A review of the 1-2 apartment residential building stock in Lithuania based on an analysis of Energy Performance Certificates

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Abstract. One of priorities of the EU's climate change policy is the energy performance of buildings. This is reflected primarily through the series of Directives the EU has enacted along the years, but is most precisely conveyed in the Energy Performance of Buildings Directive (EPBD). As part of the European Union, Lithuania has enacted its own long-term strategy aimed at transforming the current building stock in one which is more energy efficient. Building energy certification, legalized in accordance with the requirements of the directive is the primary tool used to evaluate the energy-efficiency of a building, which includes determination of the energy consumption of a building and subsequently assigning it with an energy performance class. Energy performance certificates (EPC) are obligatory for new and existing buildings in all European Union (EU) member states and provide not only a description of the energy performance characteristics of individual buildings, but are also useful source of legal information for determination of the achievements of building energy efficiency improvement strategy. Despite the current wide spread presence of EPC analyses in other European countries, similar information on the national EPC register of Lithuania is still hardly present in research studies. To this effect this paper presents a detailed overview of the stock of Lithuanian residential 1-2 apartments buildings using data from the national EPC register. The results obtained present the impact of the implementation of EPBD on Lithuanian residential 1-2 apartments buildings, including changes in thermal insulation of building elements, heating system typology, energy consumption and CO_2 emissions.

Introduction

Over the last few decades, the general trend observed in Europe, driven by a period of relative economic expansion and prosperity has been one where there was an increasing trend towards individuals being able to build an individual space as their own home - a single- or two-family residential house [1]. The quality of these 1-2 apartment buildings is primarily defined by the selection of building structures and materials, and the type and parameters of the equipment installed in them [2].

Driven by concerns on climate change, the energy consumption in buildings has become increasingly important, with various strategies and international agreements being enacted to address this issue. As is to be expected, this is also being addressed at an academic level, with specific studies aimed at looking for the most accurate and advanced methodology to make informed decisions on the design of low carbon housing [2-4].

The primary instrument for improving building energy performance in the EU is the Energy Performance of Buildings Directive (EPBD), which was first introduced in 2002 (EPBD 2002/91/EC) [5] and then subsequently revised in 2010 (EPBD 2010/31/EU) [6], and in 2018 (EPBD 2018/844/EU) [7]. The EPBD, which is the major legislative and policy instrument in the EU, relating to energy-efficiency in buildings focuses on both existing and new buildings, and in its latest revision requires the transformation of the building stock into Nearly Zero Energy Buildings (NZEBs) by 2050.

Being part of the EU, Lithuania, like all other European Countries has drawn up a National Energy and Climate Action Plan for the period 2021–2030 (hereinafter referred to as the 'National Plan'), thus integrating the provisions, objectives, targets and measures for improvement of energy efficiency and reduction of CO_2 emissions implemented and planned in the Lithuanian national legislation, strategies and other planning documents.

One of the objectives set out in National Plan is to improve the energy-efficiency and increase the use of energy from renewable sources in residential and public buildings, thus reducing CO_2 emissions. As is the norm throughout Europe, and as set out by the EPBD, the energy performance of buildings is measured and set out through building energy certification, specifically an energy performance certificate (EPC), which is obligatory for new and existing building undergoing renovation. The EPC of a building (building part) typically includes the unique number and address of the building, gross and useful area of the building, energy performance class and estimated total energy inputs per m^2 of heated area of the building (primary energy), data on the main source of heating, energy consumption for heating (primary and secondary energy), and of course the certificate number. Every EPC also includes calculation results of calculated primary energy consumption; the value of the calculated ratio of annual renewable primary energy costs to annual non-renewable primary energy costs; calculated thermal energy consumption for heating, cooling, and hot water production inside the building per square meter; calculated total electricity consumption; electricity consumption per year for lighting; the amount of carbon dioxide (CO_2) emitted into the environment by the building (its part) per year and recommendations for improvement. Overall the general idea of using EPCs was to create a clear indicator capable of differentiating buildings by their energy performance. This with the aim of influencing the building market (building owners, occupants, real estate agents etc.) towards energy-efficient buildings [8-11].

