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ENERGY PERFORMANCE-BASED RETROFIT OF APARTMENT BUILDINGS IN ALBANIA USING MASS-HOUSING TYPOLOGIES AS CASE STUDIES

Anna Yunitsyna*, Ilda Sadrija

Epoka University, Tirana, Albania

*Corresponding author′s e-mail: ayunitsyna@epoka.edu.al

Abstract
Introduction: The study is focused on the analysis of the energy performance of mass-housing residential buildings in Albania and further evaluation of the opportunities for energy retrofit of these buildings. Currently, in Albania, energy performance evaluation is mandatory for newly constructed buildings, but there are no approaches that would address the existing building stock. **Methods:** The goal of this study is to evaluate apartment buildings of the communist period in Tirana and Shkodra and apply a number of passive and active retrofit strategies, which are appropriate in the Mediterranean climate conditions. **Results and Discussion:** Improvement of thermal conductivity and energy balance can be achieved through the additional insulation of the buildings' walls and roofs and window replacement, installation of photovoltaic panels and energy-efficient lighting. The application of passive strategies reduces energy losses in Tirana by 56% and in Shkodra — by 57%. **Conclusions:** Installation of photovoltaic panels can meet cooling and lighting demands during the warm period; however, their contribution during the wintertime is insufficient to satisfy heating demands.

Keywords: apartment building retrofit, building energy performance, energy efficiency, photovoltaic systems, energy balance.

Introduction

Energy performance of buildings is critical for the community. In Europe, urban areas account for 80% of carbon emissions. Industries, buildings, and transport increase the overall pollution (Harmathy et el., 2019). Residential areas account for 30–40% of the overall energy consumption (Huovila et al., 2007). In Albania, 60% of electricity is consumed by residential buildings (Struga and Marko, 2019). Renovating a building to reduce its energy consumption is quite important during the energy crisis. According to EUROSTAT (2020), the first global decrease in energy use was caused by the global financial crisis in 2009. In 2010, energy consumption recovered, however during COVID-19 it decreased again. Currently, European countries are forced to reduce energy use due to high prices and shortage of available fossil fuel sources. In the EU, residential buildings are the main target for the investments aiming to save energy by increasing passive energy gains, minimizing the use of fossil fuels, and reducing the overall energy use and energy consumption by residents (Botta, 2005). The EU building stock is extremely diverse and includes historic, prefabricated, and modern buildings of different heights and sizes, which requires the development of a large number of renovation scenarios.

This study is focused on the evaluation of the energy efficiency of brick residential buildings of the communist period in Tirana and Shkodra. It includes a renovation proposal using passive and active strategies to improve energy balance. The retrofit scenario includes improvement of the thermal performance of buildings and generation of renewable energy using photovoltaic panels. The goal of this study is to develop a renovation technique that could improve energy performance with moderate intervention in the Mediterranean climate conditions.

New knowledge about the environmental performance of buildings led to the expansion of building environmental evaluation tools (Villegas, 2017). To make a building energy-efficient, it is necessary to analyze the dynamic thermal behavior of each of its elements, the climate and site conditions, and the behavior of its users (Yüksek and Karadayi, 2017). The general approach towards building retrofitting includes measures aimed to decrease energy consumption, reduce energy demand, control energy use, and use on-site-generated energy (Felius et al., 2020). Renovation with the use of passive house techniques is an effective strategy to reduce energy use, which goes along with the EU building energy standards (Figueiredo et al., 2020). Strategies to reduce energy demand include insulation of the building envelope, window retrofit, cold roof application, air exchange reduction, controlled ventilation, upgrade of household equipment and lighting, and thermal energy accumulation (Ma et al., 2012). Passive house design strategies are applied in the construction of new buildings all over the world. Due to low energy

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consumption, the performance of these buildings is not drastically affected by the behavior of residents, which makes it predictable in terms of energy needs (Pitts, 2017). In housing construction, renewable energy can be provided by solar water heaters, photovoltaic panels, wind power, geothermal power, and biomass power systems (Ma et al., 2012).

All retrofit measures can be divided into those related to the building envelope and installation improvements (Konstantinou and Knaack, 2011). Energy efficiency standards specify the thermal resistance of windows, doors, walls, roofs, balconies, and other exterior components, as well as cover heating, cooling, air conditioning, ventilation, lighting, controls, fans, and electricity for external lighting. The primary focus of an energy-efficient building is on the building envelope (Laustsen, 2008). Başarır et al. (2012) state that 40% of energy losses in a multi-story building are through the exterior walls, 30% — through the windows, and the rest is attributed to the roof, basement slab, and air leaks. Therefore, they find it feasible to apply retrofit strategies to the roof, windows, and walls.

In case of brick buildings, the use of the exterior layer of thermal insulation contributes to minimizing the influence of adverse weather conditions and reduces the impact of thermal bridges (Kass et al., 2015). In the UK, the application of the external insulation layer over the brick walls reduces the annual heat losses through the walls by 75% and has the 5–6.5-year investment payback period (Brannigan and Booth, 2013). The optimal thickness of the thermal insulation layer should be selected based on the balance between energy performance and cost-effectiveness (Bonakdar et al., 2017). The climate zone and annual energy consumption requirements established by national standards affect the selection of the material and thickness of the thermal insulation layer (Usta and Zengin, 2021).

Energy-efficient roofs are designed with the aim of minimizing energy losses by reflecting sunlight and absorbing less heat. A green roof can be a good decision for the improvement of the energy performance of urban buildings with flat roofs (Department of Energy, 2015). The cool roof application reduces cooling energy demands during the hot season; however, it increases energy consumption for heating in winter (Ganguly et al., 2016). A study from Sicily demonstrates that a cool roof with the adequate thermal insulation layer reduces cooling energy demands by 54% (Romeo and Zinzi, 2013). A Shanghai case shows 8.7–14.9% reduction in the heating loads depending on the thickness of roof insulation (Chen et al., 2019). Comparable results with 14–15% reduction in the heating loads of the insulated roof were achieved with the roof retrofit of a building in New Kensington, PA (Habibi et al., 2020).

Energy-efficient windows should be selected appropriately, with account for the climate zone. Glazing with the use of weather stripping as well as thermal treatment and coverings reduces cooling demands in warm climates by more than 40% (AboKhalil and Ahemd, 2013). In Hong Kong, in hot summer and warm winter, the application of low-e glazing ensures energy reduction by up to 10% (He et al., 2019), while in the colder climate of Berlin, the application of triple-glazed low-e windows reduces heating loads by up to 66% (Urbikain, 2019). Building energy performance depends on the window-to-wall ratio, the solar heat gain coefficient, and the U-value of the windows. A study from South Korea demonstrates that the change of the U-value affects the level of energy savings, while the larger size of the retrofitted windows may cause an increase in the cooling loads (Ahn et al., 2015).

