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Thermal performance analysis of traditional housing in Albania

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ABSTRACT
This paper introduces the results of a one-year research, to gather and analyse data on the traditional housing buildings in Kukes region, Albania. The energy performance and the thermal comfort conditions in five different buildings were examined. The Design Builder Energy simulation software was used to analyse the thermal performance of the selected typologies. Detailed construction activity and weather information was applied in modelling the houses. Simulation results showed that these buildings require only heating during the winter. As for the first villa, seven improvement scenarios were applied and examined. The same scenarios incorporate the use of thermal insulation of the walls and the roof as well as the use of double glazing. The results suggest that improvements and insulations in building fabrics could reduce the annual energy consumption up to 35 %.

KEYWORDS
Thermal performance, Traditional building, Parametric simulation, Design Builder

INTRODUCTION

Adaptive reuse contributes to the sustainability of the urban generation, as it extends the life cycle of the buildings, avoids demolition waste, encourages energy efficient solutions, and provides significant social and economic benefits to the society (Resuli and Dervishi, 2015). Due to the difficulty of finding maintained buildings, very few researches analyze the energy efficiency of traditional buildings in Albania (Rexhepi and Mahdavi, 2010). Previous studies have identified effective ways for the energy conservation in the existing buildings (Kaleci and Dervishi, 2014). The renovation of the existing buildings is one of them, consisting of interventions on improving the functionality and sustainability of traditional buildings. This study consists of five traditional buildings located in Lume village, in the Region of Kukes, Albania, on which, records on thermal conditions and the energy use were gathered over a period of one year.

This paper is specifically related to five case studies of traditional houses in the villages of Kukës and identifying their sustainable potentials. The selected houses have been historically exploited as a shelter for the locals, guests, and foreigners. Nowadays their conditions have deteriorated and a large amount of energy is used for heating. Increase of energy consumption is caused by the low temperatures of this area, and the absence of insulations in old buildings, specifically the wall insulation, roof insulation, and double glazing. In most case studies, the building design does not consider orientation, glazing ratio, shading devices, or thermal mass. The sustainable environment is achieved using natural resources (sun, wind, temperature variation) in sustainable approaches, which directly affect the quality of the inner space (comfort, energy efficiency, and lighting) (Rashani and Mahdavi, 2015), and hence, this study is concerned with the following objectives: i) analyzing the energy consumption and how it affects thermal conditions; ii) evaluating the thermal performance; iii) analyzing the comfort of inner spaces; and iv) developing strategies towards improvement.

METHODS

The five selected buildings diverge in terms of construction period, location, orientation and occupancy. Table 1 summarizes general information regarding the concerned houses such as area, function, construction year, presence of Kulla, and the materials used.

Table 1. Overview of the selected houses (year of construction, area, interventions, material used).

	H 1	H 2	H 3	H 4	H 5
Approximate year of construction	1930	1920	1915	1965	1940
Occupancy	full	non	non	full	partial
Interventions	*				*
Two story house	*	*	*		*
Warehouse and livestock		*	*		
Both inner and outer stairs					*
Presence of wood in main façade	*	*	*		*
Materials: Clay, Stone, Wood	*			*	*
Presence of inner wall	*	*	*	*	*

Indoor thermal Condition and Energy Used

Indoor climate parameters (indoor air temperature and relative humidity) and the energy use were simulated for all houses (living room and in the entire building over a period of one year (Jan 1st- Dec 31th). In order to evaluate the existing indoor thermal conditions, the ratios of air temperature and relative humidity are diagrammed in psychometric charts. Based on the questionaries' and gathered information, building performance simulation models were generated and secondarily used to test various improvement scenarios by means of parametric simulation software [Design Builder 2013], (see Table 2).

Table 2. Questionnaire output (thermal insulation, heating equipment, cooling equipment, lamps, thermal comfort)

Questions	H1-Results	H2-Results	H3-Results	H4-results	H5-Results
Thermo insulation	No	No	No	No	No
Heating Equipment	Mineral wood	-	-	Mineral wood	Mineral wood
Cooling Equipment	No	No	No	No	No
Lamps	Economical fluorescent lighting	-	-	Economical fluorescent lighting	Economical fluorescent lighting
Energy used for cooking	Mineral wood	-	-	Mineral wood	Electric
Thermal Comfort (Summer)	Hot-Ground floor Hot-First floor	Neutral-Ground floor Neutral-First floor	Neutral-Ground floor Neutral-First floor	Hot	Neutral-Ground floor Hot-First floor
Thermal Comfort (Winter)	Neutral	Cold	Cold	Neutral	Neutral

Simulation study

Five buildings, respectively H1, H2, H3, H4, and H5 were simulated over a period of one year. The gathered geometry and the construction records were used to generate the base case simulation models. Assumptions were made based on in situ observations, historical documents, and questionnaires'. Simulation assumptions regarding actual construction data are summarized in Table 3. To run the simulations, weather files were generated based Meteonorm (2007) software platform.