In Lithuania, certification is done on the basis of the method described in LST EN 15217:2007 '*Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings*' [16]. According to the energy performance expressed through the methodology, buildings in Lithuania can then be classified into 9 classes, namely, A++, A+, A, B, C, D, E, F, G [17]. Each class is not related to any particular numerical value of energy consumption, but rather, a building is certified as being of a particular energy performance class if it satisfies the specific criteria relevant to that energy performance class. Such criteria are based on the following principle: the legislation sets regulatory requirements for the thermal characteristics of building envelopes, efficiency of engineering systems (cooling, domestic hot water production, indoor lighting), energy consumption for heating the building and the use of any renewables on-site.

Even though the Energy performance certification has been implemented for more than 15 years, few studies have been conducted on analysing the results obtained and the actual influence of the policy implementation [9-15]. There are few studies investigating energy planning from the point of view of EPC data for buildings in Sweden and Southern Europe [18-26], but little anywhere else.

Starting with this premise the analysis presented in this paper aims to conduct the first work of its kind on EPC analysis in Lithuania. Specifically, the study uses EPCs of 1-2 apartment residential buildings, certified between the period 2014 and 2020, to analyse the effect the impact increasingly stricter EPBD requirements have had on various indicators of buildings energy efficiency along the years. Although the EPCs analysed were issued during the period 2014-2020, the analysis in fact includes EPCs covering the entire spectrum of energy performance classes, from G to A++, as buildings might have been built earlier, and therefore show an energy class which was required prior to 2014, or else the building might have been built during the time frame indicated with specification which exceed what was legally required at the time.

2. Residential building stock overview

Accounting for 55% of the total area of the building stock (Table 1), residential buildings are the most significant building segment in terms of building area. The average area of each building unit however varies significantly, for example, around 130 m^2 for single houses and around 1,450 m^2 for multi-apartment buildings. In terms of actual unit numbers single houses account for as much as 93% of the total number of residential buildings, while multi-apartment buildings account for only 7%.

Also, according to the data of the Real Property Register (RPR), at the beginning of 2020, 570,613 residential buildings with a total area of 116 million m^2 were registered in Lithuania (Table 2). In terms of construction period the majority of buildings were built in Lithuania before 1993, according to standards that were valid at the time of construction, meaning very little thermal insulation, and with thermal resistances of the building envelope mostly made up exclusively of the construction load-bearing materials (e.g. bricks, blocks or slabs). It can be seen that 1-2 apartment buildings make up 60 percent of the total living area.

In terms of space heating, only 1.4% of 1-2 apartment buildings are connected to district heating systems (Real Property Register (31.12.2019)), therefore, district heating is not a predominant engineering system. Furnaces, biofuel boilers, natural gas and heat pumps are the systems typically used. The type of heating system and the origin of the fuel source have the greatest influence on the achievement of the goals of increasing energy efficiency and reducing CO_2 emissions set in the National Plan.

Table 1. Information on the Lithuanian residential building stock by building typology

Building Typology	*Sub-group of buildings*	*Number, units*	*Total area, m²*	*Area, %*
Residential buildings	1-2 apartment buildings	529.592	69.540.001	60
	Multi-apartment buildings (<1000 m^2)	24.113	9.334.072	13
	Multi-apartment buildings 1000-5000 m^2)	15.072	37.805.494	32
	Multi-apartment buildings (>5000 m^2)	1.836	12.324	5
Total		570.613	116.691.891	100

Source: The authors of the study to develop the long-term renovation strategy of Lithuania

3. Methodology

Information from building energy performance certificates issued during period 2014-2020 were extracted from the register administered by the Certification Centre of Construction Products [21]. In order to get averaged and summed up values of building envelope properties and the efficiency of engineering systems of the various energy performance classes buildings, specific data was calculated using the NRG6 software, prepared according to the building energy efficiency evaluation methodology presented in STR 2.01.02-2016 [15]. Extracted and calculated energy efficiency data were then analysed using excel. In total, 78,740 certificates were issued for 1-2 residential apartment buildings between 2014 and 2020, however due to issues with data reliability, occasional errors present in the certificates, or the lack of data required for analysis, which occurred during calculations in older NRG versions, only pertinent to the certificates of 56,891 buildings were therefore used for the analysis This accounts to 72.4% of the total certificates issued over that analysed period.

4. Results and discussion

According to the analysis performed on the certificates analysed, it can be observed in Figure 1 that the level of thermal insulation of buildings has increased by a factor of 2.5 when comparing buildings having a D energy performance class to those having an A++ energy performance class – from 0.33 W/(m²·K) to 0.13 W/(m²·K)).