Switching to LED light bulbs has relatively high initial costs but the owners of a building can recoup the extra cost through the reduced utility and maintenance expenses (Bertoldi et al., 2001). Replacement of incandescent light bulbs with LED lights without dimming results in 62% reduction in energy consumption for lighting (Gavioli et al., 2015). Advanced occupancy control lighting systems, such as movement sensors, and automated daylight and shading control systems have the potential to increase energy savings by up to 93% (Dubois et al., 2015).

Renewable energy systems bring a valuable contribution to the reduction of overall building energy consumption (de Almeida et al., 2017). Installation of photovoltaic panels can supply all the energy needs of a building, which include lighting, heating, cooling systems, hot water and appliances (Ray, 2010). PV systems can be installed both on the roofs and facades of multi-story residential buildings, however, their performance depends on the surface orientation and the roof angle (Fina et al., 2019). The Mediterranean countries have great potential for the use of renewable solar energy, however, currently, in the southern and eastern regions, the use of fossil fuels prevails (Ciriminna et al., 2019). A PV system applied on the roof of a detached building in Madrid generated energy that could supply 43% of the annual demands (Aldegheri et al., 2014). In the case of a detached passive building in Jordan, the roof-based solar system reduced up to 83.7% of annual electricity consumption (Jaber and Hawa, 2016).

The evaluation of housing retrofit strategies applied in the Mediterranean region demonstrates that modifications of the building envelope, such as the thermal insulation of the walls and the installation of energy-efficient windows, reduce the heat transfer coefficient by 50% (Carpino et al., 2017). The results of energy-efficient retrofit of a 7-story apartment building in Athens show 80.3% of energy savings. The retrofit plan included extensive energy simulations, thermal insulation and installation of energy-efficient windows, energy-efficient lighting, smart coverings, and a night ventilation passive technique (Synnefa et al., 2017). Similar results of 80% savings were achieved in the renovation of an apartment building in Austria. The facade of the building was covered with large active and passive facade elements, the pitched roof was converted to a flat roof with arrays of photovoltaic panels, and a mechanical ventilation system with heat recovery was installed. In the case of a multi-family building in Denmark, the improvement of the R-value of the whole building envelope provided 31% energy savings (Höfler et al., 2014). The retrofit strategy used in a gated community in Egypt, based on the additional thermal insulation of the roof and walls, use of single-glazed windows with shading devices, installation of efficient lighting, and integration of PV panels, reduced the energy loads at the community level by up to 88.68%, which made the buildings nearly zero-energy (Adly and El-Khouly, 2022). In a case from Algeria, the use of passive strategies for the retrofit of a middle-story apartment building included the thermal insulation of the roof, exterior and, partially, interior walls, double-glazed windows, glazing of the verandas, and installation of shading devices, which resulted in a decrease in the annual energy loads. At the apartment level, its location, orientation, and total area affect its energy performance significantly (Djebbar et al., 2018). A retrofit case from Switzerland, with the replacement of the windows, modifications of the facade and roof, installation of mechanical ventilation and water heating systems, and improvement of lighting, shows reduction in the heating demand by 90% (Höfler et al., 2014). A combination of changes to the building envelope and installation of PV panels resulted in 70% reduction of energy consumption in Portugal (Höfler et al., 2014).

Housing stock and current retrofit strategies in Albania

The current residential architecture in Albania can be classified by year of construction and building size. The first period of housing construction started in 1929–1932 under the Austrian influence. The prevailing housing typology was represented by detached or semi-detached residential villas with one or two floors (Hoxha et al., 2018). During the period of the Italian influence (1939–1943), the first apartment buildings with a height of up to four floors were constructed. During the communist period, massive residential construction using prefabricated building typologies was performed in Albania. Urban development was strongly influenced by the theory and practice of architects from the Soviet Union. The residential neighborhoods were designed using repetitive housing units, which could be applied throughout the country. The multi-family buildings were designed as units of a simple shape with a height of up to five floors. The apartment solutions were simple and rational; nevertheless, all the standards of natural lighting and ventilation were implemented, and the minimum required sanitary equipment was installed (Ndreçka and Nepravishta, 2014). However, except for the case of the coldest mountainous regions, no measures were taken to implement central heating or cooling and water heating (Aliaj, 2003). The structural solutions were the same throughout the country, therefore, the regions with different climate conditions did not differ in terms of the amount of thermal insulation. More than half of the Albanian buildings, which were built from 1945 to 1990, have significant problems in relation to energy performance and indoor comfort of inhabitants. The apartment buildings constructed in 1960–1990 are characterized by significant energy losses due to low quality of construction, thermal bridges, uninsulated structures, single-glazed windows, and open staircases. During the last decade of the communist regime (1979–1990), a new prefabrication typology with the use of composite load-bearing panels was introduced. The 14 cm lightweight cellular concrete, which was used to produce the panels, served as thermal insulation. Bitumen paste was used for the water-proofing of the seams between the panels at the construction site. The same types of panels were applied throughout the country, however, in the cold regions, compact apartment blocks with a simple rectangular perimeter were mainly constructed, while in the warmer areas, more expressive structures with a complex perimeter were used (Abazaj, 2019).

During the transition period of the 1990s, the Albanian state had minimal control over the urban development, which resulted in the massive growth of unauthorized individual dwelling construction and the reduction of architectural and structural quality of multi-family apartment blocks. Due to the implementation of concrete frames, the height of the buidlings grew up to nine floors. The exterior walls were composed of 20 cm hollow bricks and a plaster layer without thermal insulation. A thin layer of thermal insulation was added to the roofs of the buildings, which was covered with water-proofing materials and gravel. Overall residential comfort in these buidlings is quite low due to significant heat losses and moisture inside the living space (Dobjani, 2020).

All buildings constructed in Albania after 2003 must meet the standards established in the Energy Building Code and the law on energy saving and conservation in buildings (EEA, 2016), but currently, most buildings need to be renovated with the application of energy efficiency standards. Law No. 116/2016 “On the energy performance of buildings” (Këshilli i Ministrave, 2016) stipulates the following to be taken into account during the evaluation of energy performance:

– thermal characteristics of the building structure including thermal capacity, insolation, passive heating, cooling elements, and thermal bridges;
– heating systems and hot water supply systems;
– air conditioning systems;
– natural and mechanical ventilation systems;
– lighting systems;
– design, location and orientation of the building;
– shading systems;
– interior air conditioning;
– internal loads.

According to Law No 124/2015 “On energy efficiency”, every renovated building in Albania needs to pass the energy audit in order to satisfy the minimum energy efficiency requirements (Këshilli i Ministrave, 2015). One of the parameters to be evaluated is the energy consumption of the building before and after the renovation. The national energy policies define the level of the energy performance of household appliances, such as fridges, stoves, washing machines, air conditioners, TV sets, and domestic lamps. The solar radiation values and the annual number of sunny days in the Mediterranean region are very high compared to other European countries (Buchinger et al., 2017), which makes it reasonable to use solar water heaters and photovoltaic panels for energy generation.

