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Replication studies

Influence of an unheated apartment on the heating consumption of residential building considering current regulations—Case of Serbia

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ABSTRACT

District heating system brings with it the problem of achieving a fair billing service for heating of apartment buildings in the case of uneven temperature in them. The problem is most pronounced when the individual apartments are completely excluded from the heating system of the building. The model of an existing building with 24 apartments was simulated in the software EnergyPlus, for different characteristics of the thermal envelope and different conditions of use, when the apartment with the lowest energy consumption is excluded from the heating system. It was simulated the exclusion of this apartment in which people are present and the lights and electrical appliances are turned on and in which there is no presence of people and electricity consumption (the apartment is empty). As a measure of energy flow between unheated and adjacent apartments, the parameter "stolen" energy is defined. The results of the conducted simulations show that the stolen energy is reduced by the exterior and interior insulation of the building. In this paper, data on energy flow when there is interior insulation in apartments, in particular according to the current regulations in Serbia, are especially analyzed. The results show that, depending on the case and scenario, the stolen energy ranges from 27.23 to 7.97 kWh/m^2. The insulation of interior walls of the building can significantly mitigate the problem of energy flow due to temperature differences between apartments.

1. Introduction

Reduction of specific energy consumption and increase of energy efficiency are the activities of the world community about which there is practically unanimous approval. Distribution of final energy consumption by sector is important information that affects the strategy of increasing energy efficiency. A sector that, almost without exception, consumes most of the final energy in the world is building sector. Thus, the EU building sector consumes 41% of final energy [1]. Due to the geographical position of the majority of EU member states, which means colder climatic conditions, much of the final energy consumption in buildings in the EU is related to the heating and provision of thermal comfort in the rooms. For the EU countries this part is in average of 67% [1]. In the EU there is a clear tendency to move share of energy sources for building heating towards those more efficient and environmentally acceptable. Natural gas and electricity (heat pumps) are the sources of energy for building heating, which are prevalent in the EU (39% + 25%, respectively). District heating systems, once a significant source of heating in urban areas, consists of a share of only 7% in the EU [1]. Combustion of fossil fuels in power plants of district heating systems brings with it additional costs of heat transport and employees, and there are increased losses of the system in transitional periods of heating. Economic feasibility of district heating systems can still be found in cogeneration or specific systems such as incinerators. A larger share of district heating systems in EU member states can be found in the Baltic and Eastern European countries.

In Serbia, a candidate country for EU membership, the building sector consumes 38% of final energy and heating needs of buildings have a share of 65% in this consumption [2]. The share of district heating systems in Serbia is significant and amounts to 22% [3]. The mentioned problems with the competitiveness of the heating price of district heating system, make this system in Serbia more economically uncompetitive. The district heating system brings with it additional problems related to a fair billing service for heating in buildings with a large number of apartments. Despite the possibility of measuring of heating consumption within the building, apartment or each radiator, buildings with a large number of apartments bring the problem of heat flow through the interior walls of the building, due to the uneven temperatures in the rooms, which

Abbreviations: L, living room; B, bedroom; BT, bathroom; K, kitchen; H, hall of the apartment; P, pantry; HB, hall of the building; Apt., apartment.

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Nomenclature

U	Overall heat transfer coefficient of the building construction (W/m^{2}K)
q_{st8}	Amount of "stolen" specific energy consumption of the apartment 8 (kWh/m^2)
Q_{st8}	Stolen energy consumption by the apartment 8 (kWh)
Q_{I8}	Energy consumption of the apartment 8 for scenario I (kWh)
Q_{totI}	Total energy consumption of the building for scenario I (kWh)
Q_{totII}	Total energy consumption of the building for scenario II (kWh)
A_8 (m^2)	Floor area of the apartment 8
Q_{totIII}	Total energy consumption of the building for scenario III (kWh)

can occur for several reasons. One of the current problems in the district heating billing service system in Serbia is exclusion of individual apartments in the building from district heating system, due to the high prices of this service. In these specific cases, different companies, district heating service providers, still account billing service to the excluded consumers in buildings in certain percentage of the full price, which is caused primarily by indirect heating of a given apartment through the interior walls of neighboring apartments (consumers). This percentage is in Serbia very different from company to company, ranging from 10 to 50% compared to the full price of heating service.