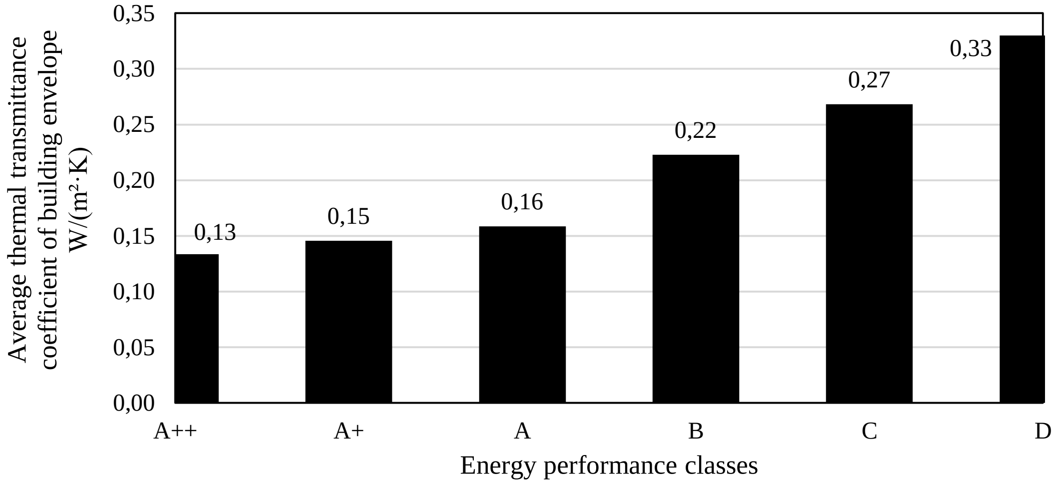

Fig. 1. Average thermal transmittance coefficient of the building envelope, in W/(m²K), in buildings of various energy performance classes.

Specifically, considering only the period when the EPBD has been in force, therefore from class C up till the latest revision of the EPBD, class A++, the average U-value of the building envelope decreased from 0.27 W/(m²·K) to 0.13 W/(m²·K).

The improved thermal insulation is reflected in a reduction in energy consumption for heating. In fact, due to the increased level of thermal insulation of the building envelope, the energy consumption used for heating decreased from 173 kWh/m² for buildings of energy performance class D to 11 kWh/m² for buildings of class A++ (Fig. 2). Additionally, the significant decrease in thermal energy consumption was also influenced by the air permeability requirements for buildings introduced in Lithuania in 2014 [28], thus reducing the heating energy consumption due to uncontrolled air exchange. Specifically, considering only the period when the EPBD has been in force, therefore from class C up till the latest revision of the EPBD, class A++, it can be seen that the annual thermal energy consumption for heating decreased from 134 kWh/m². year for class C to 11 kWh/m^2. Year for class A++.

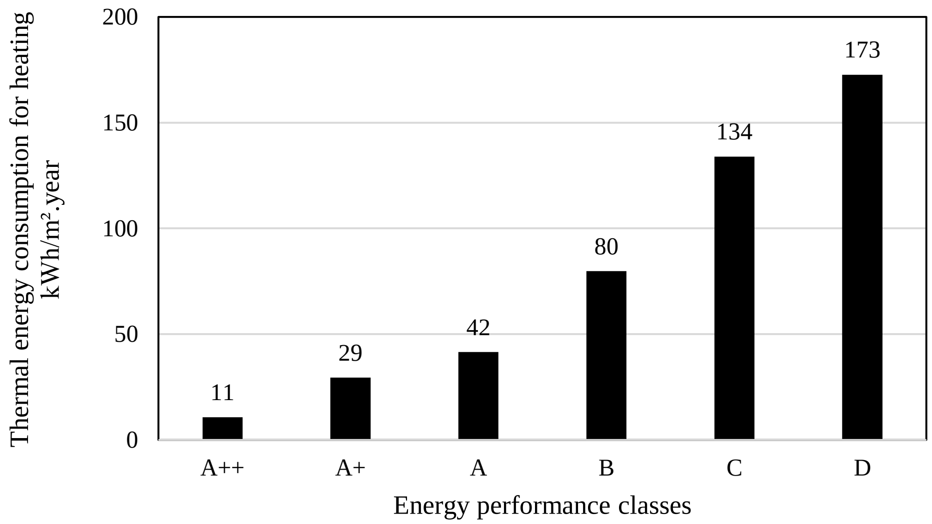

Fig. 2 Average annual thermal energy consumption for heating, in kWh/m², in buildings of various energy performance classes.