Table 3. Base case construction materials and respective U values for all houses (H1-H5).

Code	Scenario	U-Values	Description
BC 1	Base case- H1	U_{Walls}= 1.31 W.m-^{2}.K^{-1} U_{roof}= 1.95 W.m-^{2}.K^{-1} Uwindow = 2.6 W.m-^{2}.K^{-1}	Wall- 60 cm stone wall Roof- Uninsulated pitched roof, Heavy weight Window- Double glazing, Clear, Argon filled
BC 2	Base case- H2	U_{Walls}= 1.46 W.m-^{2}.K^{-1} U_{roof}= 2.11 W.m-^{2}.K^{-1} Uwindow = 5.5 W.m-^{2}.K^{-1}	Wall- 60 cm stone wall Roof- Uninsulated pitched roof, Medium weight Window- 4 mm Single glazing, Clear
BC 3	Base case- H3	U_{Walls}= 1.61 W.m-^{2}.K^{-1} U_{roof}= 2.11 W.m-^{2}.K^{-1} Uwindow = 5.5 W.m-^{2}.K^{-1}	Wall- 50 cm stone wall Roof- Uninsulated pitched roof, Medium weight Window- 4 mm Single glazing, Clear
BC 4	Base case- H4	U_{Walls}= 1.22 W.m-^{2}.K^{-1} U_{roof}= 1.95 W.m-^{2}.K^{-1} Uwindow = 2.6 W.m-^{2}.K^{-1}	Wall- 60 cm stone wall Roof- Uninsulated pitched roof, Heavy weight Window- Double glazing, Clear, Argon filled
BC 5	Base case- H5	U_{Walls}= 1.38 W.m-^{2}.K^{-1} U_{roof}= 1.95 W.m-^{2}.K^{-1} Uwindow = 2.6W.m-^{2}.K^{-1}	Wall- 70 cm stone wall Roof- Uninsulated pitched roof, Medium Window- 6 mm Single glazing, Clear

Improvement scenarios

To demonstrate thermal improvement possibilities a number of seven improvement scenarios (S1-S7) were introduced only for the first typology (H1) for parametric simulations in a 2 day interval (1st and 2nd of July). The first scenario (S1) explores the impact of the thermal insulation on the external walls. The second scenario (S2) involves the thermal insulation of the roof. The third scenario (S3) involves the use of double glazing as a replacement for of single glazing. The fourth, fifth, sixth, and seventh scenarios (S4-S7) comprise the combination of the aforementioned scenarios. The purpose is to achieve a more stable temperature in the indoor environment and to reduce energy consumption. Table 4 summarizes improvement scenarios for one selected representative house.

Table 4. Improved scenarios for H1 (WI, RI, DG, WI+RI, WI+DG, RI+DG, WI+RI+DG)

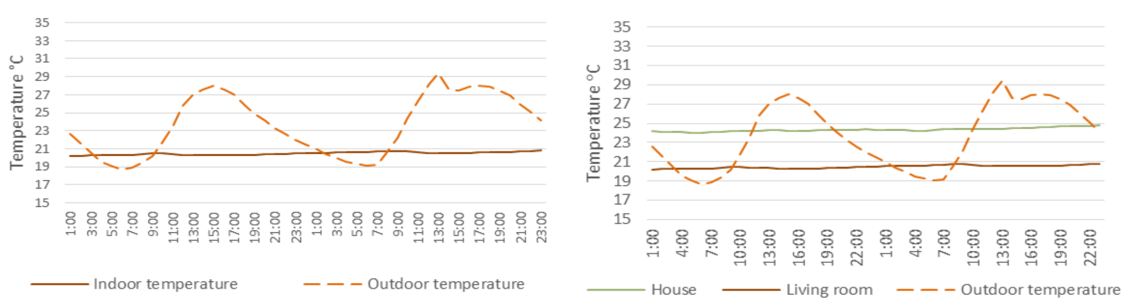
Code	Scenario	U-Values	Description
WI	Wall Insulation	U_{Walls}= 0.26 W.m-^{2}.K^{-1}	Inner Insulation PVC= 12 cm
RI	Roof insulation	U_{roof}= 0.151 W.m-^{2}.K^{-1}	Glass Wool 8 cm
DG	Double glazing	Uwindow = 1.07 W.m-^{2}.K^{-1}	Replacement of Single Glazing with Double Glazing
WI+RI			
WI+DG			
RI+DG			
WI+RI+DG			

