CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 1

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 1. Aalborg: Aalborg University, Department of Civil Engineering.

Deep Energy Refurbishment of an Old Traditional Village House to Approach Zero Fossil Energy and Healthy IEQ Status

Miloš Čokić[#1], Marija S. Todorović[#2]

[#1]PhD Student, Faculty of Technical Sciences, University of Novi Sad, Republic of Serbia

[#2]University of Belgrade, Guest Prof. Southeast University, School of Energy and Environment, Nanjing, China

[1]cokicmilos@gmail.com

[2]vea@eunet.rs

Abstract:

Paper presents results of R&D on refurbishment design methods and technologies related particularly to old traditional village houses providing their residents with: improved thermally indoor environment IEQ (Indoor Environment Quality) by air-conditioning; sanitary water and electricity supply; and an access to the ICT networks. Conducted research encompasses total BPS (Building Performance Simulation) and energy efficiency optimization of the reconstructed building for local typical meteorological year obtaining its zero fossil energy and healthy IEQ status. The case study house was constructed of wooden skeleton and cob–a mixture of mud, straw, wood chips and sand. Determined was strategy, reconstruction means, appropriate RES (Renewable Energy Sources) technologies and whole integrated sustainable building design to turn the building status to the contemporary living conditions, and environmentally conscious status preserving local architecture, construction traditions and culture. Analyzed is existing house renovated with the reference to its initial state, and compared with several scenarios of RES integrated refurbished house models using Bentley AECOsim Energy Simulator integrated with the EnergyPlus. It has been shown, that enough minimized energy loads, can be satisfied exclusively by RES and in addition based on RES use can be produced surplus electricity and sent to the grid. Heating and cooling loads are minimized, HVAC and all other technical systems energy efficiency is optimized, biomass has been selected for heating energy source and photovoltaic panels are used for the electrical energy supply for cooling, lighting, electronics, appliances and sanitary water heating. Further R&D needs: house structure/HVAC/RES integrated reconstruction technologies.

Key words – renewable energy sources integrated refurbishment, energy efficiency optimization, building performance simulation, solar photovoltaic, groundwater heat pump, integrated building's construction/HVAC/energy supply

1. Introduction

"In order to stop the global climatic changes and its more and more obvious consequences, it is urgently necessary to further develop independent, vital and elastic energy systems in which the miniaturization and distributed energy production based on the renewable energy sources – RES have vital role. Current irreversible destruction processes are to be ended, and much more intensive growth of energy efficiency and RES utilization are to be reached especially in building sector" [1].

"Energy-related impacts of buildings must be considered in their life-cycle environmental analysis focusing factors that affect energy consumption: facades concepts/building envelope alternatives, glazing and fenestration, types of building structure thermal mass and insulating materials, day-lighting and artificial lighting control, natural versus mechanical ventilation and energy-recovery opportunities, and HVAC systems regimes and operational modes such as temperature control, air volume control, motors and pump types of control, indoor and outdoor air quality and environmental protection. All of these considerations have an impact on the buildings energy efficiency, HVAC&R requirements and resulting CO_2 emission, as well as on the built indoor environment quality and occupant comfort which is not to be neglected. A holistic approach to building design requires a method to estimate the performance that will result from the energy flows and interactions between the different technical domains of buildings – HVAC and other technical systems. In the same time occupant health is to be priority and comfort is not to be neglected" [1].

"To reduce people migration to cities and reach harmonious sustainable social and economic development is necessary to harmonize rural and urban development reducing differences in living conditions, including accessibility to energy supply, reducing and suppressing environment pollution and CO_2 and other GHG emissions. Intensively and uniformly spread refurbishment of existing buildings in both rural and urban areas, in conjunction with renovation and reconstruction at master and urban planning level is necessary to reach Zero Energy1 and Energy+ (E^+ or "net-positive") and Zero CO_2 Emission (ZCO_2E) buildings" [2].

"Development based on cultural and natural heritage combined with the available most current knowledge and developed environmental, as well as information and communication technologies, has been recognized as one of the key factors to approach sustainable local development, connecting economy, cultural diversity, social and territorial coherence, environmental and social sustainability" [3].

2. Technical Description of the Case Study House

"An important aspect of national craftsmanship is represented through its building skill, as an activity that marked the civil phase in the development of human society. Traditional architecture represents the architecture, which in relation to academic and author's architecture, is based on the practice of learned traditional craftsmanship. Perhaps the most precise definition could be that it is the regional, inhabitant-characterized and traditional knowledge architecture which, apart from technical, features sacral characteristics as well.

