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*Corresponding author.

E-mail: miranda.rashani@uni-pr.edu



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Energy retrofit alternatives for three apartment buildings in Kosovo

Miranda Rashani^{1*}  and Ardeshtir Mahdavi²

¹ Department of Energy Efficiency, University of Pristina “Hasan Prishtina”, Pristina, Kosovo Region

² Department of Building Physics and Building Ecology, Vienna University of Technology, Vienna, Austria

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ABSTRACT

The need to decrease energy use represents a challenge particularly in developing countries, including Kosovo, considering the unsustainable, insufficient, and inconsistent energy supply. This contribution presents a simplified yet comprehensive approach to evaluate the energy performance improvement potential of three selected multi-family residential buildings using building energy models generated from calibrated and simplified input parameters. To this end, alternative retrofit measures were tested via a simulation-based parametric study. The energy benefit of each retrofit alternative was estimated and analyzed. Results are expected to provide valuable information towards outlining design guidelines for energy-efficient residential buildings in Kosovo.

KEYWORDS

building energy simulation, energy retrofit, parametric study, residential buildings, Kosovo

1. INTRODUCTION

In developing countries, including Kosovo, there is a major need to decrease energy use given the insufficient, inconsistent, and unsustainable energy production and supply. Therefore, energy-efficient retrofit of buildings is of ultimate importance since it embodies a large potential for reducing the total energy consumption in Kosovo. Moreover, retrofitting buildings can contribute to improving indoor air quality and thermal comfort, thereby enhancing the health, productivity, and comfort of the occupants [1–4]. Furthermore, retrofitted buildings improve and extend the life of building services, and increase the property value as well as the attractiveness of the urban area [5, 6]. Improving the energy performance of buildings has been the subject of much research in the past. Thereby, multiple considerations have been pointed out regarding the proper choice of retrofit measures, among that wide variety of possibilities. There are many related limitations and constraints, especially related to sustainability, ease of implementation, and financial investment and benefit [7, 8].

However, there is an evident gap in simplified methods and techniques for assessing and improving the energy performance of residential buildings of developing countries in particular, due to the specific context and socio-economic background. Therefore, it would be arguably useful to develop a simplified systematic framework to tackle the energy performance improvement of residential buildings in Kosovo. Around one-third of the total electricity consumption in Kosovo is used for space heating in the building sector. Therefore, there is considerable potential for decreasing energy use in reducing the heating demand of the existing building stock. This can be achieved through retrofitting the building envelope and systems and the use of advanced technologies involving thermal storage, advanced appliances, and operation controls [9, 10].

Given this background, the overall research effort is this study aimed at exploring the potential of Energy Efficiency (EE) measures in the residential building sector in Kosovo

via empirical investigation methods and application of dynamic thermal simulation modeling. To this end, three typical multi-family buildings, that are representative of the common type of architectural and construction practices in Pristina, were selected for the study. Initially, actual energy performance was documented via collected and monitored data. The collected data was analyzed, interpreted, and used to generate calibrated energy use (i.e., internal heat gain parameters) and thermal performance simulation models (i.e., thermal aspects of buildings' construction) of the selected existing buildings. Information on the case study buildings, their respective energy performance, and calibration process were presented in previous studies [11–13].

In the present study, the resulting calibrated models were further deployed to investigate the potential of retrofitting the buildings. To evaluate alternative EE measures, four energy retrofit scenarios were proposed and compared to the existing conditions represented with Base-Case (BC) models via simulation-based parametric study. The first energy retrofit scenario (S1) involved EE lighting. The existing window replacement with high-insulated glazing was considered in the second scenario (S2). Thermal envelope improvement was included, in addition to the window improvement in S2, in the third scenario (S3). The S3 scenario was further improved with the use of shading devices in the fourth scenario (S4). The energy benefit of each scenario was assessed by comparing the thermal energy demand of the selected buildings before and after the retrofit through computer simulation and mathematical calculation. Ultimately, the benefit of each retrofit measure was estimated, analyzed, and interpreted.

