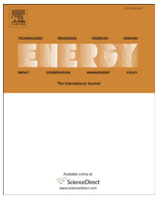
Energy xxx (2016) 1–13

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy



Influence of simulation assumptions and input parameters on energy balance calculations of residential buildings

Ambrose Dodoo*, Uniben Yao Ayikoe Tettey, Leif Gustavsson

Sustainable Built Environment Group, Department of Built Environment and Energy Technology, Linnaeus University, Växjö, SE-35195, Sweden

ARTICLE INFO

Article history:
Received 18 June 2016
Received in revised form
22 November 2016
Accepted 24 November 2016
Available online xxx

Keywords:
Energy simulation
Residential building
Parameters
Input data
Assumptions
Interactions

ABSTRACT

In this study, we modelled the influence of different simulation assumptions on energy balances of two variants of a residential building, comprising the building in its existing state and with energy-efficient improvements. We explored how selected parameter combinations and variations affect the energy balances of the building configurations. The selected parameters encompass outdoor microclimate, building thermal envelope and household electrical equipment including technical installations. Our modelling takes into account hourly as well as seasonal profiles of different internal heat gains. The results suggest that the impact of parameter interactions on calculated space heating of buildings is somewhat small and relatively more noticeable for an energy-efficient building in contrast to a conventional building. We find that the influence of parameters combinations is more apparent as more individual parameters are varied. The simulations show that a building's calculated space heating demand is significantly influenced by how heat gains from electrical equipment are modelled. For the analyzed building versions, calculated final energy for space heating differs by 9–14 kWh/m^2 depending on the assumed energy efficiency level for electrical equipment. The influence of electrical equipment on calculated final space heating is proportionally more significant for an energy-efficient building compared to a conventional building. This study shows the influence of different simulation assumptions and parameter combinations when varied simultaneously.

1. Introduction

The European Union (EU) is targeting at least 80% reduction in greenhouse gas (GHG) emissions by 2050, compared to 1990 levels, for climate change mitigation [1]. Different measures are suggested to reach this ambitious target and significant energy savings in all end-use sectors is noted to be imperative [2]. The building sector accounted for 38% of EU's total final energy use in 2011 and is expected to contribute significantly to achieve the emissions target [3,4]. EU's energy efficiency directive [5] and energy performance of buildings directive (EPBD) [6] call for member states to implement policies for improved energy efficiency in buildings and thereby reduce GHG emissions. In Sweden, the government has set out a strategy to reduce specific energy use in buildings by 20% and 50% by 2020 and 2050, respectively, compared to 1995 levels [7].

Space heating dominates the final operation energy use of the residential building stock in almost all EU countries [8]. In Sweden, about 60% of the final energy use of residential buildings is reported to be for space heating [8]. Accurate and reliable analysis of buildings' energy balance is essential to identify the scale, tradeoffs and cost-effectiveness of various measures to reduce space heating demand, and facilitate GHG emissions reductions. The EPBD [6] provides a framework methodology for calculation of energy use of buildings and suggests that such calculations should at least account for factors related to building thermal envelope, orientation, outdoor climate, indoor climate, lighting, heating, ventilation, air handling units, and passive solar systems and solar protection. Simulation tools that can account for the dynamics of factors influencing buildings' energy use as above have been developed and are increasingly used for energy balance calculations (see e.g. Refs. [9–12]). However, the accuracy and reliability of results obtained from such tools depend on the quality of input data used.

Increasingly, inappropriate simulation input data is cited as a key cause of discrepancy between predicted and monitored energy use of buildings [13–16]. Studies show that the calculated energy demand of a building can vary by wide margins within the same

---

* Corresponding author.
E-mail address: ambrose.dodoo@lnu.se (A. Dodoo).

http://dx.doi.org/10.1016/j.energy.2016.11.124
0360-5442/© 2016 Published by Elsevier Ltd.

Please cite this article in press as: Dodoo A, et al., Influence of simulation assumptions and input parameters on energy balance calculations of residential buildings, Energy (2016), http://dx.doi.org/10.1016/j.energy.2016.11.124

context depending on the assumptions and input data used for simulation. Dodoo et al. [17] noted that input data used for building energy simulation vary significantly in the Swedish context, giving considerably different estimated annual final energy demands for a case-study building. They found estimated annual final space heating demand of the building to be between 50 and 125 kWh/m^2 when the extremes of key parameter values found in scientific literature are used to perform simulations. In an Australian study, Daly et al. [18] found the final energy demand of prototype buildings to vary by more than 50% from baselines when using plausible high and low simulation assumptions.