During the last decade, several studies on the improvement of energy performance in residential buildings in Albania were conducted. A study based on the estimation of the volume coefficient of global losses for 24 buildings shows that it is necessary to add a 5 cm thermal insulation layer in order to ensure the thermal performance of a building in accordance with the European standards (Simaku, 2017). In Tirana, adding a 6 cm external thermal insulation layer to a contemporary 9-story building reduces the heating costs by 49–54% depending on the building size (Dobjani, 2020). A general evaluation of the potential performance of the entire residential building stock in Tirana demonstrates 47% energy savings. In case of a brick building, the maximum contribution was provided by 5 cm wall and roof insulation (6% and 5%, respectively), glazing (6%), reduced infiltration (9%), and the installation of PV panels (8%) (Sherifi, 2017). A retrofit scenario in Kosovo, a neighboring Albanian-speaking country, includes the replacement of the windows as well as the roof and walls in a detached brick building. Due to the poor economic conditions, the residents prefer choosing 5 cm thermal insulation and double-glazed windows, while the optimal scenario including 15 cm roof and wall thermal insulation and triple-glazed windows demonstrates a significant reduction in energy costs for a 20-year period (Bajraktari et al., 2019). An analysis of retrofit scenarios for public buildings in Albania shows improvements in the energy efficiency, however, the resulting energy demands are higher due to poor indoor comfort and currently limited use of heating and cooling systems (Novikova et al., 2020).

Methods

The annual energy demand is the main parameter of energy efficiency (Glushkov et al., 2016). It is the amount of energy consumed per square meter of the building area, which can be compared with the standards established for different building typologies and different climate conditions. Low-energy design involves the inspection of heat transfer, energy supply, and energy consumption in buildings. Ahuja et al. (2015) state that a building’s orientation, materials and components, shape compactness, volume, and perimeter complexity affect energy performance. Djebbar et al. (2019) suggest studying the specifics of the building envelope, structural solutions, heating, cooling, water heating and ventilation systems before choosing retrofit strategies.

The evaluation of energy performance started from the selection of two brick buildings as case studies. During the archival research and field observations, general spatial and structural parameters, such as the building area and height, design solutions, type of the construction system, structure of the walls and roofs, types and dimensions of the windows and doors, as well as climate conditions were studied. Based on those parameters, Revit 3D models representing all the important features of the buildings were built. At the second stage, passive and active strategies for retrofit were selected, including thermal insulation of the walls and roofs, triple-glazed windows, energy-efficient lighting, and installation of photovoltaic panels. The energy consumption scenarios of the case studies were evaluated with simulation using various software, such as PV Watts, PV CAD calculator, Design Builder, EnergyPlus engine, and Revit. The annual energy balance was evaluated after the calculation of energy gains and energy losses during heating and cooling periods.

The study addresses two prefabricated brick buildings located in Tirana and Shkodra. These buildings are similar in terms of architectural layout, spatial distribution, construction materials and techniques. Fig. 1 shows the location of the two cities in Albania and the location of the two selected buildings in the urban context.

The capital city of Tirana is located in the central part of Albania on the Plain of Tirana and surrounded by Dajti Mountain from the east and a range of hills from the south-west. The distance from the Adriatic Sea is about 27 km. Tirana is one of the largest cities in the Balkans, and during the last century, it transformed from a small settlement to a large metropolis. The urban fabric of Tirana is very diverse, and it is composed of historical Ottoman neighborhoods, prefabricated residential

Fig. 1. Location of the selected cities in Albania and location of the selected buildings in the urban context (source: the authors, 2021)

blocks constructed during the communist regime, unauthorized detached residences as well as massive residential complexes and high-rise apartment buildings constructed during the transition and democracy periods.

The city of Shkodra is located in the northern part of Albania, and it ranks fifth in the country by population. It occupies the Plain of Mbishkodra and is surrounded by the Shkodra Lake from the north, the foothills of the Albanian Alps, and Buna, Drin and Kir rivers. The distance to the Adriatic coast is about 25 km. The urban fabric of Shkodra mainly consists of mid-rise buildings, including historical Ottoman districts, prefabricated blocks and detached houses as well as mid-scale and high-rise buildings of the recent periods. The prefabricated blocks located along all the main streets of Shkodra take the significant part of its housing stock.

Both cities are located in the Mediterranean climate zone based on the Köppen climate classification (Chen and Chen, 2013). This zone is characterized by mild temperate climate with hot, dry summer. Fig. 2 gives a general overview of the climate conditions of Shkodra and Tirana.

The climate conditions of the two cities are very similar, however, there are some differences due to the difference in the surrounding geographical features. In Tirana, the average temperature of the hot season is 24.6°C and the average temperature of the cool season is 6.1°C, the warmest month is July, and the coldest month is January (Weather Spark, 2021b). In Shkodra, the average temperature of the hot season is 26°C and the average temperature of the cool season is 5.8°C, the warmest month is August (Weather Spark, 2021b). The average wind speed during the warm season is 8.9 km/h for both cities, but during the cold season, the average wind speed in Shkodra is 15 km/h, which is higher than in Tirana — 13.4 km/h. The amount of precipitation in Shkodra and Tirana is similar, while the monthly rainfall is significantly higher in Shkodra during the cold season.

- **Case Study 1 (Tirana)**

Case study 1 (Fig. 3) is a former exhibit block built during the communist period in Albania and located in Tirana near the Kombinati neighborhood, known as Kompleksi Bushi. This four-floor building has a simple geometric shape and a flat roof. It is composed of eight apartments per floor, which can be accessed from two staircases. In the post-communist period, many individual household interventions were made, distorting the block's elevations and changing them in a non-uniform manner with uncontrolled additions. Some parts of the facades remained brick, while the others were plastered and painted according to the individual decisions of the inhabitants.

- **Case Study 2 (Shkodra)**

Case study 2 (Fig. 4) is a residential building in Shkodra located on the Daut Borici Road. This brick building with a flat roof is composed of two units connected with each other by an open staircase. This type of residential building has five floors. The first floor is of mixed use and includes apartments and various businesses, services, and shops, while other floors are composed of six apartments each. Similar to the Tirana case, the facades were plastered in a non-uniform manner by the inhabitants.

The key features of these two case studies are given in Table 1.