2. METHOD

2.1. Base-case models

The BC models for each building were generated using collected and calibrated data. Since the buildings have complex geometry and occupancy patterns, simplifying and reducing the number of input parameters of the models was essential. Simulations were performed in the building energy simulation tool EnergyPlus. Initially, the geometry of the buildings was generated in the SketchUp platform using obtained data from archives and on-site observation and measurement. Next, the geometry model was exported via OpenStudio, a platform directly linked to EnergyPlus. To manage simulation time and to overcome software limitations, the buildings' geometry was simplified, and the number of thermal zones and input parameters was minimized. Accordingly, each building unit was modeled as one individual thermal zone. The unconditioned spaces with the same function that are repeated on several floors were grouped as an individual unconditioned zone. Consequently, the model of building A consists of 30 modeled zones (23 conditioned and 7 unconditioned zones), building B of 41 zones (30 conditioned, 11 unconditioned), and building C of 46 modeled zones (33 conditioned and

13 unconditioned). In the case of buildings A and B, firewalls facing adjacent buildings were designated as adiabatic surfaces. Since there was no real-time weather station installed in Pristina, typical weather year data (i.e., Meteonorm) was used to run the simulation. The geometry of the buildings and an example of the zoning of a typical floor are illustrated in Fig. 1.

These models were further populated with required input parameters on construction, occupancy, operation data, and weather. To streamline the computation, consistent internal gain parameters for all modeled apartment zones are based on the Austrian Standard (ÖNORM) [14, 15] as there are no available building user guides in Kosovo. A number of parameters were assumed based on observation, local background, and resulting data from the calibration study. A summary of BC model assumptions regarding building geometry, internal gains, and operation schedules is given in Table 1.

2.2. Energy retrofit scenarios and parametric study

Subsequent to generating BC simulation models for each building, parametric studies were performed. Design alternatives involving EE solutions for lighting and the building envelope were investigated. Note that the study did not include the improvement of building systems or the

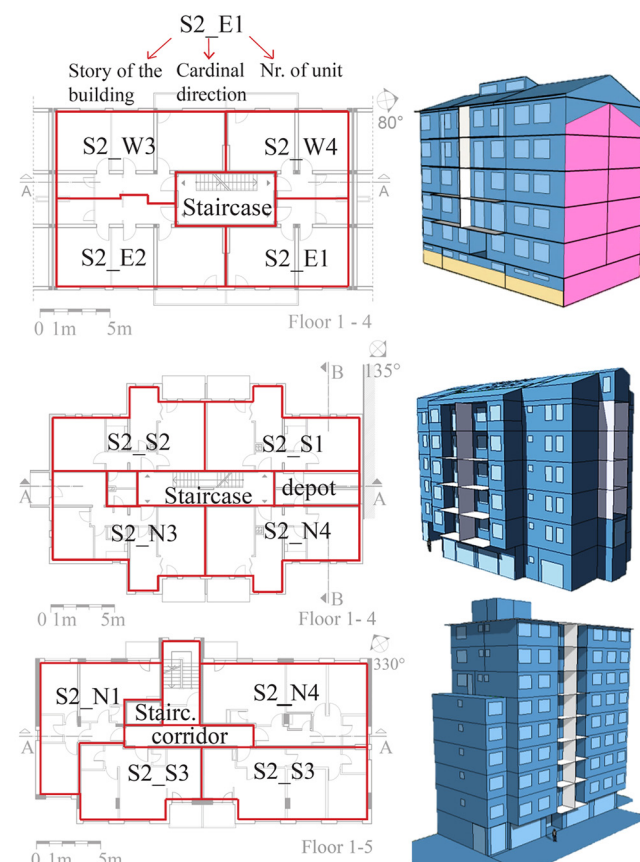


Fig. 1. An overview of modeled zones of the typical floor and geometry model of building A (top), building B (middle), and building C (bottom)

Table 1. A summary of the simulation assumptions regarding the buildings' existing situation characteristics (BC models)

