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A simulation appraisal of a switch of district to electric heating due to increased heat efficiency in an office building

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ABSTRACT

This research addresses the existing phenomenon in Eastern Europe related to office buildings heated by district heating. For enhanced heating efficiency, an office building is thermally insulated and/or run at a decreased space temperature. After that, in an office inside the building, the tenants may switch from district to less costly electricity heating due to the customary tariffs for district and electrical heating. The effects of this switch are analyzed by using software EnergyPlus. For the investigated office, it is found that a characteristic value of its heat consumption exists below which the heating switch decreases heating costs. In addition, the value of the heat consumption is recognized below which the heating switch also yields the decreased fossil fuel consumption and CO_2 emission. For all cases, the consumed heat consumption, the consumed fossil energy, CO_2 emission, and economic effects are recorded for heating devices in the excluded office. Furthermore, it is analyzed how these variables are influenced by heat transfer between the investigated office, and the adjacent offices.

1. Introduction

Scientific evidences of climate change and effects of greenhouse gases emissions have become obvious. Energy use in all types of buildings represents a huge portion, about 40%, of the total EU energy consumption. In Eastern Europe to enhance heat efficiency and decrease heat consumption in office buildings heated by district heating (DH), their adequate refurbishment and use turn out to be a priority. Although these measures should yield environmental benefits for society through a reduction in the fossil energy consumption, and thus, the CO_2 emissions, it is noticed that after decrease in heat consumption by refurbishment and low-heat use, the office owners would exclude their offices from DH. In the excluded offices (EOs), they will replace DH with electrical heating (EH). Namely, EH proves to be cheaper than DH. Then, this may diminish energy and environmental effects of refurbishment and yield to higher use of fossil fuels and larger emissions of CO_2 to environment.

The motive for this investigation is the situation with the public DH in the city of Kragujevac that there are many requests to exclude offices from the DH and heat them by electricity as the electrical heating is cheaper. The cheaper electricity heating in the EO may exist because of several reasons that can act separately or together: (1) reduced heat consumption due to better thermal insulation of the building, (2) reduced heat consumption due to the lower temperature in the EO, (3) existing tariffs for heating by different heating systems, and (4) the existence of the inter-unit (office) heat flows (IUHFs). These phenomena may yield to additional fossil energy consumption and additional CO_2 emissions in atmosphere. When there are no regulatory and legal acts, this space is very easy to switch to another system of heating. This situation may establish additional energy policy in some country that will ban the exclusion of these offices from DH or ask for the fulfilment of some additional conditions to approve the exclusion.

Lower heating price by electricity due to in-force district heating tariffs was noted by Bahnmueller et al. [1]. Namely, they found that there are quite a lot of cases, where tenants which switched to using electricity, pay much less than their neighbors still supplied by district heating. Gustafsson [2] concluded that DH prices must be competitive with the prices of EH when retrofit measures are used on existing buildings.

The most significant issue of prices for consumed heat relates to the influence of heat prices on an amount of the decrease in the fossil fuel consumption and CO_2 emissions by energy efficiency actions. Due to different heat tariffs, the heat costs differ, and in most cases the reduction in heat consumption lowers the heat costs for tenants. However this dependence may be either stronger as in the case of electricity or poorer as in the case of DH. At the other hand, it is noticed that the reduction in the heat consumption sometimes may yield to increase in the fossil fuel consumption

Abbreviations: DH, district heating; EH, electrical heating; EO, excluded office; IUHF, inter unit heat flow.

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Nomenclature

c	heating cost, €/m^2
f	fossil energy, kWh/m^2
F	fossil energy equivalent, –
m	CO_2 emission, kg CO_2/m^2
M	CO_2 equivalent, kg CO_2/kWh
q	heat, kWh/m^2
S	usable floor area, m^2
t	temperature of the excluded office, °C
t_n	temperature of neighbor offices, °C

and CO_2 emissions. Rolfsman [3] reported that the reduction in the heat consumption reduces a generation of electricity in CHP plants. The lower generation of electricity has to be covered with the electricity generation from coal condensing plants. This actually means increase in the fossil fuel consumption and CO_2 generation. Here, in this paper it is reported that the reduction in the heat consumption by different heat efficiency measures may yield the use of electricity instead of DH and thus the increase in the fossil fuel consumption and CO_2 generation.

