°C and 28°C for heating and cooling. Main modelling assumptions are given in Sec. 2.2. No energy system is modelled, hence the power calculated corresponds to needs, not demand.