The two buildings are similar in the building scale, construction materials and techniques, and state of preservation. The design is not unique, since during

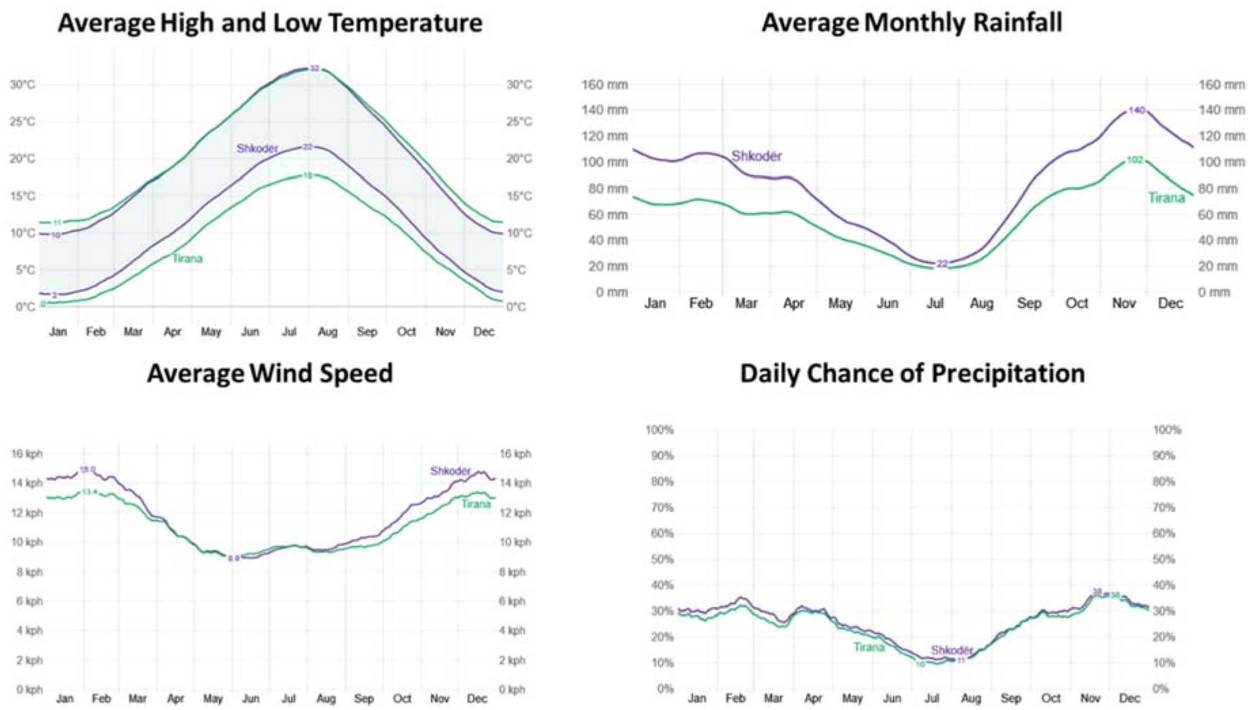

Fig. 2. Average high and low temperature, average monthly rainfall, average wing speed, and daily chance of precipitation in Tirana and Shkodra (Weather Spark, 2022)

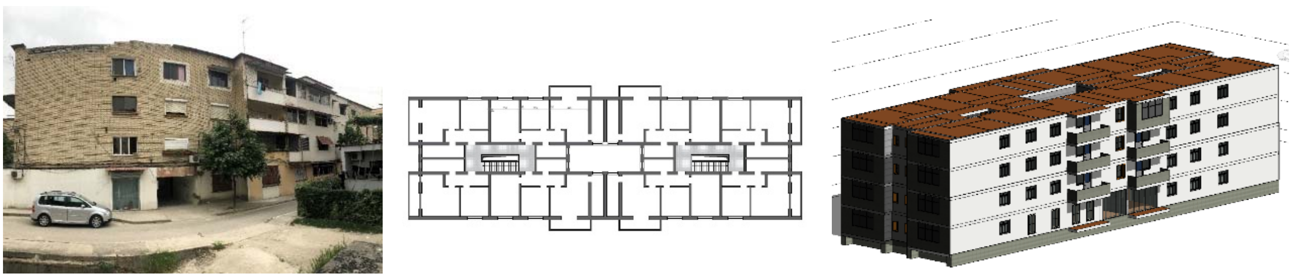

Fig. 3. Street view (photo by the authors), plan view, and 3D model of the Tirana case study (source: the authors, extracted from the Revit software, 2021)

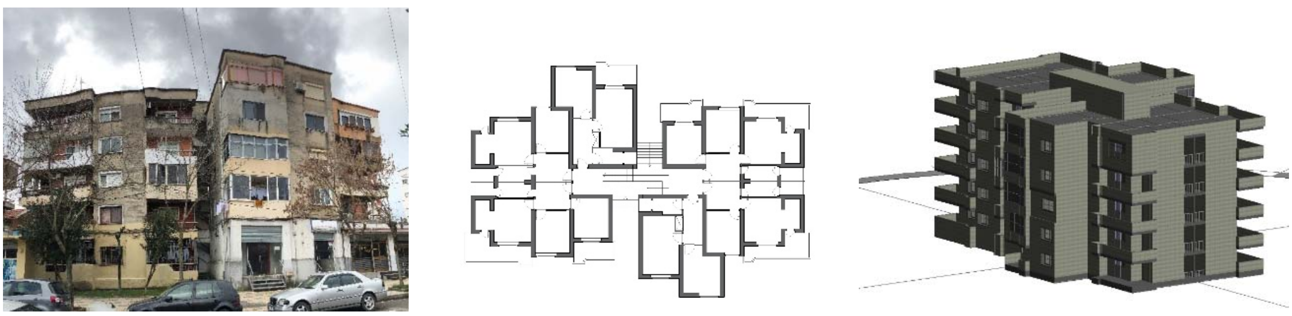

Fig. 4. Street view (photo by the authors), plan view, and 3D model of the Shkodra case study (source: the authors, extracted from the Revit software, 2021)

the communist period these dwelling typologies were repetitively built throughout the country. The apartment blocks were constructed with the use of load-bearing brick walls. The two buildings are also comparable by the number of apartments. There is no thermal insulation applied to the external walls and roofs. The existing windows and balconies are double-glazed, with wooden frames. There are no central heating and cooling systems, no central water heating. During the last decade, the residents were taking individual measures to improve the thermal performance of the buildings, including

Table 1. **Summary of two case studies**

	Case study 1. Tirana	**Case study 2. Shkodra**
Typology	Residential apartment building	Residential apartment building
No. of floors	4	5
No. of apartments	32	30
Construction year	1965–1975	1975–1980
Structural system	Load-bearing walls	Load-bearing walls
Object state	Degraded	Good
Facade	Windows, balconies	Windows, balconies
Facade extensions	Yes	No
Facade materials	Brick, partially plastered	Plaster
Windows	Single, partially double glazing	Single, partially double glazing
First floor	Services, bar, cafe, shops	Mixed use (apartments + businesses)
Footprint area, m^2	765	523
Total area, m^2	3060	2165
Perimeter, m	110	115
Total wall area, m^2	1099	1491
Total window area, m^2	221	234

the replacement of the old wooden windows with plastic ones, partial insulation and finishing of the facades, glazing of the balconies, and arrangement of additional rooms on the first floor. Heating and cooling is provided with air conditioners installed by the residents.

