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Reducing energy consumption in low energy buildings through implementation of a policy system used in automated heating systems

Mihail-Bogdan Carutasiu[a], Vladimir Tanasiev[a,*], Constantin Ionescu[a], Alexandra Danu[a], Horia Necula[a], Adrian Badea[a,b]

[a] University POLITEHNICA from Bucharest, Romania
[b] Academy of Romanian Scientists, Romania

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ABSTRACT

The objective of this article is to analyze the opportunity of the nearly zero energy building (nZEB) concept implementation in Romanian climate conditions. Similar with the values in European Union, the largest share of energy consumption in Romanian buildings is due to the interior space heating. Therefore, our study was concentrated on energy consumption and interior comfort level of the low-energy house, built in the campus of POLITEHNICA University of Bucharest. The study house was built in accordance with the Passive House Institute (PHI) standards and it's equipped with a monitoring and data acquisition system for research purposes. The implemented Smart Building Controller (SBC) has an execution mechanism driven by a complex set of "policies", which activates the heating system. It was found that the implementation of the SBC assures an optimal interior comfort and the total energy consumption for heating didn't exceed the value imposed by the PHI (15 kWh/m^2/year). The energy balance analysis indicates that the total energy consumption can be covert in a major percentage by the energy production system (photovoltaic panels), making the nZEB concept an achievable goal.

1. Introduction

The European Union (EU) energetic strategy aims a drastic reduction in domestic greenhouse gas emissions up to 80% by 2050 compared with 1990 levels, by reducing the energy consumption in key sectors. The building sector is responsible for a major share of GHG emissions (35%) and it is the largest end-use energy consumer in Europe, with a total share of 40% [1–3]. It is followed by transport (32%) and industry (25%) sectors [4,5]. It is estimated that by the 2050 the building stock will increase with 25% [6], therefore this sector requires important measures to reduce the energy dependency and implicitly the greenhouse gas emissions.

In this respect, in 2002, it has been issued the Directive on Energy Performances of Buildings (EPBD), which required all EU members to develop and improve their energetic strategy by introducing energy consumption certification schemes for buildings [7]. The recast published in 2010 came with even more ambitious plans and introduced "nearly Zero Energy Buildings" (nZEB) principle as a future requirement to be implemented from 2021 onwards for all new buildings. A nZEB is defined as: "*a building that has a very high energy performance [. . .]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby*" [8]. Implementing this concept as a cornerstone for new and retrofit buildings it is expected to reach a main energy savings of 27% for residential sector and 30% for the tertiary sector by the year 2020. This saving scenario will reduce the energy production across the EU by 11% [9].

Moreover, the EU's Energy Efficiency Plan from 2011 states that "*the sectors that deserves the highest attention are residential, tertiary and transport*" among which, the residential sector has the biggest technical potential for increasing the energy efficiency, estimated at 30% [10].

The building stock in Romania consists of 5.1 million buildings of which more than 99.6% are residential buildings [11]. Since 1992, the final energy consumption in household sector increased every year and by 2009 it surpassed industrial consumption [12]. The percentage of final energy used in building sector is higher than the average in EU, stated at 44%, followed by industry (30%) and transport sectors (26%) [5]. The main specific energy consumption for an apartment is 340 kWh/m^2/year and for an individual house 412 kWh/m^2/year from which, more than 55% is used for heating.

* Corresponding author at: Universitatea Politehnica din Bucuresti, Facultatea de Energetica – Corpul EH, Splaiul Independentei nr. 313, sector 6, Cod: 060042, Bucuresti, Romania. Tel.: +40 740316935.
E-mail address: vtanasiev@gmail.com (V. Tanasiev).

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Fig. 1. POLITEHNICA low-energy building.

Comparing this values to the ones indicated by low-energy building concepts (passive houses, intelligent buildings, minergie, effinegie, etc.) it is found that there is a high potential for reducing energy consumption in this sector. According to Romanian Energetic Strategy for 2007–2020 [13], it has been identified an energy efficiency potential of 35–50% for residential sector and 13–19% for tertiary sector in Romanian building stock.