RESULTS AND DISCUSSION

Figure 1 shows an indication of the existing thermal performance only in the first house (H1) based on the simulation results in a course of a 2 day interval (1st and 2nd of July 2017). Taking into account the weather conditions in Kukes, no cooling took place during simulation, and ventilation was considered during day and night hours with altered recesses (see Table 5). Figure 2a shows the assessment of indoor temperatures of all selected houses, compared with the outdoor temperature for a 2 day interval measurements (1st and 2nd of July 2017). As indicated in the relevant figures, the indoor temperature is more constant during day and night, compared to the outdoor temperature. Owing to that stone is the material that was used in outer walls its conductivity directly brings about a stable room temperature. A considerable difference is shown between indoor temperatures of occupied houses (H1, H4, and H5) and unoccupied houses (H2 and H3), as the absence of activity affects the sustainability of internal temperatures in H2 and H3. Figure 2b compares the humidity measurements of all houses in the 2 day interval (1^{st} and 2^{nd} of July 2017). Based on the results, the amount of humidity is lower in the occupied houses (H1, H4, and H5) because the unoccupied houses (H2 and H3) are unventilated. Additionally, Figure 3a shows the comparison of energy between five houses in one year interval, while Figure 3b,c shows the ratio of indoor temperatures and relative humidity for one month (July 2017) for H1 (occupied) and H2 (unoccupied) represented by psychometric charts. As it is shown in the charts, the houses are positioned differently related to the comfort zone. The first typology (H1) is the most comfortable one, since its construction belongs to more recent years whilst the second typology (H2) is out of the comfort zone, since it is unoccupied and the amount of humidity is bigger. Figure 4a,b and shows that energy and temperature are changed based on improvement scenarios for the first typology (H1). As shown in the figure 4b the lowest value consists the first typology (H1) due to its recent interventions and insulation system. The second lowest value consists of the fifth typology (H5) which has the same material as the fourth typology (H4) but its activity takes place only during the summer period. For the unoccupied houses (H2 and H3) the results show relatively low performance. The implementation of all scenarios together reduces the amount of energy consumption (yearly) and decreases the indoor temperature in the 2 day interval (1st and 2nd of July). As expected, interventions in the external wall, roof and windows affect directly the indoor temperature and energy consumption. The combinations of the all scenarios (WI + RI + DG) decrease the average of the indoor temperature from 25°C to 22°C during summer period and reduce the annual amount of energy consumption from 74 kWhY.m-2 to 45 kWhY.m-2.

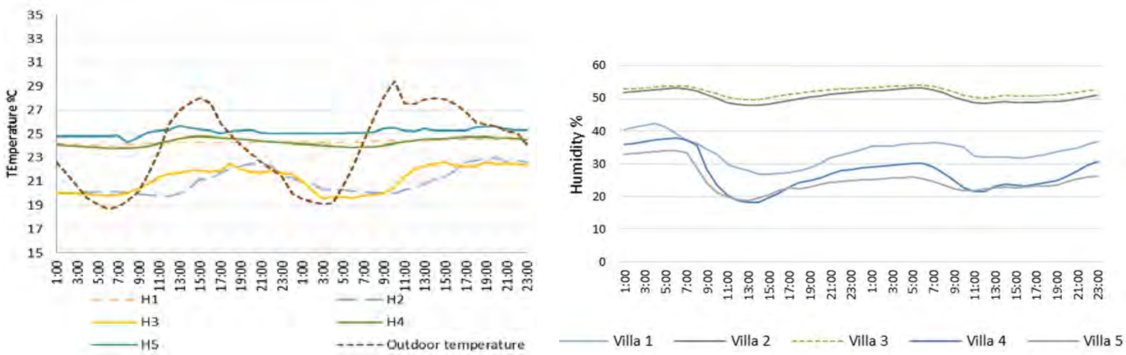
Table 5. Ventilation schedule for all houses (H1-H5)