Results

– **Improvement of the thermal insulation of the building envelope**

The walls lose 19–20% of heat used to heat the apartments. The exterior walls of both case study buildings are composed of a double brick layer and a plaster layer. The renovation strategy includes the following changes: addition of a 5 cm exterior fiberglass batt layer; improvement of the interior plaster; and addition of a 3 cm exterior plaster layer (Fig. 5).

The roof construction (Fig. 6) is similar for the two case studies. The renovation strategy includes: addition of a polystyrene layer; addition of a vapor insulation membrane; water-proofing and a protective layer; and improvement of the interior plaster.

To find the heat conduction in the case of both the walls and roofs, the first step is to find the thermal resistance of each of the materials (R_i):

$$R_i = \frac{x_i}{k_i}, \quad (1)$$

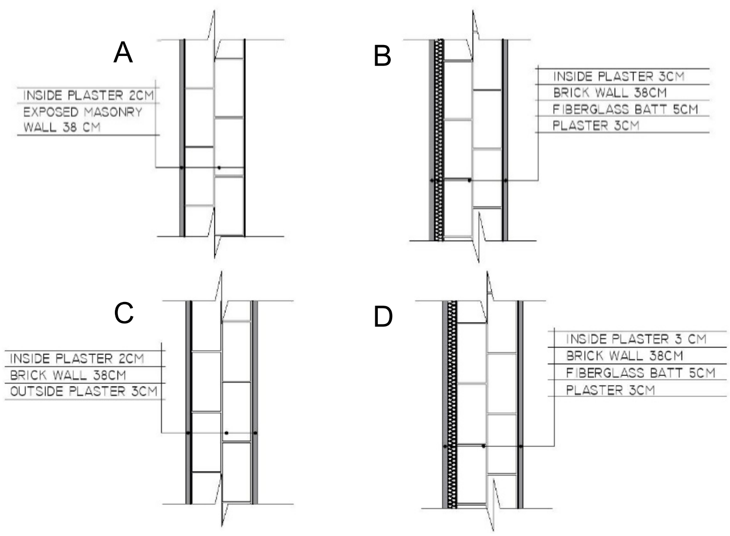

Fig. 5. Details of the existing wall in Tirana (A) and Shkodra (C) and the proposed new walls in Tirana (B) and Shkodra (D) (source: the authors, extracted from the AutoCAD software, 2021)

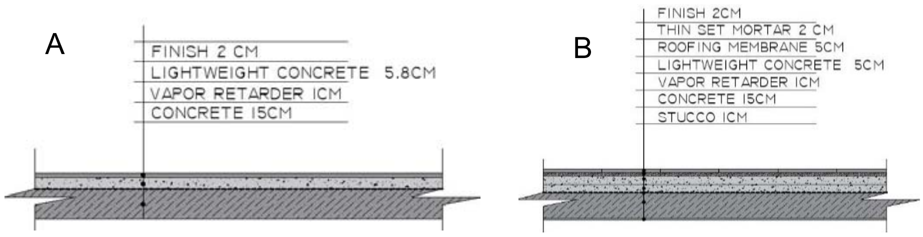

Fig. 6. Details of the existing roof (A) and the proposed roof (B) in Tirana and Shkodra (source: the authors, extracted from the AutoCAD software, 2021)

Table 2. **Material composition and thermal resistance of the existing and proposed walls and roofs in two case studies**

Materials	x exist., m	k, W/(mK)	R exist., m²K/W	x prop., m	k, W/(mK)	R prop., m²K/W
Case study 1. Tirana. Walls						
Interior plaster	0.03	0.42	0.071	0.03	0.42	0.071
Brick	0.38	0.9	0.422	0.38	0.9	0.422
Fiberglass wool	-	-	-	0.05	0.03	1.613
Exterior plaster	-	-	-	0.03	0.42	0.071
Total			0.494			2.178
Case study 2. Shkodra. Walls						
Interior plaster	0.03	0.42	0.071	0.03	0.42	0.071
Brick	0.38	0.9	0.422	0.38	0.9	0.422
Mineral wool	-	-	-	0.05	0.045	1.111
Exterior plaster	0.03	0.42	0.071	0.03	0.42	0.071
Total			0.565			1.676
Case study 1 and 2. Roof						
Interior plaster	0.02	0.41	0.488	0.02	0.41	0.488
Concrete	0.18	1.6	0.113	0.18	1.6	0.113
Polystyrene	-	-	-	0.05	0.8	0.063
Lightweight concrete	0.05	0.4	0.125	0.05	0.4	0.125
Bitumen	0.01	0.138	0.072	0.01	0.138	0.072
Total			0.798			0.860

where x_i is the thickness of the material and k_i is the thermal conductivity coefficient. The summary of the thermal resistance values of the walls and roofs before and after the retrofit is given in Table 2.

The second step is to calculate the heat conduction of multi-layered objects, which gives the total amount of heat losses during the heating or cooling period (*Q*).

$$Q = \frac{1}{\sum R} A\left(T_1 - T_2\right) 24\,\mathrm{HDD}, \qquad (2)$$

where $\sum R$ is the sum of all thermal resistance values of the layers; *A* is the surface of the material; $T_1 - T_2$ is the difference between the indoor and outdoor temperatures, and *HDD* is the amount of heating or cooling degree days in a season. The renovation strategy demonstrates 77% increase in the thermal resistance of the building walls in the case of Tirana and 66% increase in the case of Shkodra. For the roof, in both cases, an increase in the thermal resistance is 7% (Table 3). The retrofit strategy also includes the replacement of the double windows with high-performance windows with triple glazing, which increases thermal resistance by 78%.

Tirana and Shkodra are both located in a warm zone, and the two cities slightly differ in climate and in the duration of the heating and cooling seasons due to their location (climate-data.org, 2021a, 2021b; Weather Spark, 2021a, 2021b). Table 4 shows the average temperature and the duration of the hot and cold seasons in these two cities.

During the calculation of the annual energy losses, the heating loads during the cold season and the cooling loads for air conditioning during the hot season were evaluated. The indoor temperature was accepted at the level of 21°C. The energy losses for the different building envelope elements during the cooling and heating seasons calculated for the whole building and for the square meter of its area are shown in Table 5.

