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# Calibration of energy simulation model for three buildings in Kosovo

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## ABSTRACT

The energy performance of residential buildings depends on a large number of interrelated factors. The present paper outlines an approach to developing a building thermal simulation model through real-time data and sensitivity analyses. To this end, three existing multi-family apartment buildings in Pristina, Kosovo, were selected. Initially, thermal simulation models were created using multiple data sources. Model outputs were further evaluated via comparison with available and measured data. Consequently, the most influential input parameters were identified and adjusted to calibrate the models. The resulting calibrated models can be deployed to investigate the potential of alternative retrofit measures.

## KEYWORDS

energy performance, thermal performance, multi-family apartment buildings, building model, calibration, energy simulation

## 1. INTRODUCTION

In general, the evaluation of energy performance in buildings is a challenging task because it depends on a large and diverse number of interrelated factors [1]. Thermal performance evaluation in residential buildings is particularly difficult, given the complexity of the building parameters and complex patterns of people's presence and behavior [2–4]. Moreover, there is a challenge in terms of reliable estimations due to uncertainties pertaining to the onsite measurements and investigation, as well as weather forecast [5]. Furthermore, it is difficult to take into consideration the degradation of building construction and systems over time, as well as unexpected malfunctions [6].

Given this background, different approaches concerning the reliable estimation and replication of energy performance have been used in previous studies [7]. A key factor thereby is the reliability of the model input parameters [8]. Hence, extensive interest in building monitoring and operation diagnostic has arisen. In numerous studies, the simulation application Energyplus is applied for energy analysis and thermal load simulation [9]. In case of existing buildings, real-time data obtained from monitoring can be used to compare and adjust the outputs to evaluate the accuracy of a model's estimations. This process can be improved by narrowing down the most influential input parameters using statistical methods such as sensitivity analysis [10–12]. However, the calibration of simulation models is often very complex and time-consuming. Thus, simplified methods that generate calibrated building energy simulation models can be beneficial.

In this context, a simplified approach to calibrate building energy models based on collected and estimated information is presented. For this purpose, three existing multi-family apartment buildings were targeted. Constructed between 1967 and 2010, these

buildings can be suggested to be representative of typical design and construction practices in Kosovo and are exposed to similar climatic conditions. Building A is a five-story apartment building with load-bearing walls and concrete columns, flanked on two sides by adjacent buildings. Building B is a pre-fabricated building attached on one side by another building and Building C is a free-standing, nine-story building. The structure of the building is a reinforced concrete structural frame with a thermally insulated envelope. General information on the buildings and their respective energy performance has been presented in a previous study [13].

Initially, the actual energy performance was documented and analyzed using a large and diverse set of data collected from different sources, including information on weather conditions, urban layout, building typology, physical features, and construction techniques of the buildings, building materials and systems, as well as occupancy, behavior, and socio-cultural background. To gain further information, energy consumption was documented for three consecutive years and indoor and outdoor climate condition parameters were monitored on a short-term basis. For the present study, the typical-year weather data generated from Meteonorm (Version 7.x, 2015) was used since no on-site weather station was available. Note that assumptions needed to be made concerning missing data based on on-site observations.

## 2. MODELING AND CALIBRATION APPROACH

The present study involved three steps. First, the collected data was used to define input parameters related to building construction and materials, energy-use related patterns, and weather conditions. Second, initial thermal performance models were generated for one typical apartment of each of the selected buildings. Third, the assumptions regarding thermal properties of the building materials were evaluated and adjusted by comparing the simulation outputs with measured data. This resulted in calibrated building thermal parameters of the buildings. The study approach is illustrated in Fig. 1.

### 2.1. Field measurements

To better understand and replicate the thermal performance of the selected buildings, real-time temperature data for both indoor and outdoor environment were monitored and used for calibrating the building construction and materials parameters.

Thirteen HOBO® data logger (U12), which measured the air temperature (°C) and relative humidity (%) every 5 min, were installed in rooms of one selected apartment unit of each building. Special care was taken in positioning the loggers to avoid direct sunlight and any thermal radiation from appliances. In some rooms, two sensors were placed to ensure consistency of the results.