Several studies on building energy simulation have explored the effects of variabilities and uncertainties in various input parameter values on calculated final energy demand. Crawley et al. [19] compared the annual energy use for prototype buildings when simulating with distinct climate datasets for a variety of US cities. Mahdavi et al. [20] performed energy simulations of buildings in the city of Vienna, comparing predicted annual heating and cooling demands when using different climate datasets for the studied location. Wall [13] investigated the influence of different indoor air temperature set-points, internal heat gains and solar heat gains on peak load and annual total energy demand of a Swedish building. Karlsson and Moshfegh [21] and Poirazis et al. [22] assessed the impact of different indoor air temperature set-point scenarios on the predicted heating and cooling energy demand of buildings in the Swedish context. Karlsson et al. [14] investigated the potential impacts of different tenant behaviours and variations of internal heat gains, ventilation airflow rate and ventilation heat exchanger efficiency on the predicted energy demand of a Swedish low-energy building. Zhao et al. [23] simulated heating and cooling demands of buildings in different climate zones in China and explored the effects of variations of key parameters influencing the buildings thermal performance including air infiltration rate, thickness of building envelope insulation and windows U-values, external solar protection including shading co-efficient of windows, and wall to window ratios. Molin et al. [24] studied the calculated and measured energy use of low-energy buildings in Sweden and examined how the calculated energy use change from a baseline when different parameters are varied such as internal heat gains, windows solar transmittance value and orientation, air flow rate, wind speed, solar radiation, thermal envelope characteristics, and ventilation heat exchanger efficiency. Dodoo et al. [17] simulated the final energy use of a Swedish building and explored the effects of variations of key parameter values on predicted final energy use and energy savings of different energy retrofit measures. The explored parameters are connected to building envelope, occupancy behaviour, ventilation, microclimate, and heat gains from electrical equipment and persons. Many studies as reported above focused on the influence of individual input parameters and did not consider the combined effects of different assumptions and uncertain input parameters simultaneously.

In this paper, we use dynamic simulation to explore the impacts of different assumptions and parameter combinations on energy balance calculations of buildings. Our analysis builds on an earlier study [17] and it is based on key input parameter values and assumptions commonly used in Sweden for energy balance analysis of residential buildings. The considered parameters are related to micro climate, buildings' thermal envelope, and end-use household electrical equipment and technical installations in buildings.

2. Methods

2.1. Overview

We conducted detailed simulations with a dynamic hour by hour energy balance model to investigate how combinations of different input parameters and assumptions as well as their interactions affect the calculated energy demand of buildings in the Swedish context. Our analysis is based on existing and energy-efficient versions of a case-study building, representative of a typical Swedish multi-storey building stock constructed in the 1970s. Summarily, our approach consists of:

(i) modelling energy balance of existing and energy-efficient versions of the case-study building using selected reference input parameter values and assumptions;
(ii) defining potential combination and interactions of different key input parameter values and assumptions to be modelled; and
(iii) modelling and analysing the effects of interaction between the defined parameter values and assumptions on the calculated energy balance of the building versions, using the reference energy demands as baseline.

2.2. Description of case-study building

The building is a 3-storey concrete frame multi-storey residential building built in the 1970s in Ronneby municipality (latitude 56.26, longitude 15.27), Sweden. Fig. 1 shows a photograph of the west façade of the building. The building with facades of bricks and wood panels comprises 27 apartments with a total heated living floor area of 2000 m^2, and a 600 m^2 basement below ground level. The total ventilated volume of the building's living area is 5400 m^3. To compare the impacts of parameter interaction for buildings of different energy efficiency levels, a new building version is modeled with improved thermal envelope properties but otherwise identical to the existing building. The modelled energy efficiency measures are based on Dodoo et al. [17]. The energy-efficient version is modeled to meet the specific energy requirements of the Swedish passive house criteria [25] and has lower thermal envelope U-values as well as improved airtightness compared to the existing building. The airtightness of the building in its existing condition is taken to be 0.8 l/s m^2 at 50 Pa, based on [26], and this is assumed to be improved to 0.6 l/s m^2 for the energy-efficient version after implementing energy efficiency retrofit measures. The thermal characteristics of the building envelope elements in the existing and energy-efficient versions of the building are presented in Table 1. The U-values for the windows are for the complete system, including the glazing and framing. For the existing building, the windows have clear double glazing with air cavity and g-value of 0.76. For the energy-efficient building, the windows have

Fig. 1. The case-study concrete-frame building in Ronneby, Sweden.

Please cite this article in press as: Dodoo A, et al., Influence of simulation assumptions and input parameters on energy balance calculations of residential buildings, Energy (2016), http://dx.doi.org/10.1016/j.energy.2016.11.124