Based on the calculation, it can be seen that the energy consumed during the cooling period in summer is comparable to the energy needed to heat the building during the wintertime. The duration

Table 3. **Thermal resistance of the existing and proposed building elements in two case studies**

Building element	**Case study 1. Tirana**		**Case study 2. Shkodra**	
	R existing, m²K/W	R proposed, m²K/W	R existing, m²K/W	R proposed, m²K/W
Walls	0.494	2.178	0.565	1.676
Windows	0.260	1.200	0.260	1.200
Roof	0.798	0.860	0.798	0.860

Table 4. **Average temperature and duration of the heating and cooling seasons in Shkodra and Tirana**

	Case study 1. Tirana		Case study 2. Shkodra	
	Hot season	Cold season	Hot season	Cold season
Average temperature, C°	24.6	6.1	26	5.8
Duration, days	88	116	90	110

Table 5. **Energy losses during the heating and cooling seasons in Shkodra and Tirana**

Building element	Case study 1. Tirana				Case study 2. Shkodra			
	Q existing		Q proposed		Q existing		Q proposed	
	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2
Heating season								
Walls	91,976	30.05	20,860	6.82	105,765	48.85	41,853	19.2
Windows	39,633	12.95	7614	2.49	36,069	16.66	9175	4.24
Roof	34,141	11.16	36,774	12.01	30,834	14.24	28,609	13.21
Cooling season								
Walls	16,999	5.56	3856	1.26	28,643	13.23	9656	4.46
Windows	6495	2.12	1407	0.46	9769	4.51	2117	0.98
Roof	7325	2.39	6797	2.22	7114	3.29	6601	3.05

of the two periods is almost equal, which can be explained by the Mediterranean location of the two case studies. Currently, a significant amount of energy is transferred through the building walls, but the proposed renovation measures make it possible to decrease energy losses. The selected measures are efficient for the building walls and windows, but the renovated roof demonstrates only minor energy savings. In the case of Tirana, the reduction of energy losses is significantly higher, which is explained by the compact shape of the building with a smaller surface to volume ratio and smaller windows. Due to the complex plan of the Shkodra building, each room has at least two external walls, which increases energy losses.

– **Application of energy-efficient lighting**

In residential buildings, lighting accounts for 11% of energy use. New lighting technologies are more efficient than traditional ones, such as incandescent bulbs. Switching to new light bulbs, such as LED lights, results in a considerable reduction in energy loads (Baggio et al., 2017). Alteration of lighting brings significant direct cost savings. In Albania, incandescent bulbs have been used from the 1990s, but recently LED lighting has become very common. Examination of energy consumption comparison for the LED light bulb and the incandescent light bulb is based on the data provided by the online LED Bulb Power Consumption Calculator (Electrical4u, 2021).

The Tirana building has eight apartments per floor; of them four apartments have five rooms each with one lamp per room, and other four have six rooms each with one lamp per room. The four-story building has 176 light bulbs in total. The Shkodra buiding has six apartments per floor, of them two apartments have five rooms each, two apartments have six rooms each, and two apartments have seven rooms each with one lamp per room. The five-floor building in Shkodra has 180 light bulbs in total. An incandescent light bulb consumes 60 W, while a LED bulb with the same light emission consumes 10 W. For the calculation, it was assumed that the lamps work on average for 6 hours per day. For the Tirana case, the installation of the LED lighting system showed a significant drop in annual energy consumption from 19,272 kWh/year to 3854 kWh/year; for the Shkodra case, the energy consumption lowered from 19,710 kWh/year to 3942 kWh/year.

– **Annual energy performance simulation**

The simulation of the annual energy consumption was completed to estimate the energy performance of the two case studies and understand the changes that occur after the application of the renovation strategy. Detailed 3D models of the two buildings were built using the Revit software. The models were based on the actual dimensions of the two case studies. All structures and materials of the exterior and interior walls and roofs as well as window and door typologies were reflected in the model. The 3D models of the existing and renovated buildings were imported into the Design Builder software in order to perform the simulation. First, the type of building was determined, which is the multi-family residential building. Based on the location of the building, the necessary climatic data was used for the calculation. The construction of the walls, floors, ceilings, terraces, and windows was imported from the Revit

Table 6. **Annual temperatures, heat gains, and energy consumption of the existing and proposed buildings in Shkodra and Tirana**

Parameter	**Case study 1. Tirana**		**Case study 2. Shkodra**	
	Existing building	Renovated building	Existing building	Renovated building
Air temperature, °C	19.44	21.45	19.45	22.76
Radiant temperature, °C	19.58	21.90	19.36	23.07
Operative temperature, °C	19.51	21.68	19.40	22.92
Outside dry-bulb temperature, °C	15.40	15.40	16.12	16.12
Lighting, Wh/m^2	36,976	21,712	43,800	30,878
Occupancy, Wh/m^2	2572	2260	2379	2007
External infiltration, Wh/m^2	-25,224	-35,432	-17,031	-34,026
Solar gains through the windows, Wh/m^2	17,024	44,552	31,549	62,524

model, and the type of lighting was defined within the software. The annual temperatures inside and outside of the buildings, lighting, occupancy, and solar gains through the windows were found using the EnergyPlus engine (Table 6).

The simulation results show 41% reduction in electricity consumption in the case of Tirana and 30% reduction in the case of Shkodra. The occupancy is insignificantly decreased, while the solar gains rose by 62% in the case of Tirana and doubled in case of Shkodra. The application of the passive strategies results in approximately 2°C rising of the indoor temperature in both buildings.

– **Installation of photovoltaic panels on the roof**

A general rule for the installation of a solar system is to provide the maximum solar power output and use all the opportunities to accommodate the maximum number of panels on a roof. It allows the inhabitants to maximize the savings and speed up the payback period of the solar energy system. For each of the case studies, the photovoltaic system was placed on the rooftops. The arrangement of the PV panels and their performance were calculated using the PVCAD and PV Watts software (NREL, 2021). PV Watts is a popular web application, which is used in combination with the PVCAD software to estimate the energy generation of a grid-connected photovoltaic system. The electricity generation of a solar photovoltaic system is evaluated by: its power output productivity also depending on some other features, such as panel efficiency; temperature compassion; shading degree; and azimuth and tilt angle of the photovoltaic panels. The PV panels were installed in a way to maximize their number and increase energy generation. The PV panels were arranged in a fixed open-rack array with the array tilt of 20° and the azimuths corresponding to the orientation of the roof, which is south-west. The inverter efficiency was taken as 96%, DC to AC size ratio — as 1.2, and the performance and capacity factor — as 16.4%.

Fig. 7 shows the arrangement of the photovoltaic panels on the roofs of the two buildings. In the case of Tirana, there are 220 modules organized into 4 strings of 10 series-connected micro-inverters and 15 strings of 12 series-connected micro-inverters. In the case of Shkodra, there are 127 modules organized into 2 strings of 9 series-connected micro-inverters, 3 strings of 10 series-connected micro-inverters, 5 strings of 11 series-connected micro-inverters, and 2 strings of 12 series-connected micro-inverters. Since the roof of the Tirana building has a simple rectangular shape, the PV panels can be arranged in rows, while due to the complex outline of the Shkodra building, the space is not used in an efficient way, and relatively fewer panels can be applied.