Set	Element	Building A	Building B	Building C
Building geometry	Number of heated floors	5	6	9
	Orientation	E-W	N-S	N-S
	Conditioned net floor area (m ²)	1,273	1,579	1,992
	Conditioned net volume (m ³)	3,480	4,357	5,882
	Roof area (m ²)	286	355	681
	Ground floor area (m ²)	205	298	681
	Total wall area (m ²)	765	1,442	2,370
	Total window area (m ²)	219	255	595
Internal gain	People design level		16 m ² ·person	
	Lighting design level		5 W m ⁻²	
	Appliances design level		3.75 W m ⁻²	
	Domestic hot water design level		3.0 W m ⁻²	
Building operation	Operation days (ÖNORM B8110-5)		365	
	Operation hours (ÖNORM B8110-5)		8,760	
	Infiltration rate		0.5/h ⁻¹ (all zones)	
	Ventilation rate (active scenario)		0.6/h ⁻¹ (all zones)	
	Ventilation rate (passive scenario)		Winter: 0.6/h ⁻¹ (night and day) Summer: 0.6/h ⁻¹ (night), 1.2/h ⁻¹ (day)	
	Heating setpoint for passive cooling scenario (ÖNORM B8110-5)		20 °C	
	Cooling setpoint for active cooling scenario (ÖNORM B8110-5)		26 °C	

replacement of appliances. The criteria used for outlining the retrofit strategies were based mainly on the selection of measures that are most EE while at the same time cost-effective, require little and easy intervention, use materials and construction available on the local market, follow certain local construction trends, are long-lasting, and consider environmental and social factors.

To narrow down the large number of envelope retrofit alternatives, two sets of criteria were used for the proposed EE measures: a) heat transfer coefficient (U-values) that comply with the principles of the low-energy building (i.e., minimum requirements) and b) U-values that follow basic construction principles of Passive House Standard [16] (i.e., maximum requirements). Through this approach, four retrofit scenarios were considered as shown in Table 2. The simulation outputs of the parametric study included energy demand for heating (passive scenario) and cooling (active scenario) on a monthly basis.

The first scenario considers the replacement of all conventional lighting in the apartments with EE lights (12–42 W compact fluorescent lamps with 800–2,420 lumen range). All the following scenarios take this measure into account.

The second scenario S2 involved new windows with two low-E glass layers (S2-a) and three layers of glass (S2-b), two of which are low-emissivity. For both types, argon filling was selected, and window frames were assumed to be well-insulated unplasticized PolyVinyl Chloride (uPVC) frames with multiple lip packing.

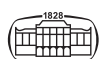
External walls, roofs, basement walls (in building A), and floors above the ground (in building A and building B) were considered for retrofitting. Since the facades of the three buildings are not considered of interest in view of historical and cultural preservation, the insulation can be applied

Table 2. Proposed retrofit simulation scenarios

Building components		S 2		S3		S4	
		S 1	a	b	a	b	a
Lighting		x	x	x	x	x	x
Window	a (min. req.)		x		x		x
	b (max. req.)			x		x	
Opaque envelope	a (min. req.)				x		x
	b (max. req.)					x	
Shading	a (min. req.)						x
	b (max. req.)						

externally on the building envelope. This technique is more convenient to install and enables the envelope component to effectively manage heat loss. Moreover, insulating the envelope externally decreases the chances of a potential thermal bridge or condensation. The exterior walls of the three buildings were assumed to be thermally insulated with External Thermal Insulation Composite System (ETICS) via Expanded PolyStyrene (EPS) insulation. The selection of EPS as the most convenient insulating material for the opaque envelope of the selected buildings was based on its flexibility, compatibility with the core structure of the buildings as well as thermal and cost efficiency.

The three selected buildings have balconies on their façade configurations but building C is the only building where the balcony slab has a thermal partitioning cast directly onto it, consequently minimizing the risk of a thermal bridge. Thus, it is implied that thermally insulating the balconies in building A and building B would lead to a high risk of the formation of thermal bridges. In this context, enclosing the existing balconies of these two buildings with



glazing material (double-glazed low-E window, filled with argon, with sliding panes and vertical frames) was proposed.