As a region-based architecture, traditional architecture is dependent on the materials from the immediate natural environment, as well as the architectural concept and construction forms are conditioned by the terrain and climate properties.

Traditional architecture is not pretentious architecture, but it does not mean that it doesn't possess the construction skills and inventive architectural solutions, which is reflected through the individuality of the architecture that does not belong to styles, but the type" [4].

The data used in this study are a part of "The Atlas of folk building of Serbia" [5] project and it was obtained through cooperation with the Republic Institute for Protection of Monuments of Culture - Belgrade [6].

The house of Slađana Micković (Fig. 1) was chosen for the case study, as an example of a typical rural, family, old house, mainly located in the area of South and Eastern Serbia and was built in the second half of the 19^{th} century (1870s). A lot of these houses are generally in bad or non-functional state, without thermal insulation, water in the household, electricity, and a significant percentage of these houses are not occupied.

Fig. 1 House of Slađana Micković in Ribare village

The analysis of the energy demand for object heating and cooling purposes is carried out in order to investigate the possibility and feasibility of refurbishment of similar buildings in this part of Serbia and across Balkans and to try to preserve a local architecture and construction traditions and culture, but at the same time to adapt this objects to modern living conditions.

A precondition for deep energy refurbishment of house would have been its justification, which is reflected through the necessary resources that would have been invested in this project, and whose quantity depends on the current functionality and condition of the building, as well as its residual life time.

The focus of this project is on the possibility not only of reducing the energy needs for heating and cooling the building by refurbishing it, but in addition to provide its residence with warm water and all necessary appliances to improve their living standard and/or their quality of life. The use of natural energy sources – biomass, solar (thermal and/or photovoltaic (PV)) and geothermal energy (groundwater) system for this household is studied in this research study.

3. Building Performance Simulation (BPS) Method

A. Location and Weather Data

The subject of analysis is the family house on one level with unconditioned attic. The house is built in the second half of 19^{th} century (in 1870s). The data used for model calculations is design climate data for the city of Ćuprija (Table 1.) and TMY (Typical Meteorological Year) for dynamic simulations (house's dynamic behavior study). The analyzed house is located in the village of Ribare, near the city of Jagodina in Republic of Serbia with an approximate distance of 11 km from Ćuprija. Fig. 2 and Fig. 3 are displaying the annual external air temperature profiles. The building is in a moderately sheltered position, although all of the facades are exposed to wind.

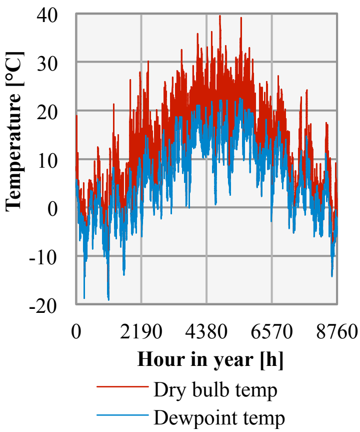

Fig. 2 Annual air temperature-hour oscillation profiles

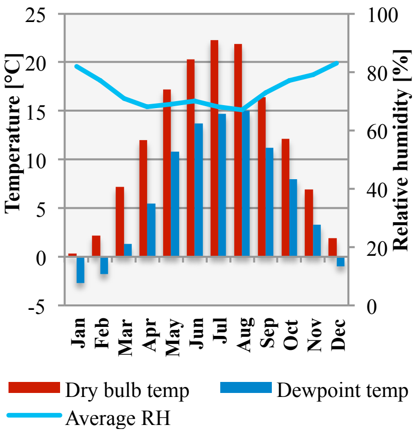

Fig. 3 Annual air temperature and humidity oscillation profiles

Table 1. Weather properties – heating and cooling design data used in calculations

Weather data: Ćuprija, Republic of Serbia		
Heating and cooling design load weather data		
Latitude	43,93°N	
Longitude	21,38°E	
Height	125 m asl	
Climate Design Data:	2013 ASHRAE Handbook	
Design data	Cooling	Heating
Design dry bulb temperature:	32,5°C	-11,6°C
Mean coincident wind speed:	2 m/s	0.5 m/s
Prevailing coincident wind direction:	340°	110°

B. Local Climate Change Relevance for Climate Resilience

According to the data of measurements (1975-2004), annual air temperature in Serbia has increased intensively, more than 4.54°C /100 years. Shorter periods have higher positive values, which practically mean that the warming has been intensified annually in recent years (Fig. 4) [7].

