ISSN 2004-2965 Energy Proceedings, Vol. 22, 2021

International Conference on Applied Energy 2021
Nov. 29 - Dec. 5, 2021, Thailand/Virtual
Paper ID: 857

Energy Performance of the Millennium Buildings (1992 – 2014) in Latvia

Ruta VANAGA[1*], Ritvars FREIMANIS[1], Juris ANTUŽS [1], Zigmārs ZUNDĀNS [1], Andra BLUMBERGA [1]

[1]Institute of Energy Systems and Environment, Riga Technical University, Āzenes iela 12/1, Riga, LV-1048, Latvia

ABSTRACT

In the light of decarbonsation of existing building stock energy efficiency performance of all building periods should be evaluated. The focus of the paper lies on building built after the collapse of the Soviet Union and before stringent energy efficiency measures came into force. Complex analysis of energy performance parameters, indoor air quality, and in-situ measurements of thermal resistance of walls were performed. Results show that legislative norms have a significant impact on the thermal performance of thermal envelope, but there are no significant changes in ventilation heat losses. Analysis of energy consumption for heating indicates that the energy efficiency benchmark set for renovated buildings in Latvia is set too high and does not promote decarbonisation of existing building stock.

Keywords: decarbonisation of existing building stock, heating energy consumption; indoor air quality; thermal resistance in-situ measurements; transmission heat loss coefficient; ventilation heat loss coefficient

1. INTRODUCTION

To fight climate change, the EU has set the goal to become climate neutral by 2050 [1]. To decarbonize existing building stock it has to overcome renovation wave aiming to achieve nearly zero-energy level as the amendment in the EU Directive on the energy performance of buildings suggests [2].

The building stock in Latvia can be divided into four main groups: <1945; 1946 – 1991; 1992 – 2014, and new buildings complying with energy performance norms.

To first two group studies have been conducted in Latvia analyzing soviet time buildings [3], [4], state of art retrofitting strategies for historic buildings [5], energy performance particularly of historic brick buildings as well as in other former Eastern block countries Lithuania dealing with similar issues – renovation of historic and soviet time buildings [6]–[8], Estonia [9]–[11] and others [12], [13]. Studies cover lifecycle perspective in building renovation, energy efficiency goals as well as indoor air quality.

Buildings built in 1992 – 2014 are the "grey area" – there is no general knowledge of this period. The study presented in the paper analyses the energy performance of these Millennium buildings built during 1992 – 2014.

The most commonly used building lifespan in building life cycle analyses is 50 to 60 years [14]. The life cycle of the building covers all phases from the extraction and production phase of construction materials to the demolition of the building [15]. However, the expected lifespan of individual components of the building is significantly shorter [16], [17] 10 to 30 years.

The total costs during the life cycle of the building come from initial investments, permanent maintenance costs, and costs for capital repairs. The largest investment for capital repairs is expected during the life cycle of the building in the period starting from 30 years (Fig. 1) that lines with the age of the oldest buildings from the period (1992 – 2014).

Figure 1. Costs during the life cycle of the building [17], [18]

Analysis of the energy performance of Millennium buildings will provide insights into the grey sector of the existing building stock and allow to make suggestions in the road to decarbonised building stock.

2. METHOD

To assess the level of energy efficiency in the Millennium buildings, 5 tasks have been identified (see Fig. 2):

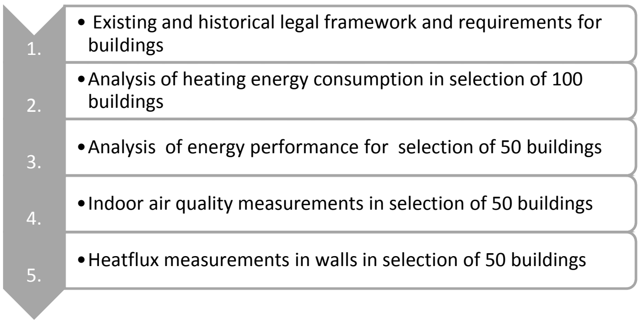

Figure 2. Method of the study

As part of the study, an analysis of the heating energy consumption in 100 selected buildings is carried out. 20 buildings from each five-year 1992-1996, 1997-2001, 2002-2006, 2007-2011, 2011-2014 periods were selected including both residential and public buildings. Data regarding the year of construction of buildings is obtained from the Riga City Construction Board, heating energy consumption data are gathered using publicly available data on monthly heating energy consumption provided by the largest heating energy supplier in Riga City AS "Rigas Siltums". To calculate the specific heating energy consumption of buildings in kWh/m2g, information is obtained from the State Cadaster information system of real estate.