Fig. 8 shows the monthly distribution of the energy produced by the PV panels of the two buildings. Due to the greater roof surface, the monthly energy

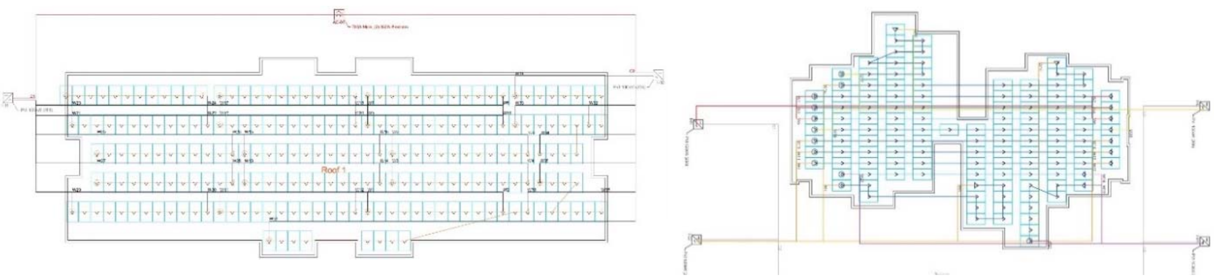

Fig. 7. PV panel modules placed on the roof of the building in Tirana (on the left) and Shkodra (on the right) (source: the authors, extracted from the PVCAD software, 2021)

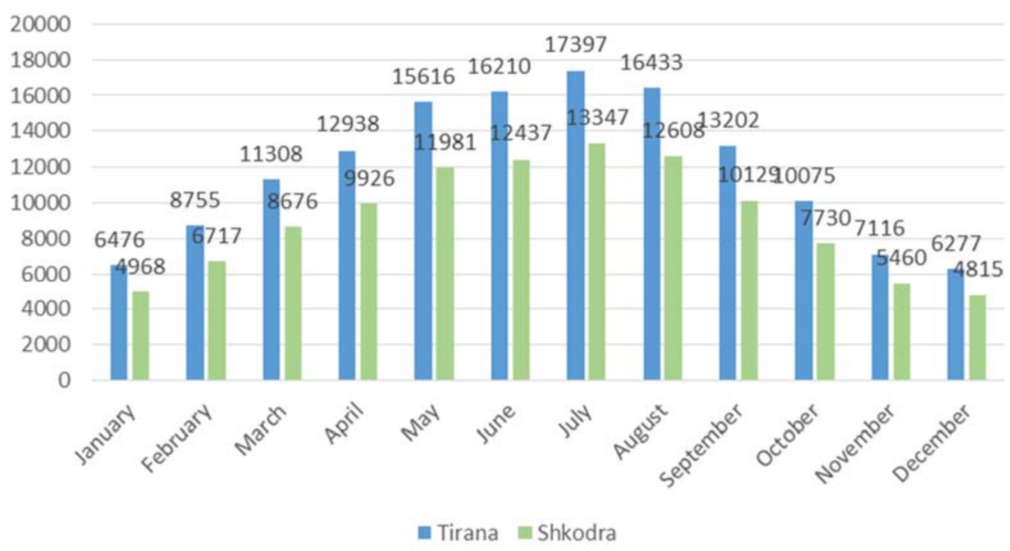

Fig. 8. PV panels' monthly energy performance chart for Tirana and Shkodra cases, kWh

generation of the Tirana building is higher than that of the Shkodra building. However, the climate differences between the two cities are minimal and the average solar radiation received by a square meter of the roof surface is the same for both cases, which is 5.13 kWh/m^2/day. The building located in Tirana can potentially produce in total 141,804 kWh/year, with the highest energy generation in summer months, and the Shkodra building can produce 108,793 kWh/year. Due to the larger total area, the annual production of solar energy per square meter for the Tirana case is 46.34 kWh/year, which is lower than in Shkodra with 50.25 kWh/year per square meter.

– **Annual energy balance**

The energy balance of the two selected buildings of the communist period shows positive results after the renovation with new efficient applications. The two case studies were built using different construction techniques and they are located in places with minor temperature differences. The study proposes two strategies aiming to gain renewable energy by the installation of photovoltaic arrays on the building roof and minimize energy losses through the building envelope and appliances. The contribution of each of the renovation strategies to the annual energy balance of the building can be viewed in Table 7.

The application of the passive strategies for the renovation results in a 56% decrease in energy losses for the Tirana case study and a 57% decrease for the Shkodra building. The annual energy balance is positive for both cases; however, the Tirana case shows higher performance both in terms of energy saving and energy generation. Installation of the photovoltaic panels on the roofs can cover all the heating, cooling, and lighting demands for both cases of renovation being evaluated on

Table 7. **Annual energy balance of the existing and renovated buildings in Shkodra and Tirana**

Building element	**Case study 1. Tirana**				**Case study 2. Shkodra**			
	Q existing		Q proposed		Q existing		Q proposed	
	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2	Whole building, kWh	Per m^2, kWh/m^2
Energy losses								
Walls	108,975	35.61	24,716	8.08	134,399	62.08	51,509	23.79
Windows	40,636	13.28	9021	2.95	45,838	14.98	11,292	5.22
Roof	46,958	15.35	43,571	14.24	37,948	12.40	35,210	16.26
Lighting system	19,272	6.30	3854	1.26	19,710	9.10	3942	1.82
Total	185,831	60.73	81,162	26.62	237,895	109.88	101,953	47.09
Energy gains								
PV panels	0	0	141,804	46.34	0	0	108,793	50.25
Total energy balance								
	-185,831	-60.73	60,642	19.82	-237,895	-109.88	6840	3.16

a yearly basis. In the case of Tirana, the generated energy overpasses the needs of the building after the retrofit by 75%, while in the case of Shkodra, the positive difference is only 7%. However, it is necessary to evaluate the performance of the PV system during the coldest month, which is January. Based on the solar panel performance data (NREL, 2021), the daily production of solar energy by the whole building in January is 1.97 kW for the Tirana case and 1.35 kW for the Shkodra case, while the heating loads are 24.94 kW and 27.76 kW, respectively. During the heating period, for both buildings, the contribution of the PV panels into the energy balance is minimal. In the case of Shkodra, the number of photovoltaic panels is minimal, which covers the energy needs, while in the case of Tirana, the number of panels can be reduced since the energy production exceeds the heating, cooling, and lighting demands.

Discussion

The study evaluates the energy performance of the retrofitted mass-housing apartment buildings constructed in all the main cities of Albania. The energy consumption of a typical building can be taken as reference for the evaluation of performance of a similar building (Kmet'kovä and Krajčik, 2015), therefore, the results of the analysis of these two case studies can be applied to all similar buildings constructed during the communist period in the coastal areas and the lowlands of Albania.