Problem related to a fair billing service for district heating in buildings with a large number of apartments is actual in the EU, too. Heat transfer inside the building with a large number of rooms of different temperatures is a complex process, which is very difficult to be accurately measured. A larger number of researchers has contributed to overcoming the problem of energy flow in buildings with a large number of apartments. By its Directive 2012/27/EU, the EU provides the measurement of heat consumption in apartments, either by measuring at the entrance of the apartment (if there is a horizontal distribution network), or by measuring on each radiator separately. However, the complex problem of heat flow after this Directive remained unresolved and actual. In [4] the reduced consumer interest in Sweden for the billing of energy (and hot water) by measuring in each apartment was indicated, although in general billing by the consumption stimulates awareness of consumers about need to conserve energy. The reason lies in the high standards of energy efficiency in Sweden and low specific heating consumption, where the division of the billing, per apartment, based on consumption does not have necessary effects. The authors also emphasize the problem of heat transfer between apartments that is not regulated by the mentioned Directive of the EU. The authors in [5] point to the lack of information and lack of interest of the consumers about the possibility of adjusting the thermal comfort in buildings or the unavailability of easy adjustment of the existing heating systems. All these problems and conditions affect the diversity of the temperature in the building rooms. The authors in [6] proposed the method for correction of billing of energy consumption because of the possible large energy flows between the apartments. Also, the authors indicate the complexity of the problem and the large number of influencing factors, as well as the problem of too high costs of additional measurements in apartments. Similarly, the authors in [7] propose an original method for the recording of transferred (stolen) energy in the apartment buildings. In the paper the complexity of the problem and the large number of influencing factors was emphasized. A certain group of authors used the available software for simulating the energy flow in complex systems of buildings between associated apartments, to indicate the possible and significant flows of energy caused by uneven temperatures, heat gains and losses, the inertia of the system. In [8] the authors used TRNSYS simulation software for modeling imaginary building-hotel and proposed the model for prediction of heat flow between building rooms which upgrades energy distribution based only on the measurement of energy. The authors in [9] and [10] use the software IDA ICE for modeling of existing buildings in order to point out the problem of energy flow between the apartments in the building. In [9] the authors simulated the flow of energy in the existing three-stories building with 18 apartments for several proposed scenarios. As expected, the highest consumption of energy in the near of unheated apartment have apartments with a largest contact surface (floors and ceilings). The increase of the energy consumption of adjacent apartments in relation to the base model was over 20%. In [10] the authors observe particularly energy flows through certain envelope elements of unheated apartment or apartment with different temperature in relation to the adjacent apartments and indicate the amount of heat flow. In [11] the authors used EnergyPlus software for modeling three-story building with 50 apartments. Within the various simulation scenarios the authors point to possibility of using energy flows from adjacent apartments to reduce heating costs according to existing tariff systems.

These papers emphasize the problem of energy flow in apartment buildings and uneven temperatures in them. Defining a fair billing system in buildings with district heating system is a very complicated task. A large number of factors may affect the energy flow. Increasing the number of measuring devices can be economically discouraging. All of the mentioned simulation models consider buildings with uninsulated interior walls which separate the apartments, and the energy flows lead to significant changes of the heating consumption of adjacent apartments. The question is whether it is necessary to invest in additional measurements of energy consumption and the development of a model for the distribution or perhaps it is a better solution to insulate interior walls in order to significantly reduce the mutual influence of apartments.

The aim of this paper is to obtain data that define mutual influence of adjacent apartments with uneven temperatures on the energy flow. In order to get the results as close as possible to the reality, a classic, existing residential building with multiple apartments was chosen for the model. In particular, the basic idea was to obtain data on the thermal behavior of the building with a zone (apartment) with lower temperature in relation to the rest of the building, in different simulated scenarios. This is an increasingly frequent case within the district heating systems in Serbia (exclusion of the apartment from the heating system of the building). According to the reviewed literature, the novelty of this paper is the obtaining of data on the thermal behavior of the building with a cold zone, when it is thermally insulated from the rest of the building, which is, among other things, envisaged by the current Regulations on Energy Efficiency of Buildings of the Republic of Serbia [12]. Also, as a measure of energy flow between unheated and adjacent apartments, the parameter "stolen" energy is defined. Expected information will help to solve the problem related to a fair billing service for district heating in the described situations.

2. Simulation model

2.1. Building model

The investigated building is an existing residential building in the city of Kragujevac (Serbia), with 24 apartments in four levels