A person spends around 90% of his or her time in indoor spaces. Thus, indoor air quality is an important factor for public health. The non-compliant microclimate at the premises is a serious risk factor that can cause diseases, reduce work productivity, and negatively affect the quality of life in general. The provision of favorable conditions, as well as the prevention of a harmful environment, should be a priority. The human right to a healthy indoor climate is enshrined in the Constitution of the World Health Organization and includes the right to breathe fresh air and to feel thermal comfort [19].

The energy efficiency level of the building is closely linked to the air exchange level in the building. The higher the air exchange, the higher the energy consumption for heating. Studies carried out by the authors have shown that air quality is often unsatisfactory in buildings without mechanical ventilation [20], [21], which also coincides with observations elsewhere in the world [22], [23]. Using only periodic opening of windows, the ventilation of rooms is not ensured to the required extent, the level of CO_2 concentrations in rooms exceeds the good quality level. It affects the well-being of the inhabitants and might have a wider impact on gross domestic product in the future as described by Blumberga et al [24] if pupils' are learning in the premises with increased levels of CO_2.

Therefore, in addition to the energy performance analysis of the building, indoor air quality measurements are also carried out. Small-scale environmental parameter and CO_2 concentration remote reading device CO_2 Node is used, which provides data transmission via the LoRaWAN network provided by the telecommunications company SIA ''TET''. The device measures three essential parameters of the indoor microclimate: temperature, [°C]; relative humidity, [%]; CO_2 concentration level, [ppm].

The CO_2 concentration level measurement equipment is located at the height of the operating zone corresponding to the type of building. In the sample buildings, CO_2 Node equipment is located at a height of ~ 1,1 m corresponding to the height defined as in the operating area of the premises, where most of the time is spent by people sitting [25].

A concentration of 1000 ppm in the room, by 600 ppm above the concentration in the outdoor air, is considered to be satisfactory. Above 1400 ppm air quality is considered to be low according to DS/EN 13779 [26].

3. RESULTS

3.1 Analysis of heating energy consumption data

In Fig. 2 it can be seen that energy consumption in the selection of buildings shows a decrease in energy consumption with a slight slope of the graph. Nevertheless, in the last five years, there are buildings with energy consumption close to that of the first five years. Three buildings have significantly higher consumption exceeding the level of 200 kWh/m^{2}a.

Compared to the benchmarks set by legislation, 20 out of 108 sample buildings exceed the highest benchmark by more than 10%. In about half of the buildings, the energy consumption is lower than the lowest set benchmark for renovation i.e. 80 kWh/m^{2}a (fig. 3.).

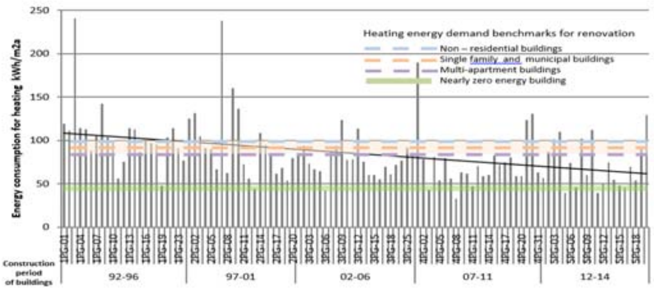

Figure 3. Energy consumption for heating in selected buildings built during 1992 - 2014

The selection consists of 57 non-residential and 51 residential buildings. The energy consumption of non-residential buildings in the selections ranges from 33 to 240 kWh/m^{2}a, for residential buildings 39 – 142 kWh/m2a. Out of 20 buildings exceeding the highest benchmark 100 kWh/m^{2}a, 15 are non-residential buildings.

3.2 *Energy performance analysis of selected buildings*

The analysis of energy performance assessments is based on the information provided in the building energy certificate. The selection includes buildings of various functions - apartment buildings, office buildings, commercial buildings, medical buildings, educational buildings, and individual buildings with other functions.

In Fig. 3 energy consumption for heating is combined with transmission heat loss coefficient H_T and ventilation heat loss coefficient H_{VE}. It can be seen that buildings with energy consumption for heating differing significantly from other buildings have a significantly higher H_T or H_{ve} coefficient - 1PG-03 and 2PG-07 have a significantly higher transmission heat loss coefficient H_T, while buildings 2PG-09 and 2PG-10 have a significantly higher coefficient H_{ve}, but 4PG-01 has a higher set indoor temperature (Fig. 4).