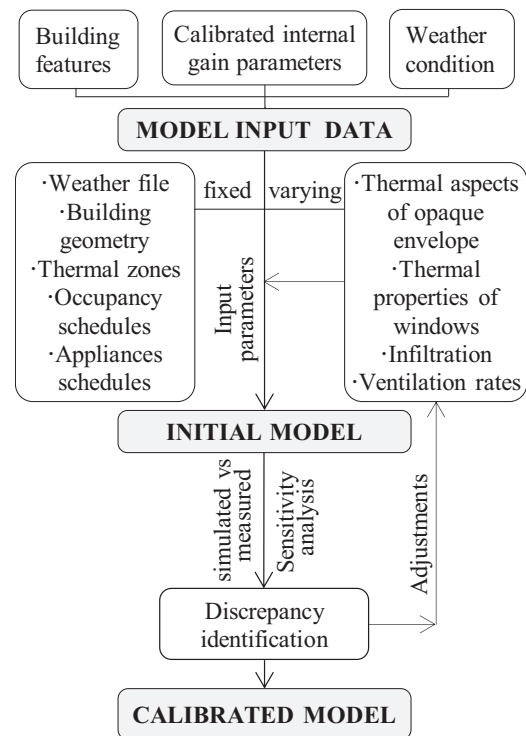


Fig. 1. A schematic illustration of thermal performance model calibration

The monitoring was conducted for the periods from February 15, 2015 to May 15, 2015 and from July 15, 2015 to February 15, 2016.

Additionally, two more data loggers were mounted outside the apartment of Building B (the same apartment was used for indoor monitoring) and set to monitor outdoor air temperature and relative humidity every 5 min for the period from July 15, 2015 to November 31, 2015. Given the relative proximity of the three buildings (less than 2 km apart), the measured outdoor thermal parameters were used for all three selected buildings.

### 2.2. Model input parameters

The building geometry, construction method, and building materials were documented using the collected information. In a previous study [12], a method for calibrating information on the energy-use patterns in these buildings was presented. The results have been used to populate the models with internal heat gain parameters.

### 2.3. Initial thermal performance simulation model

Due to the complexity of the simulation platform and limitations on obtaining real-time measured data, the thermal simulation study was conducted employing one typical apartment unit of each building. The geometry of the apartments was initially outlined in SketchUp [14] and further exported to EnergyPlus [15] through OpenStudio [16]. Each room of the apartments was modeled as a distinct

thermal zone. The apartments' floors, ceilings, and walls adjacent to neighboring apartments were assumed to be adiabatic. The constructed geometry models were further populated in EnergyPlus with information on building materials and construction properties, obtained from a previous study [13]. The internal gains parameters used (occupancy and presence, plug load, lighting load, and their respective duration of use) were adopted from the calibration study results from a previous study [12]. The infiltration rate was set at  $0.5 \text{ h}^{-1}$  for all zones of each building, based on heuristically-based considerations as no other source of information was available. Apartments are ventilated naturally and without air-conditioning systems. The ventilation rates were specified based on information obtained from detailed interviews with occupants as well as observations. The simulations were carried out in the non-heated period, therefore heating load was not considered in the models.

The selected apartment of Building A is a two-room apartment ( $48 \text{ m}^2$ ) located on the first floor. The apartment's external walls are oriented toward the east. The model for this apartment was generated with 4 distinct zones, of which 3 were subject to indoor environment measurements. The selected apartment of Building B is a two-room apartment of  $73 \text{ m}^2$ , located on the second floor, facing south-west. In total, the model has six zones. The selected apartment of Building C ( $78 \text{ m}^2$ ) is located in the corner of the building, on the fifth floor. Its longest external wall is north-oriented, while the other external wall faces the east. The geometry of the apartments with respective modeled zones (marked with Z) are illustrated in Fig. 2.