	H1		H2		H3		H4		H5	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Ventilation hours	09:00-17:00	22:00-01:00	-	-	-	-	09:00-17:00	22:00-01:00	09:00-17:00	22:00-01:00
% of opening	80 %	20 %	-	-	-	-	80 %	20 %	80 %	20 %



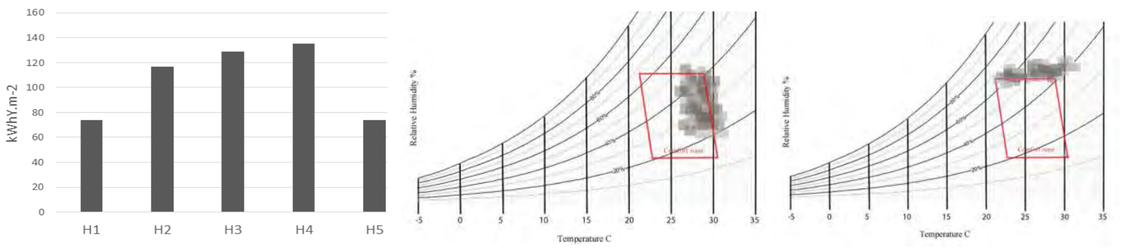
a) b)

Figure 1. a) Base case temperature (living room of H1), b) Symptoms. Base case temperature (living room and H1) in a 2 day interval (1^{st} and 2^{nd} of July 2017).



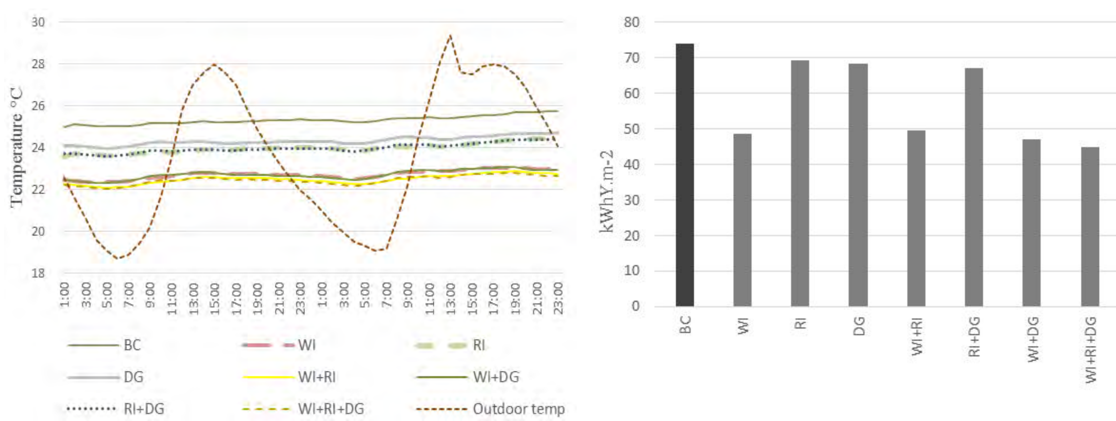
a) b)

Figure 2. a) Comparisons of BC temperatures (H1-H5), b) Comparisons of BC humidity's (H1-H5).



a) b) c)

Figure 3. a) Simulated heating loads/yearly (H1-H5), b) Hourly temperature and relative humidity H1, c) Hourly temperature and relative humidity H2.



a) b)

Figure 4. a) Comparison of BC and Scenario Temperatures (H1-H5), b) Scenarios heating loads (H1).

CONCLUSIONS

The paper is about a study conducted on the comfort and energy consumption of five traditional housing conditions in Northern Albania, using one year simulation measurements. Given the climatic conditions in Kukes, traditional houses require only heating during the winter and no cooling in summer. The simulation results establish that thermal comfort is directly connected to the climate conditions, manufacture fabrics, dwelling shape, and occupants' activity. Altered involvements to the building's fabrics can bring about better performance. Certain combinations of improvement measures (such as insulations in walls, roof, and double glazing) have the ability to recover the thermal performance of the buildings in the climatic context of Kukes, Albania. Wall insulation and other related arrangements have significantly increased the temperatures and condensed the energy consumption, compared with the other scenarios (30 to 35%). Replacement of glazing and roof insulation affects less the thermal comfort (2 to10%). Future studies may address the impact of the change of the structure and activity on the energy consumption of the building.

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