In this regard, the increased thermal insulation is only but one of the factors which have influenced the reduction in the average thermal energy consumption for heating. Technological changes such as a larger market share of heat pumps and limitations on the use of non-renewable fuel sources have also impacted. Figure 3 shows that the largest share of buildings using heat pumps for space heating are those having EPCs of class A++, class A+, and class A. Heat pumps dominate in the heating of A++ class buildings. Renewable solid fuel boilers are the predominant technology used for heating class C and class B buildings. Furnaces on the other hand, are found in low energy performance buildings of classes E, F, G.

Other interesting aspects is the increased use of gas boilers, when comparing buildings from class F to class A. For A++ class buildings, this energy source (natural gas) is not acceptable because it is a non-renewable energy source. Class C emits more CO_2/m^2. year than class B because as shown in Fig.3 – in buildings having an energy performance class C, solid fuel boilers are the dominant technology.

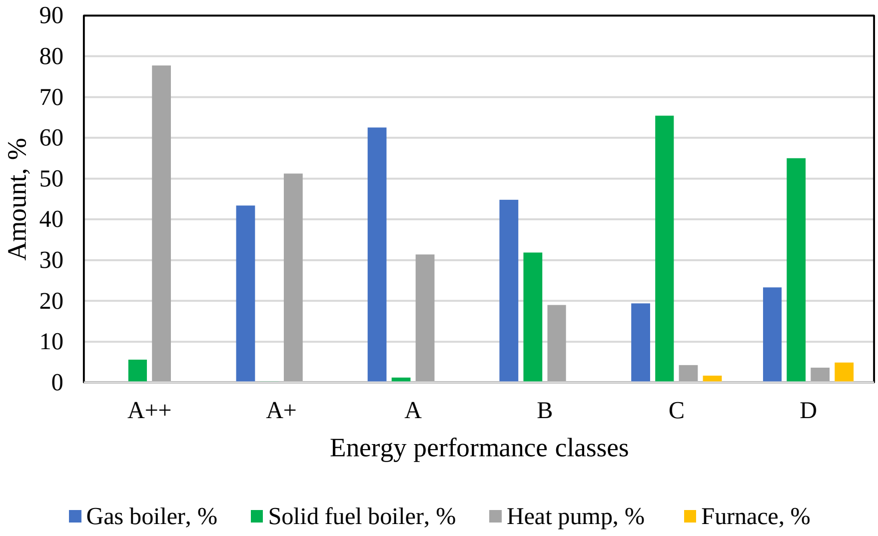

Fig. 3. Distribution of heating sources in 1-2 apartment residential buildings.

As shown in Figure 4, around 77% of CO_2 emissions of the 1-2 apartment residential building stock are emitted by buildings having an EPC certification lower than class C. Accordingly, it stands to reason that the 1-2 apartment residential buildings with an EPC lower than class C, and all buildings using fossil fuels should be treated as a priority segment in the context of the reducing CO_2 emissions.