The roof of building A is most probably damaged due to the deterioration of the structural materials; therefore, it was assumed that it has to be reconstructed. As for building B and building C, only the insulation layers were candidates for replacement. In the three roof refurbishments, the selected insulation material was polystyrene foam Extruded Polystyrene Insulation (XPS). The reason for this choice is the high compressive strength, higher water resistance, and higher thermal resistance if water is present.

The un-insulated ground floor and basement walls that are in direct contact with the ground (basement walls of building A and ground floor of building A and building B) were assumed to be insulated on the internal layer with an aerogel blanket that stands out for low thermal conductivity despite the small thickness. These boards are capillary active, thus reducing condensation risk and thermal bridge issues. The ground floor of building C is unconditioned. Therefore, its insulation was not considered to be cost-effective.

Information on selected insulation materials (type, thickness, thermal properties) for the building envelope of the three buildings for the retrofit scenario S3 a) and b) is shown in Table 3. As the airtightness of buildings generally increases after thermal improvement of the envelope, the infiltration rate was decreased to $0.4/h^{-1}$ for all modeled zones in the three buildings.

For the present study, Venetian external blinds were selected given the adjustability of their angle, which can help modulate radiation transmittance and reflectance of the

windows while allowing some view of the outdoors. The blinds were intended to minimize the heat gains on summer days (blinds 50% closed from 7 a.m. to 7 p.m.) while allowing night cooling of the buildings (blinds fully open). In winter, the shading devices were considered to be fully open during the day and 70% closed from 7 p.m. to 7 a.m. to limit heat loss from the indoor environment.

3. RESULTS AND DISCUSSION

The results pertaining to the simulated annual whole building energy demand for space heating and cooling for each retrofit scenario for the three buildings are presented in Table 4 and Figs 2 and 3. The potential of each retrofit scenario to reduce the annual heating and cooling demand in the modeled buildings is numerically shown in Table 5.

These results undoubtedly demonstrate a considerable opportunity for energy performance improvement of the selected existing buildings (see Figs 2 and 3 as well as Tables 4 and 5). As expected, the EE lighting can increase - to a very small degree - the energy demand for space heating and slightly decreases the cooling demand (1–2%).

Improving the thermal properties of the glazing solely by replacing old windows with double-glazed new ones (S2-a) resulted in a decrease in the energy demand for heating (6.6% in building B up to 12% in building C), although the impact is more noticeable in the reduced demand for cooling by about 25%. However, it is found that further thermal improvement of the glazing (S2-b) does provide additional

Table 3. Overview of proposed building envelope thermal insulation for the retrofit scenario S3

Buil.	Scen.	Wall EPS ins. (m)		Roof XPS ins. (m)		Floor Aerogel. (m)		Window Low-E, argon fill. (mm)		
		thick. (m)	U-value ($W m^{-2} \cdot K$)	thick. (m)	U-value ($W m^{-2} \cdot K$)	thick. (m)	U-value ($W m^{-2} \cdot K$)	thickness (mm)	U-value ($W m^{-2} \cdot K$)	g-val. [-]
A	S3-a	0.15	0.210	0.15	0.191	0.016	0.424	6-12-6	1.16	0.58
	S3-b	0.25	0.131	0.25	0.120	0.032	0.264	3-12-3-12-3	0.78	0.48
B	S3-a	0.10	0.202	0.15	0.222	0.016	0.532	6-12-6	1.16	0.58
	S3-b	0.20	0.128	0.25	0.131	0.032	0.302	3-12-3-12-3	0.78	0.48
C	S3-a	0.15	0.223	0.15	0.235	/	/	6-12-6	1.16	0.58
	S3-b	0.25	0.140	0.25	0.145	/	/	3-12-3-12-3	0.78	0.48

Table 4. Simulated total annual heating (for the passive scenario) and cooling (active scenario) demand for the three selected buildings for each retrofit scenario

Scenario	Annual heating demand (kWh/y)			Annual cooling demand (kWh/y)		
	Building A	Building B	Building C	Building A	Building B	Building C
BC	92,091	142,172	156,653	33,165	31,747	63,871
S1	93,287	143,913	159,868	34,127	31,131	62,549
S2-a	83,256	132,831	137,902	24,280	23,864	50,864
S2-b	79,795	128,852	128,840	24,069	22,722	50,590
S3-a	52,895	80,342	107,936	32,820	38,755	54,461
S3-b	48,259	69,865	91,581	35,805	41,669	55,451
S4-a	-	-	-	9,203	10,977	16,150
S4-b	-	-	-	10,129	10,899	16,956