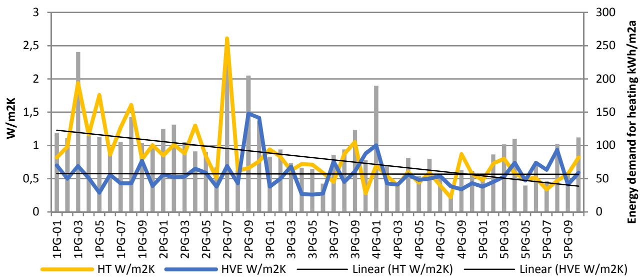

Figure 4. Energy consumption for heating in selected buildings combined with heat loss coefficients H_T, H_{ve}

Looking closer to the changes in the heat loss coefficients HT and Hve it can be seen that the transmission heat loss coefficient HT has decreased, which is related to the changes in the regulatory requirements for the thermal performance of building envelopes. But for ventilation heat loss coefficient Hve there is no tendency to increase or decrease depending on the year of construction, the direction coefficient of the trend line is close to zero.

3.3 *Indoor air quality measurements*

Fig. 5 shows the minimum and maximum temperature values recorded during the measurements. The set indoor air temperature depends on the user's comfort requirements. Therefore, it cannot be claimed that a reduced or elevated temperature indicates a reduced level of comfort.

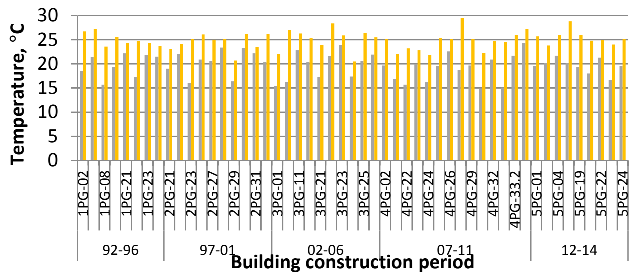

Figure 5. Minimum (blue) and maximum (orange) temperature values recorded in premises of selected buildings

Fig. 6 shows the minimum and maximum values of relative humidity recorded during the measurements. Satisfactory relative humidity of the indoor air is in the range of 30 to 50%. It can be seen that in eight buildings a maximum relative humidity level of more than 50% was recorded, which may be since in the room where the sensor is located there is an additional source of moisture (living room combined with kitchen, cafe). In the other eight buildings, the lowest recorded relative humidity is below 20%. Seven of these buildings are non-residential.

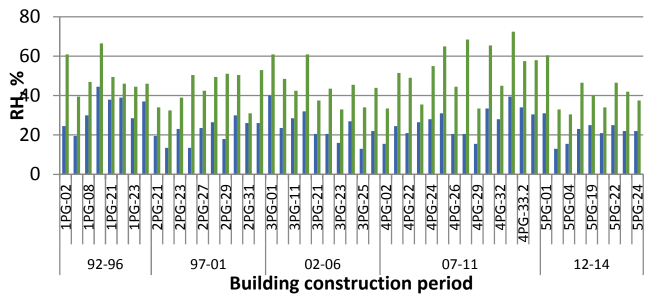

Figure 6. Minimum (blue) and maximum (green) values of relative humidity recorded in premises of selected buildings

Figure 7 shows the maximum values recorded during the measurements for the CO_2 concentration in the premises of selected buildings. Maximum values above 1000 ppm were recorded in 29 of the 50 buildings. In 10 buildings, the maximum CO_2 concentration in a room exceeds 2000 ppm. These are all residential buildings. The CO_2 level depends on the occupancy of the building, the level of user activity, the air exchange at the time of observations, therefore the measurements does not explain all buildings of the millennium period, but it gives an indicative insight into the real situation in the operation phase of the building. Measurements were performed under conditions relevant to the type of building. Some buildings were randomly occupied during the observation period. The performed measurements do not show strong tendencies that would indicate the connection with the construction period of the buildings.

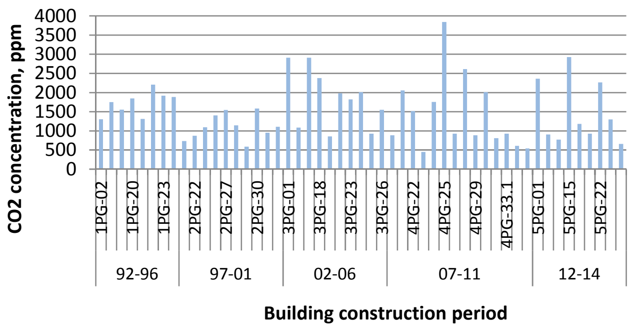

Figure 7. Maximum values recorded during the measurements for the CO_2 concentration in the premises of selected buildings

With the development of construction technologies and energy-efficient construction trends, buildings become more airtight. On one hand, it reduces heating energy consumption due to reduced air exchange caused by infiltration, but on the other hand, it can reduce indoor air quality if only natural ventilation is provided. Research shows that in residential buildings without mechanical ventilation, user-controlled ventilation through windows does not ensure consistently good indoor air quality. But in buildings with mechanical ventilation, it can be seen that the level of 1000 ppm is not reached. In some cases concentration of CO_2 is in the range of 500 - 600 ppm, which may indicate that the ventilation system control is not adapted to changing loads, indicating that there is potential for energy savings.