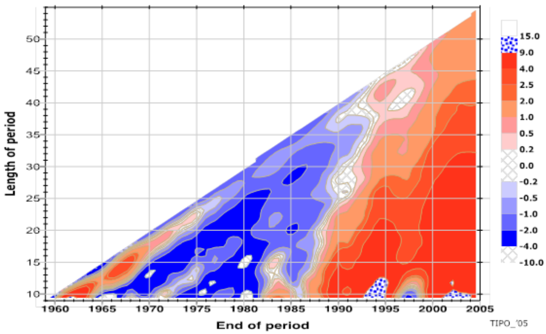

Fig. 4 Sliding trend °C/100 years, annual air temperatures in Serbia

C. House Construction Properties

The analyzed building is dilapidated expendable old house (Fig. 1). The Serbian house is generally built out of material that could be found in the nearby milieu [3]. Main characteristic of houses exposed walls is that they are consisted of the materials that can be found in the environment and are made of a mixture of mud, straw, wood chips, sand, and their thermal characteristics are determined depending on their composition [10].

The objects structural whole is consisted of wooden skeleton (supporting beams and columns) and the cob walls [10] (Fig. 5). The floor plate upper plane is approximately 50 cm from the terrain zero level and it's consisted of layer of rammed earth and limited by stone blocks on its perimeter. Rammed earth layer thickness changes in MO2-MO5 in order to keep the total ground floor thickness at 50 cm [*-Table 2.]. Wooden boards laid on wooden beams are forming a ceiling/internal floor. The roof has a wooden structure with approximately 40° roof pitch on north and 30° on other sides. It is covered with old clay tiles. Due to minor variations in geometric characteristic of the object in the drawings, some dimensions had to be adjusted to obtain a functional entity, but without compromising the quality of the analyzed models calculation results.

The property is consisted of the conditioned ground floor that has three rooms, separated with cob partition walls an total area of 51.42 m^2 and unconditioned attic that has an area of 58.25 m^2. The entrance doors are located on the entry room west wall. There is a brick fireplace in entry room. Entry room is connected with the living room and bedroom. The living room and the bedroom are not interconnected. Ground floor height is 2.8 m. Each room has windows with one layer of plain glass.

With the setting of insulation layer, thermal refurbishment of the building would also include the replacement of existing windows with the triple-glazed windows with low-emission glass, and the replacement of the wooden entrance door with the metal thermally insulated door. One living room window is oriented to west (0.89 m^2 area). Two windows (living room and bedroom) are oriented to the south and have a total surface area of 1.78 m^2, while the fourth window is positioned on the east wall (entry room) and has an area of 0.27 m^2. Of course, the entire refurbishment analysis process is justified only in case that the object static functionality is preserved or restored if necessary. 3D presentation of house model MO1 was constructed in Benley AECOsim Building Designer [11] (Fig. 5).

D. Virtual House Models and BPS Software

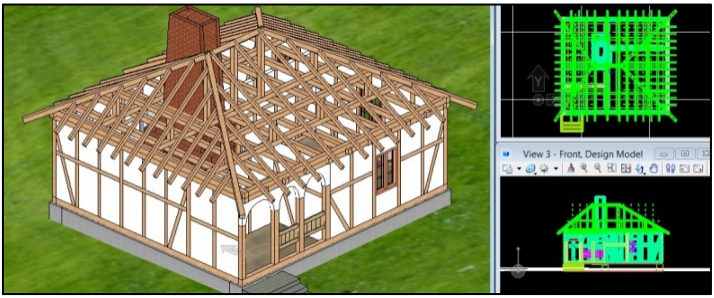

Fig. 5 AECOsim Building Designer house model with displayed roof and envelope structure

Bentley AECOsim Energy Simulator [12] with academic license was used as the analysis software. It supports simulation and analysis of building mechanical systems, environmental conditions, and energy performance and it is integrated with EnergyPlus energy simulation software [13]. The software also supports 3D object elements geometry input, which is accompanied by additional modeling capabilities such as material characteristics input and design; climate data assignment; heating and cooling temperatures setting and schedules; the choice of heating and cooling systems; building occupancy schedules and other processes such as lighting design and schedules, household appliances design and schedules and other functions.