To perform the calibration study, reliable calibration run intervals have been identified using all available weather databases (i.e., five-point daily values obtained from local institutes, data loggers, and typical-year database). The data sources have been compared and evaluated graphically and statistically during the non-heated period, targeting the periods when the three sets of data coincide best. Ultimately, four intervals for thermal performance model calibration that have been selected to perform the calibration process are displayed in Table 1.

#### 2.4. Calibration of the thermal performance models

A calibration effort was undertaken to test the reliability of the thermal performance model assumptions. The simulated indoor air temperature was compared to measured indoor temperature data of the respective modeled zones, in terms of the five-minute time-step. The selection of the variables that most likely influence the modeling results were based on uncertainty analysis and heuristically-based considerations. The selected variables were further adjusted via sensitivity analysis, resulting in calibrated values. The Root Mean Square Deviation (RMSD) and Coefficient of Variation of RMSD CV(RMSD) were used to minimize the modeling error via evaluation of the deviation between the model and the monitored data, whereas the non-dimensional bias measure Mean Bias Error (MBE) (i.e., the sum of errors) was

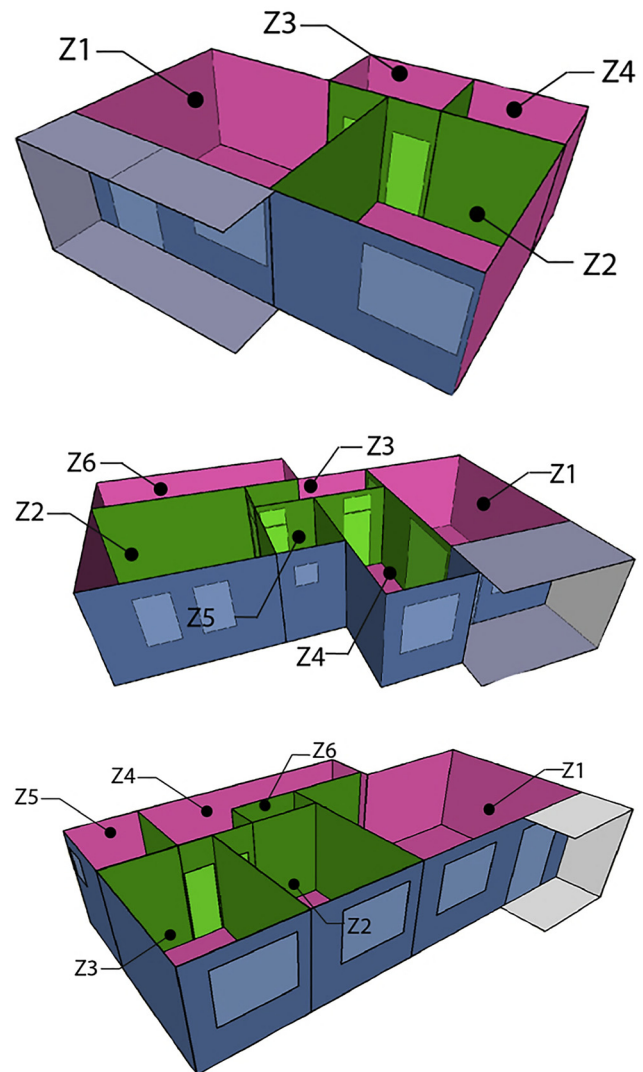


Fig. 2. Geometry layout of the initial thermal performance model of the apartment of Building A (top), Building B (middle); and apartment of Building C (bottom)

Table 1. Calibration run periods for the thermal performance models

Run periods	Start date	End date
1st	July 22, 2015	July 23, 2015
2nd	August 21, 2015	August 22, 2015
3rd	September 08, 2015	September 10, 2015
4th	September 25, 2015	September 28, 2015

used to observe how close simulated data corresponded to measured data for each time-step. The acceptable error margins between simulated and monitored data agreement carried out in five-minute intervals was set at 10% for MBE and 30% for CV(RMSD) [17].