The implementation of the EPBD recast in Romanian national strategy didn't stipulate the framework for nZEB and in October 2013 Romania was formally requested by EU Commission to ensure full compliance with its obligations under EU legislation regarding energy efficiency in buildings. This infringement procedure was started for not notifying the Commission of national measures to transpose the directive into national law [14,15], as required for all members by 2013.

Even if the implementation of nZEB in Romanian legislation is imposed by the EU Commission, the number of buildings that meet the standard is low. The studies conducted so far [16–19] regarding the possibility of implementing very efficient buildings shown that the passive house standard is applicable in Romanian climate conditions. By increasing the thermal insulation in a building envelope and usage of renewable energy sources in the energy balance, the implementation of nZEB is an achievable goal.

2. The low energy building

2.1. Passivhaus standard

The "passivhaus" term refers to an energy-efficient standard for buildings, developed and implemented by the Passivhaus Institute from Germany. It is a specific standard for buildings, which succeeded to maintain a year-round good internal comfort with minimum specific energy consumption and without using active heating and cooling systems [20]. This can be achieved through a combination between a special type of architecture, compact shape, very good insulation level with minimal thermal bridges, high air tightness, optimal use of external and internal heat gains, and a high efficient mechanical ventilation and heat recovery unit (MVHR) [21,22].

The requirements for a house to be certificated as passive refers to energy demand for heating and cooling (less than 15 kWh/m^2/year), total primary energy demand (less than 120 kWh/m^2/year – regardless of energy sources), total heat load (less than 10 W/m^2), air-leakage at a pressure of 50 Pa (less than 0.6 air changes per hour) and *U*-values for the envelope (less than 0.15 W/m^2/K for the opaque elements and under 0.8 W/m^2/K for the windows) [23–25].

Using this standard combined with a very efficient heating, ventilation and air conditioning (HVAC) system based on renewable energy sources, (geothermal heat pumps, earth-to-air heat exchangers – EAHX, pellet stove, etc.) the energy demand for heating has been reduced by 80% compared with conventional buildings and by 75% compared with new buildings [23,25]. The total construction cost does not exceed the cost of a typical building by more than 16% with a payback time of investment of 18 year, supposing that the energy costs registers an annually growth rate of 10% [26].

2.2. The case study house

Applying the Passivhaus Standards, a low-energy building was built in University POLITEHNICA of Bucharest (UPB). The duplex (Fig. 1) consists of two-floor identical buildings with a total treated area of 140 m^2 each. The HVAC system is different in each house. The east house is equipped with an EAHX (detailed in the next chapter), while the west house uses a geothermal heat pump. This paper focuses on the east house, which is used for research purposes (also termed "Laboratory House"). In this regard, it is equipped with a monitoring system described in chapter 4.

The occupancy schedule is different from a standard house and during the night the house is unoccupied. The energy consumption by activity also is atypical compared with a standard building (the living room counts for more than 40% of total, while the kitchen for just 3% as detailed in chapter 6), due to the occupancy distribution and no cooking activities.

The materials used for the envelope and the windows of Laboratory House have high thermal performances which are described in Table 1. The *U*-values for the opaque elements (roof, exterior walls and ground floor) are lower than 0.15 W/m^2/K. The exterior triple-glazing windows have a *U*-value of 0.6 W/m^2/K and total solar absorbance coefficient (*G*-value) of 50%, complying with the recommended values stated in Passivhaus Standard.

For domestic hot water production the house is equipped with a solar panel system, a 200 L hot water tank, and an electrical resistance for peak periods.

A part of the energy consumed for operating the house is provided by a photovoltaic panel system connected to the grid, thus avoiding the need for energy storage system. As is shown in Table 2, the total nominal power of the PV panels is 2.9 kW.

3. The HVAC system

The studied low-energy house is equipped with an HVAC system composed of two heat exchangers: earth-to-air heat exchanger and double-flow mechanical ventilation with heat recovery unit