3.4 Thermal transmittance of buildings external walls

Comparing the obtained U values with the minimum normative requirements for wall heat transmission (Fig. 8), it can be seen that within the uncertainty limits (weighting against the lower border of uncertainty), the calculated U value exceeds the minimum requirements in 22 buildings. 11 of 50 U values correspond with actual 2021 requirements.

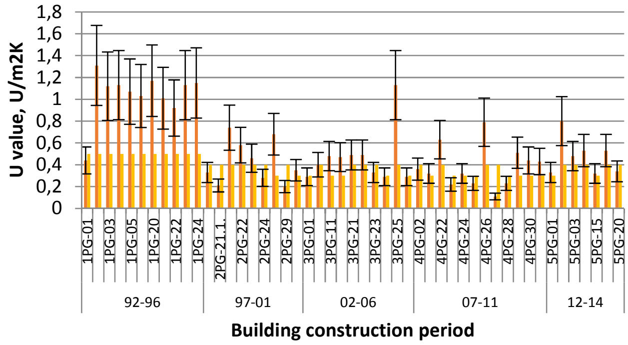

Figure 8. Calculated U value (Red) based on in–situ measurements and normative U value (orange) at the time

In the period 1992 – 1996 calculated U values might indicate that buildings have been designed according to the norms before 1992.

When performing measurements in - situ, it is not possible to obtain a result of laboratory rotation accuracy. If the heat flow measurement is performed with a large time lag from the construction time of the building, the measurement uncertainty increases and is influenced by many factors. The influence of various these factors cannot be reliably confirmed or denied - initial construction defect, unevenness in the building element, degradation of material properties, the influence of thermal bridges. Regular diagnostics of factors influencing the energy efficiency of a building would provide more accurate information. It is recommended to incorporate into regulatory enactments the requirement to control construction works in the essential energy efficiency parameters – air tightness, heat transmission. It would allow assessing whether the indicators set in the project have been achieved and to assess the changes in these parameters over time. Carrying out such an inventory would ease the building's energy management and decision-making when evaluating the necessary measures to increase the building's energy efficiency in the lifetime of a building.

3.5 Discussion and conclusions

The paper presents the study on the energy performance of buildings built between 1992 and 2014. Analysis of: 1) energy consumption for heating; 2) H_T, H_{ve} coefficients; 3) indoor air quality is performed and 4) thermal transmittance of walls is calculated based on in-situ measurements.

Analysis of the heat loss coefficients H_T and H_{ve} indicates that thermal envelope performance has increased significantly, but the optimization of ventilation heat losses has not happened. It indicates that there lies additional energy efficiency potential. Both legislators and practitioners should explore possibilities to reduce the impact of ventilation heat losses on the energy demand of a building. The new paradigm of air supply should ensure both – energy efficiency and optimal indoor air quality. Indoor air quality measurements indicate that using only windows for air supply leads to exceeding optimal indoor air quality levels in short term. Using mechanical ventilation systems on other hand in some cases does not exceed 600ppm CO_2 concentration, which indicates that there is a potential for energy savings.

Analyzing the energy consumption for heating of selected buildings concerning the actual benchmarks for building renovation (80 – 100 kWh/m^{2}a), it can be concluded that most buildings do not require significant measures to increase the energy efficiency of a building. Without more stringent or diversified benchmarks, there is a risk that energy efficiency measures will not be taken at all or will not be carried out to a sufficient extent in the mid-life renovation of a building. Thus, for the next life cycle stage of 25 years, the current level of energy efficiency would be "conserved". It is recommended to review the set achievable benchmark for the energy performance of buildings for building renovations, lowering or diversifying according to a wider range of building types, taking into account cost-effectiveness. To achieve the ambitious decarbonisation targets in 2050, it is also recommended to set a gradual reduction of the benchmark for building reconstructions, aiming at a level of deep renovation to reach a near-zero energy building level.

ACKNOWLEDGEMENT

This research has been developed within the project "Improvement of building energy efficiency technologies" (No. 03000-3.1.2-e/163) supported by the National Research Program of Latvia.

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