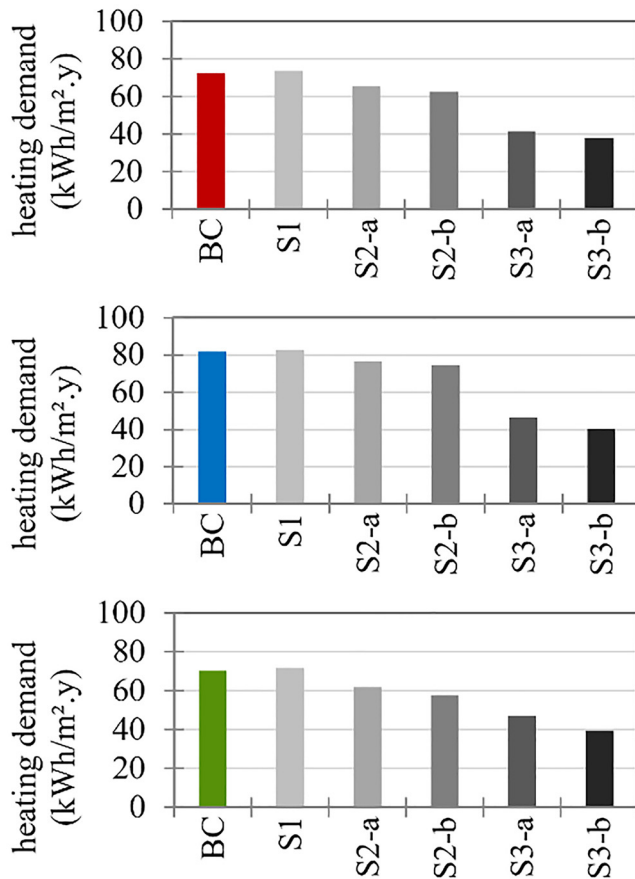


Fig. 2. Simulated total annual heating demand per floor for each scenario for building A (top), building B (middle), and building C (bottom)

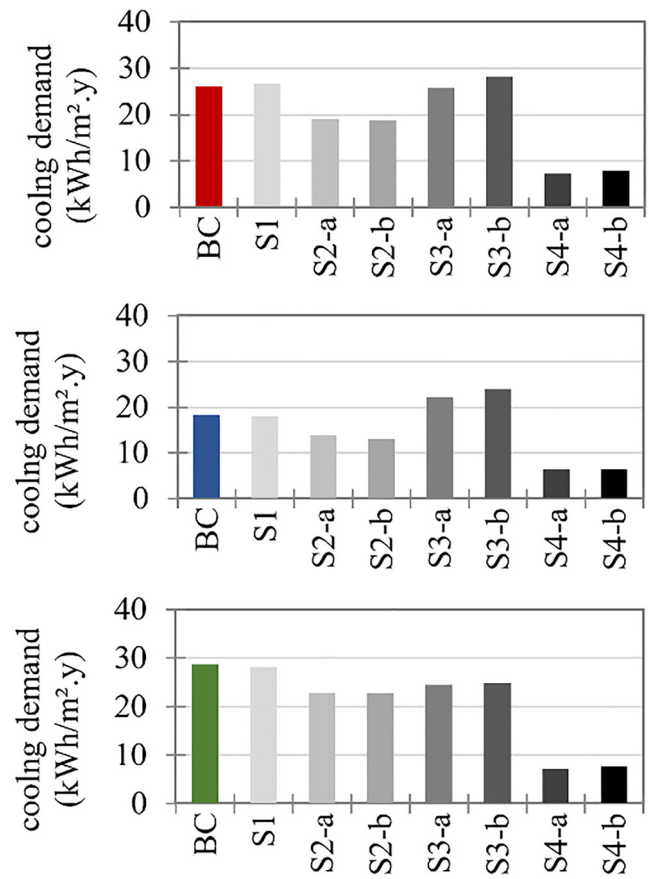


Fig. 3. Simulated total annual cooling demand per floor for each scenario for building A (top), building B (middle), and building C (bottom)