4. Building's Structure Energy Refurbishment Models

A. Minimization of Energy Loads and Demands

Energy demands analysis includes the analysis of five house models. The first model (MO1) is a house in its present state, while the other models have insulation layers added to improve the thermal properties of the building. The model in AECOsim Energy Simulator [12] is shown in Fig. 6.

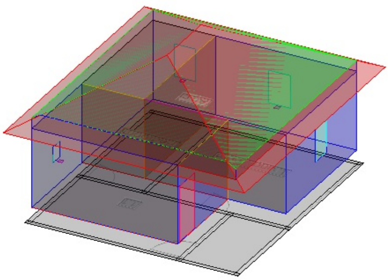

Fig. 6 AECOsim Energy Simulator house model – isometric view

In the model MO1, the air change rate value is set to 3 h^{-1} because of the bad condition of the structure, which has old wooden doors and windows, and air leakages through cracks and other openings in the structure. For all other models (MO2-MO5) air change rate value amounts 1 h^{-1}, under the assumption that the refurbished building has no leakages through cracks, as well as the new doors and windows have good airtightness that provides less air infiltration into the house.

House models MO2-MO5 have a heat transmission coefficient of external walls, ground floor and roof, which are as follows: U(MO2) $\leq$ 0.4 W/(m^2·K); U(MO3) $\leq$ 0.3 W/(m^2·K); U(MO4) $\leq$ 0.2 W/(m^2·K); U(MO5) $\leq$ 0.1 W/(m^2·K), as well as U $\leq$ 0.4 W/(m^2·K) for internal floor/ceiling, U $\leq$ 1.5 W/(m^2·K) for windows and U $\leq$ 1.6 W/(m^2·K) for entrance door. Partition walls in MO1-MO5 are the same as MO1 wall.

Table 2. House structural elements - layers structure and thickness

Construction layers thickness d [m]					
(ins. to outside)	MO1	MO2-MO5	(above to below)	MO1	MO2-MO5
Ground floor			Ceiling/Internal floor		
Timber flooring	–	0.02	Timber board	–	0.03
Concrete screed	–	0.05	Mineral wool	–	Table 3.
Vapor barrier	–	0.00017	Timber board	0.03	0.03
Mineral wool	–	Table 3.	Roof		
Bituminous waterproofing	–	0.003	Clay tile - Red/Brown	0.01	0.01
Clay, dry	50	*	Waterproofing	–	0.00038
Wall			Mineral wool	–	Table 3.
Plaster	0.01	0.02	Glass wool	–	Table 3.
Cob [9]/Wooden beams	0.15	0.15	Vapor barrier	–	0.00017
EPS	–	Table 3.	Gypsum board	–	0.0125
Plaster	0.01	0.02	Gypsum board	–	0.0125 (MO5)

Table 3. Thickness of thermal insulation layers

Insulation layer thickness [cm]		MO1	MO2	MO3	MO4	MO5
Ground floor - Mineral wool		0	7	10	17	38
Wall – Expanded Polystyrene		0	7	10	16	34
Ceiling/Internal floor - Min. wool		0	8	10		
Roof	Mineral wool	0	9	12		
	Glass Wool	0	0	0	8	26

Table 4. Heat transmission coefficient values

U values	MO1	MO2	MO3	MO4	MO5
Constr. element	U [W/m^{2}K]				
Ground floor	1.162	0.374	0.294	0.196	0.098
Wall - Ground floor	1.920	0.378	0.285	0.192	0.097
Ceiling/Internal floor	2.187	0.367	0.309		
Wall - Attic	0.855	0.300	0.239	0.169	0.090
Roof	4.995	0.387	0.298	0.185	0.099
Door	5.333	1.333			
Window	5.801	1.039			

Windows of models MO2-MO5, with single glazing (4 mm thick glass) were replaced by triple-glazed windows with low-e glass and gas-filled chambers (4 + 8 + 4 + 8 + 4 mm), while the ordinary entry wooden doors (d = 3 cm) are replaced with metal thermally insulated door (d = 6 cm).

Building's envelope walls are insulated with layer of expanded polystyrene (EPS), while the layer of mineral wool was used for ground and internal floor insulation. Combination of two layers of mineral and glass wool was used for roof insulation.

In addition to air-conditioning (heating and cooling) household total energy demand calculations include electricity use for interior lighting, home appliances, and sanitary water heating as it is assumed that the space will be reorganized after the refurbishment and added will be a bathroom. Therefore, the additional use of electricity for domestic hot water, as well as the additional washing machine energy use was calculated for models MO2 - MO5.