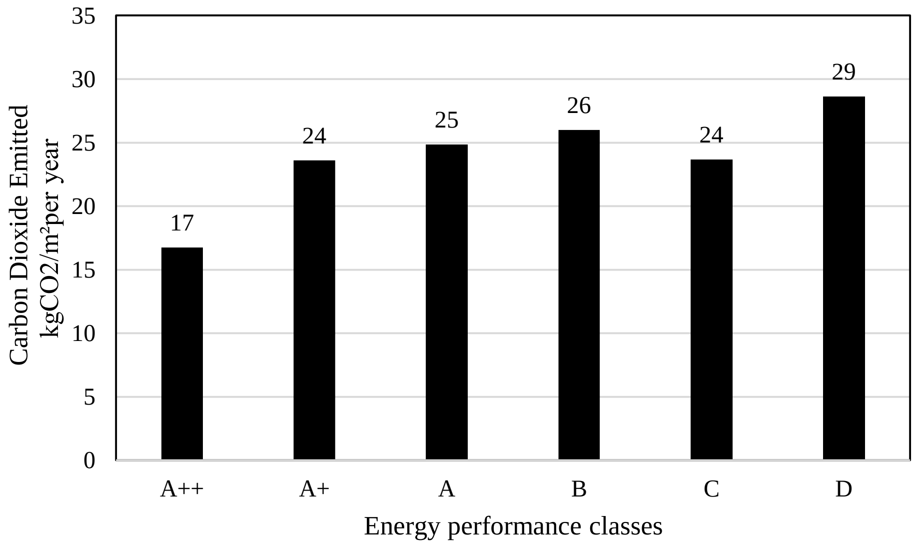

Fig. 4. Average amount of CO_2 emitted in $kgCO_2/m^2$ per year.

Figure 5 shows that the heated area of buildings having an energy performance class B to A+ tended to decrease. This is a very positive effect in terms of CO_2 emission reduction, given that when the heated area decreases as the building efficiency increases. The heated area of A++ energy efficiency class buildings is observed to increases, but this is not expected to have a significant impact on the total heating energy consumption, since A++ class efficiency indicators are much higher, and heating using heat pumps is much more efficient in reducing the use of non-renewable energy compared to gas boilers used in buildings of classes A and A+.

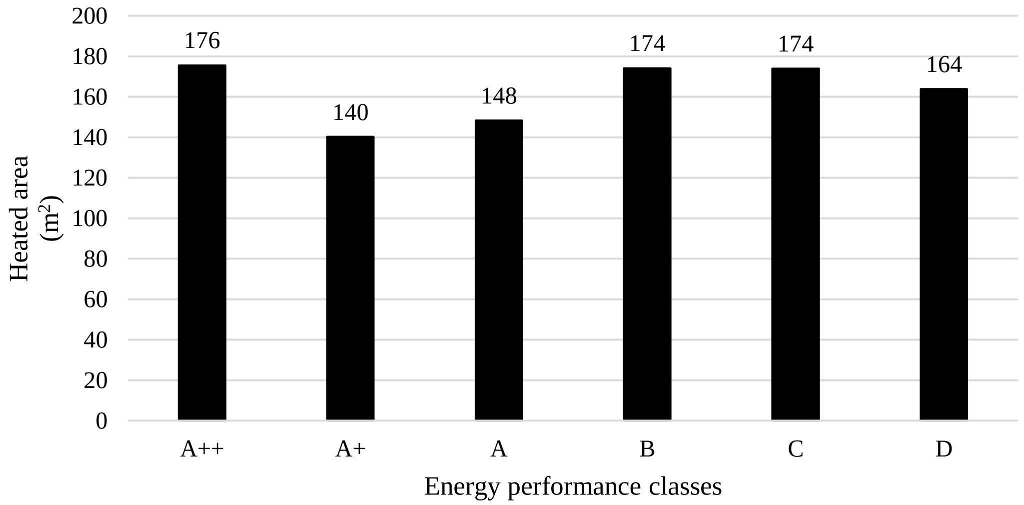

Fig. 5. Average heated area of the building

The design tendencies of glazed parts of building envelope also changed from 2006 until 2021, as shown in Figure 6. Due to the increased glazed area, it is expected that the energy consumption for heating and cooling will increase in winter and summer respectively. This is expected to be counterbalanced by a reduction in the use of artificial lighting.