The equations pertaining to the statistical indicators used in the present study are as follows:

Table 2. Calibration steps for Building A, B, and C

Building	Variable	Zones/Item	Unit	Initial value	1st	2nd	3rd	4th	Calibrated value
A	Infiltration rate	All zones	1/h	0.5	0.5	0.6	0.6	0.5	0.5
	Ventilation rate	Z1*	1/h	1.0	1.5	1.5	2.0	2.5	2.0
		Z2*	1/h	1.0	1.5	1.5	2.0	2.5	2.0
		Z3*	1/h	1.0	1.5	1.5	2.0	2.0	2.0
		Z4	1/h	1.0	1.5	1.5	2.0	2.5	2.0
	Solar transmittance	Clear 4 mm	-	0.82	0.82	0.91	0.72	0.72	0.72
	Thermal conductivity	EPS	W/(m.K)	0.040	0.040	0.045	0.035	0.040	0.040
		Brick	W/(m.K)	1.10	1.10	1.30	0.80	1.10	1.10
	Density	Concrete	kg/m <sup>3</sup>	2,240	2,240	2,240	2,400	2,100	2,240
B	Infiltration rate	All zones	1/h	0.5	0.3	0.5	0.5	0.5	0.5
	Ventilation rate	Z1*	1/h	1.0	2.0	0.5	1.5	1.5	1.8
		Z2*	1/h	1.0	2.0	0.5	1.0	1.0	0.8
		Z3*	1/h	1.0	1.0	0.5	0.8	0.8	0.5
		Z4*	1/h	1.0	2.0	0.5	1.5	1.5	2.0
		Z5	1/h	1.0	2.0	0.5	2.0	2.0	2.0
		Z6	1/h	1.0	1.0	0.5	1.0	1.0	0.5
	Solar transmittance	Clear 4 mm	-	0.82	0.82	0.82	0.72	0.91	0.82
	Thermal conductivity	EPS	W/(m.K)	0.040	0.040	0.040	0.035	0.045	0.040
		Concrete	W/(m.K)	2.33	2.33	2.33	2.00	2.50	2.33
	Density	Concrete	kg/m <sup>3</sup>	2,240	2,240	2,240	2,400	2,100	2,240
C	Infiltration rate	All zones	1/h	0.5	0.5	0.3	0.4	0.4	0.4
	Ventilation rate	Z1*	1/h	1.0	0.5	1.5	1.5	1.5	1.8
		Z2*	1/h	1.0	0.5	1.5	1.5	1.0	0.8
		Z3*	1/h	1.0	0.5	1.5	1.5	0.5	0.5
		Z4*	1/h	1.0	0.5	0.5	0.5	0.5	0.5
		Z5	1/h	1.0	0.5	1.5	1.5	1.0	2.0
		Z6	1/h	1.0	0.5	0.5	0.5	1.0	2.0
	Solar transmittance	Clear 4 mm	-	0.82	0.82	0.82	0.91	0.72	0.72
	Thermal conductivity	EPS	W/(m.K)	0.040	0.040	0.040	0.043	0.038	0.038
	Density	Concrete	kg/m <sup>3</sup>	2,240	2,240	2,240	2,400	2,100	2,240

\*Monitored zone

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (x_i - y_i)^2}{n}}, \quad (1)$$

$$CV(RMSE) = \frac{RMSE}{\bar{x}} \times 100, \quad (2)$$

$$MBE = \frac{1}{n} \sum_{i=1}^n (x_i - y_i). \quad (3)$$

In Eqs (1)–(3)  $x_i$  is the measured indoor air temperature value at the time-step  $i$ ,  $y_i$  is the simulated mean indoor air temperature value at the time-step  $i$ ,  $n$  is the sum of the total number of time-steps in the calibration interval, and  $\bar{x}$  is the mean of measured indoor air temperature values of the respective calibration intervals.

### 3. RESULTS AND DISCUSSION

The selected calibration variables for the three buildings, their initial values and their allowed calibration ranges for all modeled zones of the selected apartments for the study

are shown in Table 2. The comparison of the performance of the initial values and calibrated values for the monitored rooms are illustrated in Table 3. Figure 3 illustrates the comparison between measured and simulated indoor air temperatures for initial versus calibrated models in the three apartments for a reference day, in terms of time-series plots.

