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Heat loss rate of the Finnish building stock

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Abstract

This paper presents a bottom-up model for studying the heat loss rate of the building stock. The model is a step towards more complex building-stock power modeling, whose goal is to predict the sources and the amount of demand response potential under different conditions. The heat loss rate is the fraction of thermal power needed to compensate for the heat loss via exterior walls, windows, roofs, floors and ventilation in the buildings. The heat loss rate depends on the physical characteristics of the building envelope and ventilation and on weather conditions.

We first examine the current state of power and energy modeling. We then describe the research object of this study and the calculation method. The calculation results presented in the third section are illustrated at the hourly level, sorted by the main source of the heating energy of the building. In addition to the analysis of the building stock level, the heat loss rate was calculated on a building level using some typical building information models for validation purposes. The validation indicated that the results obtained with the two methods were consistent and that the order of magnitude was reasonable. The Finnish building stock was used as a research object in the demonstration of the model. Finally, some further needs for research are discussed.

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*Keywords:*buildings stock; energy systems; heat loss rate; power modeling

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1. Introduction

Energy efficiency is a central issue in the fields of both politics and academic studies. The European Union has set targets to significantly reduce the annual consumption of primary energy and greenhouse gas emissions by 2020 (Directive 2009/28/EC). Legislation supporting this development has been widely enacted on national levels. Furthermore, the amount of regulation related to energy efficiency is continuously growing. A number of studies have been carried out regarding the energy consumption of building stock (Balaras et al. 2005; Balaras et al. 2007; Dascalaki et al. 2011; Howard et al. 2007; Magalhães and Leal 2014; Mata et al. 2013; Tommerup and Svendsen 2006).

In the Nordic climate, such as in Finland, the peak power consumption maxima occur in winter when the use of heating energy is at its highest. Although the highest power peaks appear during winter, the peaks are not only a phenomenon of the coldest season. Power use varies as a function of time every day throughout the year. The power and energy use of buildings is influenced by different factors, such as the weather, the physical characteristics of the building, HVAC systems and their settings, building automation and the behavior of users (Zhao and Magoulès 2012).

The capacities of both the power distribution network and the power production infrastructure are sized based on the estimated maxima of power usage. Thus, the investment costs of the energy distribution and production systems depend on the expected future peaks. For example, in Finland there are reserve electric power plants on standby for exceptional power demand situations. These power plants have a low annual utilization rate. The additional fuels used during the power demand peaks consist mainly of fossil sources. Thus, if the power demands of the buildings could be managed more successfully, the need for additional reserve power plants would be lower, possibly leading to both economic and environmental benefits.

To better manage the power use, there have been theoretical discussions - and currently even practical applications - on so-called demand response, in which the timing of energy consumption is managed. Energy consumption is managed with the help of signals based on prevailing conditions outside of the place of energy consumption (Jota et al. 2011). In demand response, at least part of the energy consumption is timed based on an indicator of the demand situation, such as using the hourly energy price in the energy markets or the current electric power frequency as an input signal. The demand response can be an automatic or manual process. It can also be used to even out the differences in power demand in both peaks and gaps and to help adjust the energy systems. Energy users can participate in reducing the peaks of energy systems by cutting their consumption. This can be done, for example, by changing the timing of the energy use or by changing the energy source (Albadi and El-Saadany 2008).

When energy efficiency is examined, the focus in the building sector has often been on the total energy consumption during the investigated period of time, such as one year. Current construction regulations guide the evaluation of energy consumption in buildings at the annual level. For example, in the calculation of the E-value, the target of the inspection in energy calculations for construction permits or energy certificates is currently stated as the annual energy consumption. However, from the perspective of the entire energy system, not only the total annual energy consumption but also each instance of consumption is important. The situation may be changing. In the Energy Performance of Buildings Directive (2012/27/EU), power management and its demand response were seen as a part of energy efficiency. This mode of thinking is progressing toward national legislation of the EU's member states.

We have developed a model for estimating the heat loss rate in building stock with the goal to predict the amount and the sources of demand response potential in different situations. By the heat loss rate we mean the thermal power needed to compensate for heat loss via the walls, roof, floor and ventilation in the buildings (fig. 1). This method is introduced and demonstrated in this paper.