Table 5. Simulated whole building annual heating (passive cooling scenario) and cooling demand (active scenario) per floor area for each scenario ($\text{kWh/m}^2 \cdot \text{y}$) and their respective potential reduction (%) compared to BC

Scen.	Building A				Building B				Building C			
	heating		cooling		heating		cooling		heating		cooling	
	dem.	red.	dem.	red.	dem.	red.	dem.	red.	dem.	red.	dem.	red.
BC	72.4	-	26.1	-	81.8	-	18.3	-	70.3	-	28.7	-
S1	73.3	-1.3	25.8	0.9	82.8	-1.2	17.9	1.9	71.8	-2.1	28.1	2.1
S2-a	65.4	9.6	19.1	26.8	76.5	6.6	13.7	24.8	62.0	12.0	22.9	20.4
S2-b	62.7	13.4	18.9	27.4	74.2	9.4	13.1	28.4	57.9	17.8	22.7	20.8
S3-a	41.6	42.6	25.8	1.0	46.3	43.5	22.3	-22.1	47.0	33.2	24.5	14.7
S3-b	37.9	47.6	28.1	-8.9	40.2	50.9	24.0	-31.3	39.5	43.8	24.9	13.2
S4-a	41.6	42.6	7.2	72.3	46.3	43.5	6.3	65.4	47.0	33.2	7.3	74.7
S4-b	37.9	47.6	8.0	69.5	40.2	50.9	6.3	65.7	39.5	43.8	7.6	73.5

heating and cooling demand reduction rate but not at notable rates (up to 4 kWh/m^2).

As depicted in Figs 2 and 3, both variants of S3 and S4 scenarios a) and b), compared to the respective BC, may generate significant enhancement of the energy performance of the buildings. As Table 5 demonstrates, the S3-a results display a large extent of heating demand reduction rates (of approximately 43%) in buildings A and B and slightly less in building C (reduction rate of 38.2%). Regarding cooling

demand, minor reductions are found in building A (up to 8.9%) and in building C (up to 14.7%) compared to - considerably higher - values in building B (up to 31.3%). This occurrence can be partially explained by the dissimilar building settings and orientations.

As expected, a combination of night-time ventilation and the use of shading devices (S4) can achieve a radical decrease in space cooling requirements. The results of S4 against S3 are reduced by around 70% in the three buildings for both

criteria a) and b). Based on these results, it is possible to emphasize that energy demand for cooling depends, among other things, on the thermal insulation of the envelope, window quality, solar control, and ventilation.

Ultimately, the best retrofit option in view of the simulated heating demand for the three buildings leads to the S4 a) and b) scenario, which involves lighting improvement and all-inclusive envelope retrofit. As Table 5 reveals, the potential of S4-b to decrease the heating demand amounts to a 50% reduction rate (47.6% for building A, 50.9% for building B, and 43.8% for building C) and the cooling demand by around 70% (69.5% in building A, 65.7% in building B, and 73.5% in building C). However, even though this scenario intends to meet the Passive House criteria, the simulated heating loads for the three buildings are considerably higher than the specified limits of $25 \text{ kWh/m}^2 \cdot \text{y}$ [16]. It should be emphasized that this study's outcomes are based on simplified numerical and digital simulation models. Yet, the present contribution offers a proper basis for further studies of a greater scope of intervention that involves a larger extent of measures involving building systems.

Ultimately, it can be suggested that this approach to improving the energy performance of the buildings can substantially benefit the economy of the families, indoor comfort, and the environment.