Based on the European experience, the reduction of energy losses by 80–90% can be considered as a goal for any retrofit project. In the northern countries, there is a complex approach towards retrofit strategies aiming to decrease energy consumption and demand, control energy use, and generate energy on site. In the southern and Mediterranean countries, modifications of the building envelope as well as solar panels and water heaters are commonly used, while other strategies are not applied. In Albania, the studies are focused mainly on the thermal insulation of walls and windows, which results in a relatively low reduction in energy demands of 47–54%; however, a more complex approach is found in a work by Sherifi (2017). In the present study, the passive retrofit strategies result in a 56–57% reduction in the energy demands, which is slightly higher than the average score for Albania.

The thermal insulation of the exterior walls brings the greatest reduction in the heating and cooling loads. Energy losses through the walls reach 56% in the case of Tirana and 58% in the case of Shkodra. The 5 cm insulation layer is added following the recommendations of Simaku (2017) and Sherifi (2017) for Albania. In the case of Tirana, this resulted in a reduction in energy losses through the walls of up to 30%, which is similar to the average value for Albania of 29.9–32.4% (Simaku, 2017). In the case of Shkodra, the rate dropped to 50%, which is caused by the complex building shape with low compactness. The energy losses through the roof in the Tirana case reach 20%, which is higher than in Shkodra with 16% and higher than the average value for Albania of 7.7–11.2% (Simaku, 2017). The thermal insulation of the roof does not affect significantly the overall performance of the two buildings; however, it should affect positively the thermal comfort in the apartments located at the top floors.

The energy losses through the windows reach 22% and 19% for case study 1 and 2, respectively. According to the literature (Başarır et al., 2012; Djebbar et al., 2018; Höfler et al., 2014), double glazing is the most commonly used retrofit option in the southern countries. Triple glazing and low-e glazing are commonly applied in the northern European countries (Urbikain, 2019), China (Ahn et al., 2015) and South Korea (He et al., 2019). In Albania, double glazing was selected by Sherifi (2017), while Bajraktari et al. (2019) suggest applying triple glazing for retrofit. In the case of Tirana, the application of the triple-glazed windows causes 22% reduction in the energy losses, while in Shkodra it reaches 26%.

The installation of the energy-efficient LED lighting systems brings 80% reduction in the lighting needs, which is higher than the results expected by Gavioli et al. (2015). The difference can be explained by the different location of Albania with the higher amount of natural light and solar radiation. However, Dubois et al. (2015) state that there is a greater potential of energy savings through the application of smart systems and controlled lighting.

The evaluation of the performance of the PV panels goes along with a study of Buchinger et al. (2017), where the authors state that due to the low annual energy demands and large amount of solar radiation, it is possible to reach zero-energy balance through the installation of photovoltaic and solar thermal systems. The application of the PV panels on the entire roof surface results in the high annual energy production, which exceeds the energy demands in the case of Tirana by 75% and in the case of Shkodra by 7%. The results of the study are valid for mid-story buildings having 4–5 floors. In higher buildings, the number of households and interior energy consumption will be higher, while the rooftop photovoltaic panels will produce the comparable amount of energy.

Conclusion

The goal of this study was to estimate the energy performance of the residential buildings of the communist period in Tirana and Shkodra under the existing conditions and apply a number of passive and active retrofit strategies in order to make them more energy-efficient. Particular decisions were made at the level of the building envelope, such as the installation of triple-glazed windows and 5 cm thermal insulation of the roof and walls, and at the level of appliances, such as the replacement of incandescent light bulbs with LED lamps. Additionally, photovoltaic panels were installed on the roofs, providing an extra source of renewable energy. The evaluation methods included the development of a Revit 3D model for the buildings, application of the PW CAD and PW Watts software in order to calculate the layout and the productivity of the solar panels, use of the LED Bulb Power Consumption Calculator, and calculation of annual energy transfers by the building elements using the DesignBuilder and EnergyPlus software. The comparison of the results shows considerable reduction in the energy losses after the retrofit. Solar panels cannot supply all the heating needs during the cold season but they can provide energy for cooling during summer and cover other household demands during the rest of the year. The study shows that maximum energy losses occur through the building walls, however, other elements of the building envelope and building systems cannot be neglected, since they bring considerable contribution to the annual energy balance.

Despite similar climate conditions and similar building materials, the case study of Tirana has better energy performance in comparison to the case study of Shkodra. This can be explained by some parameters of the building volume, such as the simple shape of the building, rectangular plan, smaller windows, and smaller number of apartments. Due to the complex shape, the energy losses of the Shkodra building through the outer envelope are higher, and the shape of the roof allows solar panels to be installed efficiently, covering all the roof surface. Additionally, the Shkodra building has more floors, which means higher occupancy demands.

The evaluated case studies have the least estimated energy reduction in comparison with the best European practices. Similar retrofit strategies can be used for all brick buildings constructed in Albania during the communist period. The choice of the interventions is explained by the economic conditions of Albania, therefore, low-cost measures, which are easy to implement, were selected. To reach the higher level, additional strategies should be applied, such as adding mechanical ventilation with heat recovery, installing solar water heaters, central water heating systems and hot water distribution, ensuring thermal insulation of the basement, closing open staircases and terraces, providing exterior shading systems as well as lighting management and control.

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МОДЕРНИЗАЦИЯ МНОГОКВАРТИРНЫХ ДОМОВ В АЛБАНИИ С УЧЕТОМ ЭНЕРГЕТИЧЕСКИХ ХАРАКТЕРИСТИК НА ПРИМЕРЕ ТИПОЛОГИЙ МАССОВОГО ЖИЛИЩНОГО СТРОИТЕЛЬСТВА

Анна Юницына*, Ильда Садрия

Университет Эпока, Тирана, Албания

*E-mail: ayunitsyna@epoka.edu.al

Аннотация
Введение: Исследование посвящено анализу энергоэффективности жилых домов массовой застройки в Албании и дальнейшей оценке возможностей энергетической модернизации данных зданий. На данный момент в Албании оценка энергоэффективности обязательна для новых зданий, однако в отношении существующего фонда зданий не разработано ни одного соответствующего подхода. **Методы:** Цель данной работы — выполнить оценку многоквартирных зданий коммунистического периода в Тиране и Шкодере и применить ряд стратегий пассивной и активной модернизации, подходящих для условий средиземноморского климата. **Результаты и обсуждение:** Улучшение теплопроводности и энергетического баланса может быть достигнуто за счет дополнительного утепления стен и крыш зданий и замены окон, установки фотоэлектрических панелей и устройства освещения с низким энергопотреблением. Применение пассивных стратегий приводит к снижению потерь энергии на 56% в Тиране и на 57% в Шкодере. **Заключение:** Установка фотоэлектрических панелей позволяет покрыть потребности в охлаждении и освещении в теплый период, однако в зимнее время их работа не может обеспечить удовлетворение потребностей в отоплении.

Ключевые слова: модернизация многоквартирных зданий, энергоэффективность здания, энергоэффективность, фотоэлектрические системы, энергетический баланс.