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Influence of Buildings Configuration on the Energy Demand and Sizing of Energy Systems in an Urban Context

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Abstract

Energy interaction among buildings play a vital role when considering the energy demand at neighbourhood or urban scale which notably influence the energy system sizing problem. The proper representation of buildings and their effects such as drag force effects, generation of turbulence, shading etc. are crucial in the evaluation of building energy demand and subsequently in energy system sizing. This is not practiced in present literature. To achieve this, we couple a meteorological model, a building energy model and an energy system tool. We show that the use of local climatic data and urban planning scenario have a significant impact on the design of energy systems. More importantly, the results of the study show that co-simulation platform coupling meteorological model, building simulation model and energy system designing model can help to design energy efficient neighbourhoods with more renewable energy integration.

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Keywords: Building orientation; co-simulation; energy system designing; meteorological model

1. Introduction

Energy requirements in urban areas are rising very fast and this trend is expected to continue with the increase in the urban population (70% by 2050). New buildings are built according to more and more stringent norms which can make them either net-zero or energy positive buildings. However, the core of the existing buildings is still old and renovation strategies and scenarios will not be able to make neighbourhoods or buildings in urban areas fully

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autonomous. Building optimization has been amply discussed in recent literature considering various aspects of the building especially considering the energy flow [1]. Lately, this has been extended considering building energy systems along with the various aspects of the building including location of windows, thickness of the walls, orientation etc. [2], [3]. However, this is a challenging due to its computationally demanding nature. When moving from building scale to neighbourhood scale, the complexity of the problem increases significantly [4].

A number of recent studies have focused on combining energy system sizing problem with building simulation in both urban and neighbourhood scale [5], [6]. However, most of these studies do not consider the impact adjacent buildings on the thermal and electricity demand (due to lighting). Effect of shadowing and boundary layer is not considered in most of the instances. The proper representation of buildings and their effects such as drag force effects, generation of turbulence etc. are crucial in the evaluation of building energy demand [7] as they can impact the convective heat transfer coefficient [8]. Hence, it is important to represent micro-climate accurately in the building simulation process which will be subsequently used for energy system sizing. More importantly, appropriate representation of micro-climate can be used along with building simulation and energy system sizing to optimally locate buildings with less thermal demand and more opportunity to integrate renewable energy technologies. This can lead to sustainable neighbourhoods with lower carbon impact.

In order to fill this gap, in this study we focus on combining building simulation model [9], [10], energy system sizing tool and an urban meteorological model [11] in order to assess the impact of building positioning on energy system designing in neighbourhood scale. We analyse the influence of using local climatic data and architectural aspects on energy demand of the building and subsequently to the energy system sizing for energy sustainable buildings. In the next section we describe the models used in the current study. We then show the results obtained and discuss them. In the final section we conclude on the most important findings in this study and give a few perspectives to further develop the simulation platform.

2. Methodology

A co-simulation platform combining a meteorological model, the Canopy Interface Model (CIM) [11], [12], a building simulation model, CitySim [9] and energy system design model [13]–[15] has been developed.

2.1. Overview of the modelling framework

CIM is a 1D meteorological model that can work offline as a stand-alone module while using as input data from the climatic dataset (such as Meteonorm [16]) or can be coupled with a 3D meteorological model (such as WRF [17]). CIM calculate high resolution vertical profiles of the variables considering the local environment (for example considering the presence of buildings and their density). The meteorological model is used to generate profiles wind speed, direction and air temperature profiles. CIM uses a diffusion equation derived from the Navier-Stokes equations but reduced to one direction only. It has subsequently been coupled with the CitySim building simulation software (see Figure 1) in order to determine the energy demand of a district [7], [8], [18]. Equations are taken from Mauree et al., [11] to account to the obstacles density and height in the canopy.

In the current study the coupling strategy is defined as in Fig. 1. This means that, for each time step, CitySim is run at the first time step with the typical Meteonorm data. The calculated surface temperature is then used as a boundary condition for CIM along with the other meteorological variables (wind speed, wind direction, and air temperature). CIM then calculates high-resolution vertical profiles that are then feedback to CitySim for the calculation of the energy demand.