4. CONCLUSION

The present contribution introduces a simplified approach for a comprehensive and systematic investigation of the EE building retrofit potential, which would enable and support the decision-making process toward EE building retrofit in Kosovo. Thereby, three typical multi-family apartment buildings located in Pristina, Kosovo, were selected. The study was carried out using a high-resolution empirical database through a simulation-based parametric study. To this end, to facilitate calculation time and to overcome software limitations, a systematic approach was followed, whereby a simplified base-case model was generated based on calibrated input parameters as well as norms and standards on user guides for each building. The generated models were further deployed to explore the potential of EE measures. Four retrofit scenarios were tested, aiming to achieve significant reduction rates of energy demand for heating and cooling of indoor spaces. Results show that the use of the selected measures can bring about considerable reduction rates of energy demand for heating (up to 50%) and an approximate cooling energy reduction rate of 70% in the studied buildings.

The outcome of the study is expected to provide valuable information toward outlining design guidelines for energy-efficient residential buildings in Kosovo.

REFERENCES

- [1] Y. Liu and W. Guo, "Effects of energy conservation and emission reduction on energy efficiency retrofit for existing residence: a case from China," *Energy and Buildings*, vol. 61, pp. 61–72, 2013.
- [2] M. Frontczak and P. Wargocki, "Literature survey on how different factors influence human comfort in indoor environments," *Building Environ.*, vol. 46, no. 4, pp. 922–937, 2011.
- [3] G. M. Mauro, M. Hamdy, G. P. Vanoli, N. Bianco, and J. L. M. Hensen, "A new methodology for investigating the cost-optimality of energy retrofitting a building category," *Energy and Buildings*, vol. 107, pp. 456–478, 2015.
- [4] S. Dervishi, F. Pashako, X. Dushaj, and I. O. Dervishi, "Energy performance optimization of traditional housing in Mediterranean climate," *J. Building Eng.*, vol. 45, 2022, Paper no. 103423.
- [5] M. A. Tovar, "The structure of energy efficiency investment in the UK households and its average monetary and environmental savings," *Energy Policy*, vol. 50, pp. 723–735, 2012.
- [6] O. Pombo, B. Rivela, and J. Neila, "The challenge of sustainable building renovation: assessment of current criteria and future outlook," *J. Clean. Prod.*, vol. 123, pp. 88–100, 2016.
- [7] B. Wang, X. Xia, and J. Zhang, "A multi-objective optimization model for the life-cycle cost analysis and retrofitting planning of buildings," *Energy Build.*, vol. 77, pp. 227–235, 2014.
- [8] R. Wu, G. Mavromatidis, K. Orehounig, and J. Carmeliet, "Multi-objective optimization of energy systems and building envelope retrofit in a residential community," *Appl. Energy*, vol. 190, pp. 634–649, 2017.
- [9] X. Zhang, J. Shen, Y. Lu, W. He, P. Xu, X. Zhao, Z. Qiu, Z. Zhu, J. Zhou, and X. Dong, "Active Solar Thermal Facades (ASTFs): from concept, application to research questions," *Renew. Sustain. Energy Rev.*, vol. 50, pp. 32–63, 2015.
- [10] C. H. Radha, "Traditional houses energy optimization using passive strategies," *Pollack Period.*, vol. 13, no. 2, pp. 185–194, 2018.
- [11] M. Rashani and A. Mahdavi, "Energy performance assessment of existing multi-family apartment buildings in Kosovo," *Energy Proced.*, vol. 78, pp. 782–787, 2015.
- [12] M. Rashani and A. Mahdavi, "Calibration of energy simulation model for three buildings in Kosovo," *Pollack Period.*, vol. 16, no. 3, pp. 120–126, 2021.
- [13] M. Rashani and A. Mahdavi, "Calibration of building energy use models: a case study of three residential buildings in Kosovo," in *Proceedings of the 3rd Central European Symposium on Building Physics*, Dresden, Germany, September 14–16, 2016, pp. 521–526.
- [14] ÖNORM B 8110-5, Thermal Insulation in Building Construction - Part 5: Model of Climate and User Profiles (In Austrian). Wien, Austria: Austrian Standards, 2011.
- [15] ÖNORM EN 16798-1, Energy Performance of Buildings - Ventilation for Buildings - Part 1: Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Acoustics - Module M1-61 (In Austrian). Wien, Austria: Austrian Standards, 2015.
- [16] Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard. Darmstadt: Passive House Institute, 2016.