The results reveal a strong relationship between the predicted and observed values already in the initial models for the three selected buildings (see Fig. 3 and Table 3). In the present analysis, the predictions seem to fit well, due in part to the use of detailed and calibrated information regarding the occupancy and internal gain as well as detailed representation of the buildings' main attributes. In general, results pertaining to the MBE test clearly demonstrate that the model estimates are usually higher than monitored data. As it can be seen in the table, the MBE results show higher deviations in case of Building A, with the highest magnitude of 4.38 in overestimating the simulated data versus the real data. The simulated data in Building B is also repeatedly overestimated (up to -1.9). However, the error analysis test deployed in Building C shows somewhat better MBE results, ranging from -1 (overestimation) to 1 (underestimation).

Table 3. Calibration results pertaining to the thermal model of the buildings

Building	Run period	Monitored zone	Initial model			Calibrated model		
			MBE	RMSD	CV(RMSD)	MBE	RMSD	CV(RMSD)
A	1st	Z1	-2.65	2.68	9.32	-0.65	0.75	2.62
		Z2	-2.57	2.60	9.04	-0.31	0.61	2.11
		Z3	-2.71	2.73	9.81	-0.30	0.55	1.99
	2nd	Z1	-3.12	3.18	11.21	-0.91	1.11	3.91
		Z2	-3.85	3.91	13.97	-1.26	1.43	5.12
		Z3	-3.46	3.51	13.07	-0.92	1.15	4.28
	3rd	Z1	-3.29	3.37	13.05	-0.55	0.95	3.68
		Z2	-4.38	4.45	16.96	-1.46	1.62	6.17
		Z3	-4.12	4.14	16.32	-0.90	0.98	3.85
	4th	Z1	-1.99	2.04	9.02	0.15	0.52	2.29
		Z2	-3.27	3.31	14.55	-0.44	0.68	2.99
		Z3	-3.08	3.09	13.90	0.14	0.31	1.40
B	1st	Z1	-1.33	1.46	5.01	-0.56	0.85	2.93
		Z2	-0.92	1.07	3.61	-0.34	0.68	2.28
		Z3	-0.67	0.78	2.67	-0.04	0.45	1.55
	2nd	Z1	-1.31	1.45	5.05	-0.40	0.81	2.80
		Z2	0.63	0.59	1.92	0.61	0.87	1.85
		Z3	-0.40	0.60	2.04	-0.39	0.70	2.03
	3rd	Z1	-1.87	1.97	7.42	-0.56	0.85	3.19
		Z2	-1.15	1.27	4.56	-0.29	0.66	2.38
		Z3	-1.06	1.13	4.13	-0.13	0.45	1.63
	4th	Z1	-1.90	1.97	8.28	-0.45	0.76	3.19
		Z2	-0.86	0.99	3.91	0.21	0.49	1.93
		Z3	-0.82	0.91	3.70	0.38	0.55	2.23
C	1st	Z1	-0.98	1.18	4.07	-0.16	0.61	2.10
		Z2	-0.21	0.66	2.25	-0.16	0.67	2.10
		Z3	0.06	0.41	1.40	0.08	0.55	1.28
		Z4	-0.34	0.65	2.25	-0.12	0.57	1.97
	2nd	Z1	-0.76	1.00	3.57	0.21	0.74	2.61
		Z2	-0.13	0.74	2.59	-0.12	0.72	2.53
		Z3	0.26	0.46	1.63	0.08	0.35	1.21
		Z4	0.04	0.42	1.44	0.06	0.32	1.09
	3rd	Z1	-0.64	0.91	3.40	-0.17	0.54	1.99
		Z2	0.49	0.86	3.11	0.18	0.52	1.89
		Z3	0.42	0.67	2.45	0.00	0.44	1.60
		Z4	0.08	0.32	1.17	-0.46	0.52	1.09
	4th	Z1	0.00	0.58	2.48	0.17	0.57	2.45
		Z2	0.73	0.86	3.58	0.12	0.41	1.69
		Z3	0.98	1.07	4.50	0.17	0.33	1.39
		Z4	0.31	0.59	2.48	-0.41	0.53	2.21

The relatively high quality of the initial thermal-energy models is further confirmed by the CV(RMSD) analyses results that satisfy the criterion for calibrated models on an hourly basis.