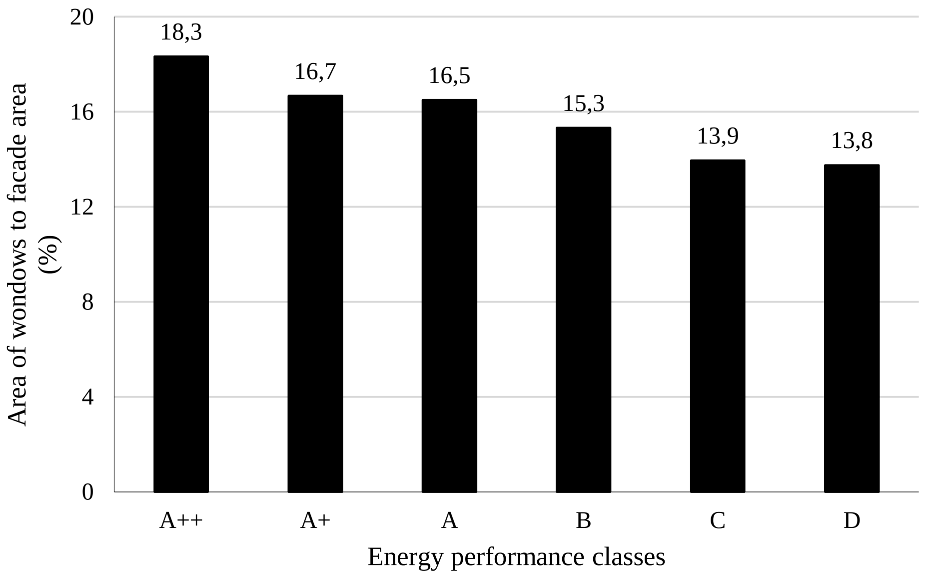

Fig. 6. The average part of the windows area in the facades of the 1-2 apartment building

Lithuania underwent significant changes in the regulation of energy efficiency in buildings. The summary of results of the primary energy consumption analysis allows to conclude that the requirement issued by the energy performance directives to move to the construction of 1-2 apartment buildings of class A++ (NZEB) in Lithuania from 2021 was successfully implemented, leading to a significant reduction in primary energy consumption for heating (Fig.7). It should be noted that relatively high primary energy consumption remains in the buildings of class A++ with regard to lighting, electric appliances (46.58 %), and hot water production (19.11 %).

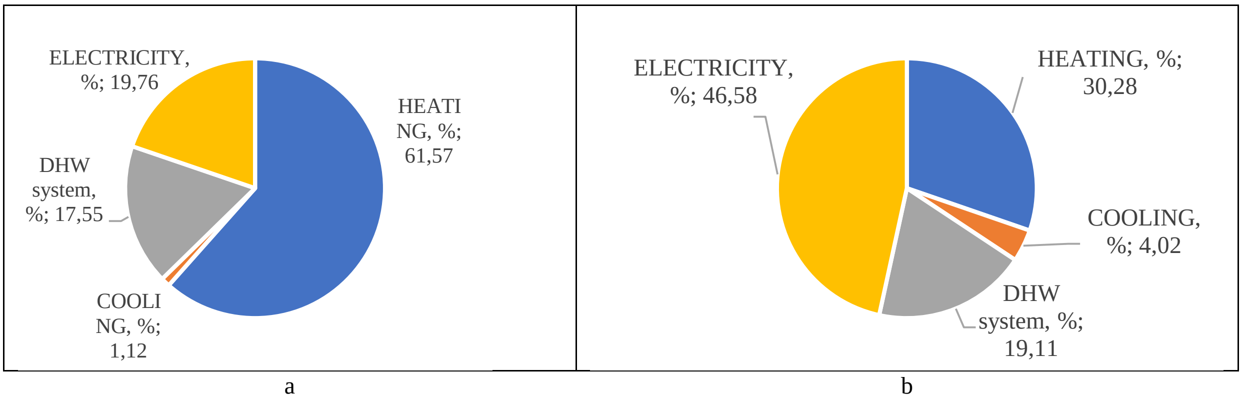

Fig.7. Primary energy consumption in buildings of energy performance class C (a) and energy performance class A++ (b), (%)

Conclusion

Lithuania underwent significant changes in the regulation of energy efficiency in buildings. The conclusions presented below describe the changes that define the differences between buildings complying with the requirements of building energy performance classes from C to A++, i.e., in certain aspects, these conclusions describe the impact of increasing requirements of EPBD directives on changes in various indicators of buildings. Stricter legislation has in fact led to a reduction in the average U-value of the building envelope, a change in the typology of systems used for heating, and hence in the amount of CO_2 emission. The analysis of the energy performance certificates also showed that buildings of the highest energy efficiency class have increased heated area and window area, increasing the energy for heating, so the strengthening of the requirements for the A++ class, which meets the NZEB, has been justified. In terms of CO_2 emission and also increase of use of renewable energy - heat pumps are starting to dominate in buildings with class A++. It should be noted that relatively high primary energy consumption remains in the buildings of class A++ with regard to lighting, electric appliances (46,58 %), and hot water preparation (19.11 %), therefore, it must be priority to reduce energy consumption for these purposes continuing to increase the energy performance of buildings moving towards the 'zero emission' buildings.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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