If the tenants try to save electrical energy by reducing the space temperature in the offices IUHFs appear. Then, for its heating, the EO also uses the heat of DH from the neighbor offices. This situation is so called "heating theft" as it is an additional consumption of heat that costs something but it is not paid by the office owner. However, the costs for this energy are either paid by other users that are connected to DH or they are paid by the heat plant if for this building, the district heating payment is flat by the heated volume.

The existence of the IUHFs in the multi-unit buildings heated by DH is noted by several researchers. Yao et al. [4] suggested that in the multi-unit buildings, heat may be delivered as heat transferred through the wall from the warmer unit to the other adjacent ones, and the warm air rising from lower units to the higher ones. Pakanen and Karjalainen [5] theoretically verified IUHFs in a public building. As noticed by Kazakevicius et al. [6], such metering gives the EO owner an incentive to lower its own heat (and temperature in the EO) and "steal heat" from neighbors, i.e., permit heat from neighbors to leak through their own walls. However, nobody paid attention to the situation when the EO has higher temperature then the neighbor offices and heats them.

The paper reports an investigation of an office building heated by DH, when there is switch from DH to EH in the EO. For higher heat efficiency, the building is either refurbished and/or air temperature is decreased in the EO. After these measures if it is cheaper, the tenants switch the DH to EH in the EO. The consequence of this action is analyzed by using software EnergyPlus. Space heating is simulated during the 6-month heating season in Kragujevac, Serbia. Two characteristic values of the equal cost and environmentally friendly heat consumption will be introduced and calculated to find what the heating switch means for the heating costs, fossil fuel consumption, and CO_2 emissions. For the heat efficiency measures, the consumed heat, the fossil energy, CO_2 emissions, and heating costs are recorded for heaters at the EO during its either DH or EH. Furthermore, it is analyzed what are the actual amounts of the consumed heat, the fossil energy, CO_2 emissions, and heating costs at the EO when the EO is either sub-heated or over-heated.

2. Model

To obtain the data on heat consumption in some buildings, either measurement or software simulations may be done. To do adequate measurements, the application of relevant measuring instruments (calorimeters, thermometers with data loggers) requires high investments. Accordingly to model the office building, EnergyPlus software is used and the required data are obtained by using EnergyPlus simulations.

2.1. EnergyPlus software

To simulate heating, cooling, lighting, ventilation, water network, and other mass and energy flows in a built environment, EnergyPlus software may be used [7]. This software may model energy use in a residential building. EnergyPlus takes into account all factors that influence thermal loads in the building, such as they are electricity devices, lighting, pipes in the building, solar radiation, wind, infiltration, and shading of open rooms. This software enables us to simulate energy behavior of the residential building for defined period. The software is intensively validated [8]. The software was already used for the research in multi-storey buildings (see Chidiac et al. [9] for such investigations in similar moderate climates like in Serbia).

In Fig. 1, the model of the investigated building is shown in OpenStudio plug-in used Google SketchUp environment [10]. Google SketchUp is a program for 3D modeling. One way to define the geometry of the building in EnergyPlus is by using text editor; however, the OpenStudio plug-in saves a lot of time that is useful when modeling this multi-office building. In addition, to save time, it is important to use relative coordinates.

2.2. Description of the building

The simulation is performed for an office building in Kragujevac built in 1962 and retrofitted with thermal insulation in 2010

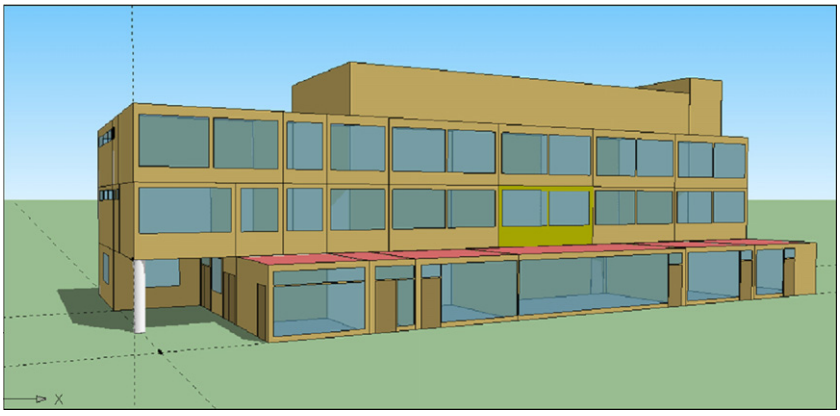

Fig. 1. Appearance of the office building.