The initial thermal-energy simulations could be thus further improved to yield better predictions. The selected input parameters found to be most influential in the calibration process relate to the thermal parameters of both the construction materials and air change rates of the buildings. As it can be seen in Table 3 and Fig. 3, Building A's model can be improved by altering the ventilation rates and by adjusting solar gain from windows. A similar procedure was followed in Building B, although the influences of thermal parameters of the building envelope materials were less

significant. On the other hand, besides the air change rates, thermal parameters of glazing and insulation material influenced calibration results in Building C. Adjusted assumption concerning thermal insulation and solar heat gains resulted in an improvement in the performance of the model of Building C.

The conducted statistically-based calibration study points to the promising potential of generating thermal energy simulation models that can be deployed to evaluate alternative energy retrofit measures. However, calibration studies involving only one apartment per building might be insufficient. Thus, a larger number of building units in the calibration study are more likely to improve the reliability of model-based predictions.



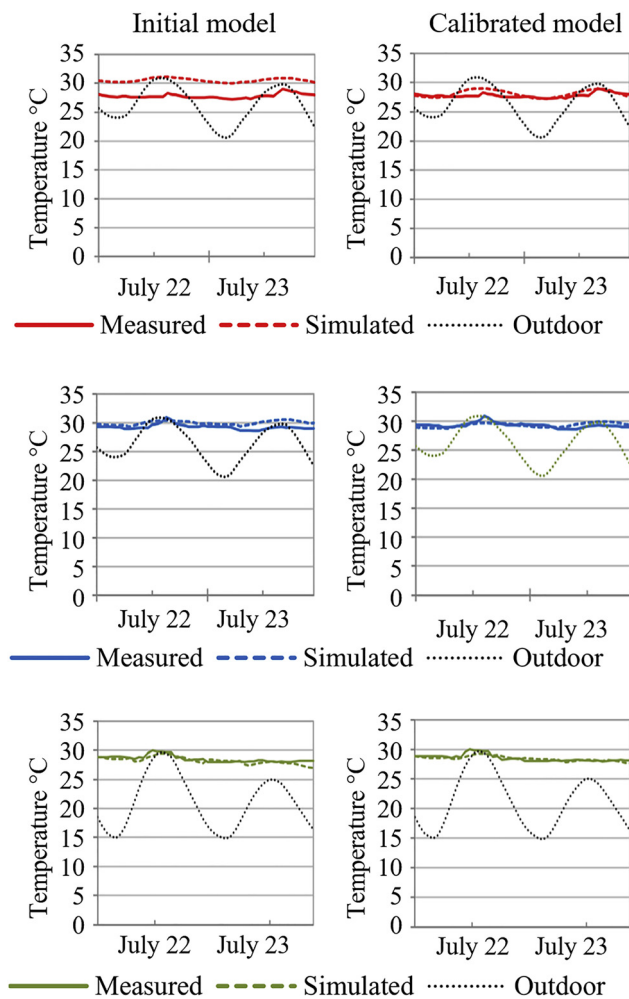


Fig. 3. Simulated versus measured indoor air temperature for the initial model (left) and calibrated model (right) for a reference calibration run (July 22–July 23, 2015) in Building A (top); Building B (middle); and Building C (bottom)

