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Prediction of the HVAC energy demand and consumption of a single family house with different calculation methods

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Abstract

In this study a comparative energetic analysis is investigated of a single family house with different calculation procedures. One of the methods that were used is the Ministry without Portfolio Decree No. 7/2006 for energy certification and MSZ-140-04 for energy demand calculations (by using WinWatt computer software) that are a widely used in the Hungarian practice by HVAC designers and experts. Passive House Planning Package (PHPP) is also more and more common used PC software in Hungary due to the continuously tightening energy requirements. To see the differences and imperfections between these methods the heating, cooling and ventilation system was designed of a given single family house and the annual energy consumption was investigated with these methods. To perform the investigation in more detailed three different heating systems were designed. In the first case the heat source is a condensing boiler operated with floor heating. In the other two cases the thermal systems are heat pumps with floor and ceiling heating. One of the heat pumps is an air-to-water system, the other one is a geothermal heat pump. The advantages of the heat pumps are that heating, cooling and domestic hot water energy is produced by only one equipment and efficiency. However comparing investment and operating costs for the heat pumps with gas boiler the payback time is very long based on this study. The investment costs, payback periods are investigated for the three different systems evaluating the results also with PHPP and WinWatt computer software tools in this study.

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Keywords: energy consumption ; heat pump ; passive house

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1. Introduction

The energy efficiency of buildings is regulated by the EU acquis [1] and national legislation [2]. By 2018 buildings in the public sector there will be more and more nearly zero-energy (nZEB) and, by 2020, this will apply to all buildings [3]. The definition of a nZEB will be, at least, within the limits of the requirements set for buildings which are currently optimally energy-efficient, including passive houses. A passive house is a proven path that leads to a sustainable building [4], and has been recognized in Europe, in terms of its methodology, almost for two decades [5]. Owing to energy flow optimization, passive houses save 80–90% of space heating energy in comparison with conventional buildings [4]. The energy efficiency of the passive house standard is demonstrated by the large number of passive houses (39,390) that have been built in Europe as of 2012 [6], and their number increases. A passive house [5] requires a maximum of 15 kWh/(m2 year) of useful energy for heating purposes. Low transmission heat loss is achieved by well-insulated and airtight building envelopes without thermal bridges [7]. A passive house has an integrated controlled ventilation system with exhaust air heat recovery, which reduces heat loss due to ventilation [8-10] and provides healthy indoor air quality [11-12]. Heat loss under a peak heating load in the heating season is kept under 10 W/m2 and can be covered by hot air heating [13]. Such houses eliminate the need for conventional heating systems [14]. Heat pumps are increasingly used to generate heat [15, 16]. The evaluation of the energy efficiency of residential buildings through the use of different simulation tools, as well as a partial methodological evaluation for the energy efficiency of individual building components, requires the use of a large number of parameters. This is also true for the PHPP'07 tool, i.e. the Passive House Planning Package – The energy balance and Passive House design tool [17], which had been developed in Europe to provide support to designers in the overall planning of highly energy efficient buildings. Since the use of the tool requires more project data, it cannot, for example, be used in the preliminary design phase for planning a building. Passivhaus Planning Package (PHPP12) is a simplified steady state building simulation tool that is primarily targeted at assisting architects and mechanical engineers in designing Passivhaus buildings [18]. Passive buildings compared to the standard ones require significantly less energy for heating and ventilation, while internal heat gains are almost the same. The energy demand for heating in passive buildings is less than 15 kWh/m2, while for example in new residential in Poland – 60–120 kWh/m2 [19]. Heat gains cover about 20% of whole energy loss in the case of a standard building and up to 65% in a passive house [20]. This fact leads to two important conclusions. Firstly, increasing the heat gains, e.g. by appropriate orientation of windows, may contribute to a significant reduction of energy need for heating [21-28]. Maximization of gains can at the same time cause increase of energy need for cooling, which was confirmed in the article of Enshen [29]. Secondly, a fluctuation of internal heat gains can cause significant change of the internal air temperature and requires specific control strategies. Appropriate control is necessary to obtain good thermal comfort as well as high energy efficiency. Because of it to predict correctly the internal environment conditions in a very low-energy buildings (like passive buildings – nearly zero-energy buildings) and calculate correctly their energy needs, precise building and system models have to be used. What is even more important, much attention should be paid to the appropriate determination of internal heat and moisture gains as well as airflows between building zones, all of which factors are often determined in a simplified way. For example, simplified methodology defined in standard ISO 13790 [30] can be suitable for buildings with standard energy need, but for very low-energy buildings the methodology has to be more precise. Otherwise real energy performance of buildings can be higher than calculated and energy savings lower than predicted. This aspect is particularly important due to the recast of the Energy Performance of Buildings Directive and implementation of 'nearly zero' energy buildings [31]. The aim of this research was to compare the existing national standards: Decree No. 7/2006 (Degree) based on Energy Performance of Buildings Directive; MSZ-140-04 based on heat loss and heat gain calculation with Passive House Planning Package (PHPP) to evaluate the HVAC energy consumption of a single family house in Hungary. Additionally during the comparison three different HVAC systems were designed to the house: (1) condensing boiler with floor heating; (2) air-to water heat pump with floor heating; ceiling heating and cooling; (3) ground source heat pump with floor heating; ceiling heating and cooling. In each case the house is supplied with fresh air by air-to-air heat recovery ventilation system. Based on the different designed systems the investment costs are determined. Using the existing national standards and PHPP the annual energy consumption of the designed HVAC systems are predicted. By this way the payback time is calculated, the calculation procedures are also compared and differences are investigated.