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Impact of spatial accuracy on district energy simulations

Ina De Jaeger[a,b]*, Glenn Reynders[a,b], Dirk Saelens[a,b]

[a] *KU Leuven, Department of Civil Engineering, Building Physics Section, Kasteelpark Arenberg 40 – box 2447, BE-3001 Heverlee, Belgium*
[b] *EnergyVille, Thor Park 8310, BE-3600 Genk, Belgium*

Abstract

An integrated approach using district energy simulations is essential to analyse energy efficient buildings and cities. Thereby, an accurate building representation in dimensions of space is considered as an essential boundary condition. Nonetheless, district energy simulations are often carried out using a limited set of archetype buildings. This paper analyses therefore the impact of a more accurate building representation in district energy models, for a given district. Three approaches to include building geometry with a different level of detail are extensively analysed through a comparison of geometrical properties, peak power, total energy use and overheating risk. The GIS-based approach is favoured for the design of district energy systems, as it enables a more accurate and automatic implementation of the spatial dimension of the dynamic energy simulation results.

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Keywords: district energy modelling; district energy systems; district energy simulations; GIS; CityGML

1. Introduction

Because of the integration of more renewable energy sources, the importance of storage and demand response has increased considerably, especially within the context of 4th generation thermal networks [1] and smart electricity grids. Consequently, the need to design energy systems at district level increases, as opposed to the more traditional approach focussing on the individual building level [2]. For this purpose, District Energy Simulation tools such as the OpenIDEAS framework could be used. OpenIDEAS is a simulation environment in the Modelica language that enables the integrated assessment of district energy systems, through integrated simulation of thermal and electrical systems [2]. An accurate simulation of the energy flows within the district, using these district energy models, requires

* Corresponding author. Tel.: +3216372413.
E-mail address: ina.dejaeger@kuleuven.be

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an accurate definition of boundary conditions and model parameters in space and time. The spatial dimension is important to assess the geographical distribution of peak power and total energy use, which allows determining optimal network topologies and sizing of components [3].
However, a literature review [2,4-7] shows that district energy simulations are often carried out using a limited set of representative buildings or "archetypes" e.g. using the resulting typologies of the TABULA project [8] or other studies [9], due to a lack of input data and an efficient methodology to process this input data. Consequently, both detailed building geometry and spatial distribution of the buildings within the district are lacking. To consider the correct spatial distribution, geographic information systems (GIS) are proposed as they contain a precise geometric representation of the analysed district, although their level of detail varies significantly from one country to another.

Within this context, this research uses existing tools for district energy simulations and CityGML import and adds new features to these tools in order to provide boundary conditions with a higher geometrical accuracy. As this work assesses the impact of a more detailed residential building geometry, only the energy use for space heating is considered. Therefore, multiple key performance indicators (KPIs) were defined for geometrical properties as well as for the energy assessment:

- *KPIs related to geometry:* ground floor area, heated floor area, heated volume, external wall area, window area, total loss surface area and internal wall area
- *KPIs related to energy performance:* peak power, total energy use and overheating risk (evaluated as exceeding time above 25°C)

As the aim is to estimate the influence of a model with a higher spatial accuracy, the geometrical properties of the different buildings were compared and their influence on the energy performance of the buildings was assessed in order to determine to which extent the accuracy of the results of a model with a detailed geometric building representation is enhanced compared to the reference models with a lower level of spatial detail.

In the next Section, a *GIS-based methodology* to quantify the energy use of a certain district is presented and the case study is introduced. In Section 3, the results that are obtained through three different modelling approaches are analysed. A detailed comparison of these KPIs is shown. In Section 4, the advantages and the challenges of the proposed *GIS-based methodology* are discussed. Finally, the main conclusions are formulated in Section 5.

2. Methodology

In this Section, the *GIS-based methodology* that provides the necessary boundary conditions for district energy simulations is presented. Since this methodology only deploys data sources that are available for the entire Flemish territory, this methodology could be applied to every district in Flanders. First, the case study is introduced. Subsequently, the *GIS-based methodology* is addressed extensively (Figure 1). As explained further, this methodology deploys the commercially available FME tool to setup the CityGML models, TEASER to translate these CityGML models into IDEAS Modelica models and OpenIDEAS to run the district energy simulations in Dymola.

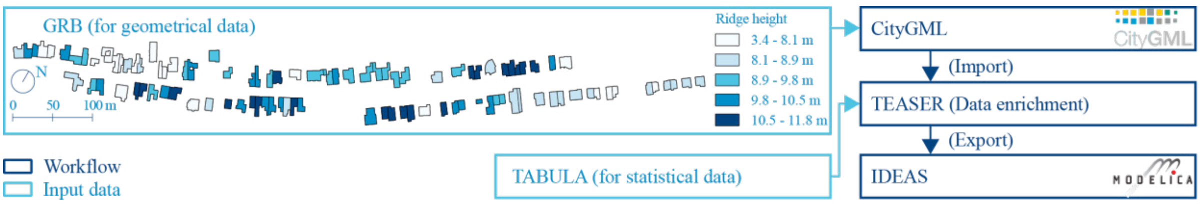

Fig. 1. Graphical overview of the proposed GIS-based methodology to quantify a district's energy use.

2.1. Introduction to the case study

For the purpose of examining the effect of modeling with a higher spatial accuracy, three different approaches were compared to simulate a small neighbourhood and to determine its energy use for space heating, along with its peak power and its risk of overheating. For this research, a street of 99 buildings in a Flemish rural district ("Muisstraat" in Haaltert) was examined. The considered district consists of 15 terraced, 56 semi-detached and 28 detached dwellings.