## 4. CONCLUSION

The present contribution presented a simplified approach for a comprehensive and a systematic assessment of thermal parameters of multi-family apartment buildings in Kosovo. The study was carried out using an empirical database including high-level energy performance information (i.e., monthly energy bills and monitored indoor temperature data). Three typical multi-family residential buildings located in Pristina, Kosovo, were selected to conduct the study. The selected buildings vary in terms of construction method and age (1967–2010) and are exposed to similar weather conditions. Initially, a large set of data was collected, analyzed, and interpreted. The collected data was used to create calibrated energy simulation models. The assumptions pertaining to the thermal parameters of the buildings were tested using a numeric simulation application. In the absence of detailed weather data, the typical-year data was used. For an 11-day period, simulation results were based on monitored weather data. Simulation results and monitored

data were systematically compared. Consequently, the input parameters that most affect buildings' thermal performance were identified and adjusted to calibrate the models. Ultimately, these calibrated models can be deployed to investigate and compare the cost-effectiveness of energy efficiency measures in the pertinent building sector in Kosovo.

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## REFERENCES

- [1] Z. Ma, P. Cooper, D. Daly, and L. Ledo, “Existing building retrofits: Methodology and state-of-the-art,” *Energ. Build.*, vol. 55, pp. 889–902, 2012.
- [2] P. Hoes, J. Hensen, M. Loomans, B. de Vries, and D. Bourgeois, “User behavior in whole building simulation,” *Energ. Build.*, vol. 41, pp. 295–302, 2009.
- [3] A. Mahdavi and F. Tahmasebi, “People in building performance simulation,” in *Building Performance Simulation for Design and Operation*. J. L. M. Hensen and R. Lamberts, Eds., Ch. 4. London: Routledge, pp. 56–83, 2011.
- [4] A. Deralla and A. Mahdavi, “Thermal performance analysis of traditional housing in Kosovo,” in *Proceedings of the 2nd Central European Symposium on Building Physics*, Vienna, Austria, Sep. 9–11, 2013, 2013, pp. 217–221.
- [5] Y. Heo, D. Graziano, L. Guzowski, and R. Muehleisen, “Evaluation of calibration efficacy under different levels of uncertainty,” *J. Build. Perform. Simulation*, vol. 8, no. 3, pp. 135–144, 2015.
- [6] Y. Heo, R. Choudhary, and G. A. Augenbroe, “Calibration of building energy models for retrofit analysis under uncertainty,” *Energ. Build.*, vol. 47, pp. 550–560, 2012.
- [7] D. N. Zetz and I. Kistelegdi, “Comfort simulation supported sketch plan optimization of the University of Pécs, Medical School extension,” *Pollack Period.*, vol. 15, no. 2, pp. 166–177, 2020.
- [8] G. Kővári and I. Kistelegdi, “Building performance simulation modeling techniques,” *Pollack Period.*, vol. 11, no. 2, pp. 135–146, 2016.
- [9] 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,” *Energ. Build.*, vol. 107, pp. 456–478, 2015.
- [10] P. Paliouras, N. Matzaflaras, R. H. Peuhkuri, and J. Kolarik, “Using measured indoor environment parameters for calibration of building simulation model – A passive house case study,” *Energy Procedia*, vol. 78, pp. 1227–1232, 2015.
- [11] M. Royapoor and T. Roskilly, “Building model calibration using energy and environmental data,” *Energ. Build.*, vol. 94, pp. 109–120, 2015.
- [12] 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, Sep. 14–16, 2016, 2016, pp. 521–526.
- [13] M. Rashani and A. Mahdavi, “Energy performance assessment of existing multi-family apartment buildings in Kosovo,” *Energy Procedia*, vol. 78, pp. 782–787, 2015.
- [14] SketchUp 8: 3D Design Software, 2014. [Online]. Available: <https://www.sketchup.com>. Accessed: Jul. 22, 2018.
- [15] EnergyPlus, Department of Energy, US, 2015. [Online]. Available: <https://energyplus.net/>. Accessed: Jul. 22, 2018.
- [16] OpenStudio 1.3.0, 2014, National Renewable Energy Laboratory. [Online]. Available: [www.openstudio.net](http://www.openstudio.net). Accessed: Jan. 10, 2018.
- [17] *ASHRAE Guideline 14-2002*: Measurement of energy and demand savings, American Society of Heating, Refrigerating and Air-Conditioning, Atlanta, GA, 2002.