Fig. 7 displays the specific heat losses and gains and Fig. 8 shows heating and cooling loads in conditioned ground floor.

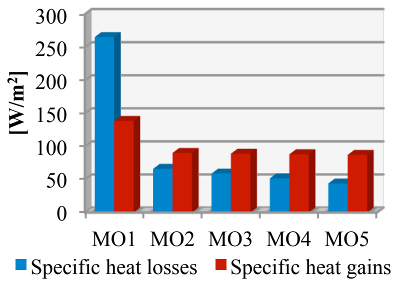

Fig. 7 Specific heat losses and gains

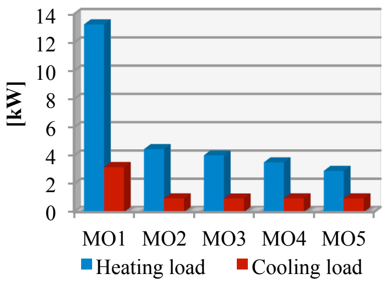

Fig. 8 Heating and cooling loads

Interior lighting, home appliances and hot water supply (HWS) energy loads are shown in Table 5. The energy demands are calculated according to daily household needs, occupation and illumination.

Table 5. Design Loads values

Design Loads [W]					
Process	MO1	MO2	MO3	MO4	MO5
Heating	13284	4460	4024	3522	2921
Cooling	3184	969	962	970	971
El. Appliances	360	463			
Lighting	320				
HWS	0	1500			

B. Indoor Environment Quality

The living room is illuminated with 2 light bulbs with a total output of 160 W, the bedroom with a single light bulb with an output of 60 W, while the entry room is illuminated with a single light bulb with a total output of 100 W. Energy demands of household appliances and lighting system are calculated according to daily household needs, occupation and illumination. Typical occupancy of these types of buildings is approximately 2-4 persons, and for the purpose of this analysis the number of the household occupants is set to 4 persons with the corresponding household occupancy schedule.

Fig. 9 shows the annual air temperature change in unconditioned ground floor and unconditioned attic (free floating regime). By the increase of the insulation layer thickness, there's an increase in air temperature values in all rooms during the year. As a result, there is a less energy need for heating (MO2-MO5), as well as increase in the energy need for cooling (MO2-MO5). Comparing MO2-MO5 to MO1, the important factor of energy use for heating and cooling is the infiltration of outside air into the room, which has a higher value for MO1 compared to other models, which further contributes to higher energy demands for heating and cooling in comparison to other models (MO2-MO5).

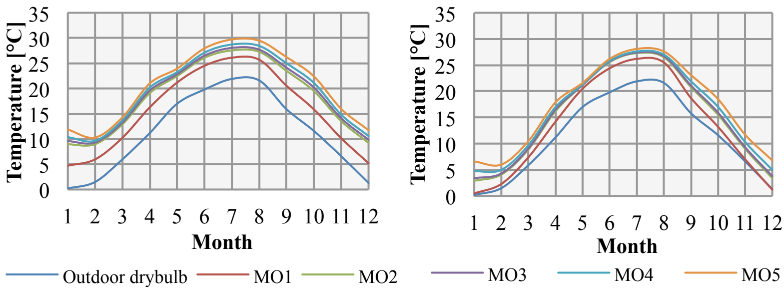

Fig. 9 Monthly mean air temperature change for unconditioned ground floor (left) and unconditioned attic (right)

To provide residents necessary thermal comfort air-conditioning system has been designed setting the ground floor heating temperature to 20°C during the winter, and the cooling temperature to 24°C during the summer period, while the attic is unconditioned.

As expected, results show the reduction of energy needs for ground floor conditioning (Table 6.). Energy demands vary, as the consequence of placed thermal insulation layers, new doors and windows. There is an evident total energy need decreasing tendency, as a result of insulation layers increasing thickness and thereby the reduction of heat transmission coefficient value of objects walls, floors and roof. As for heating and cooling energy demands, the decrease of heating and an increase in cooling energy needs can be noted for models MO2-MO5, but still, the sum of energy requirements for the households temperature maintenance, decreases with the increasing thickness of the thermal insulation layers for models MO2-MO5. Lowest energy demand for heating is related to MO5, and to MO2 for cooling.

Table 6. Annual energy needs related to corresponding loads

Energy demands [kWh/year]					
Model	MO1	MO2	MO3	MO4	MO5
Heating	14091.53	3107.26	2648.47	2207.64	1714.12
Cooling	1078.94	523.63	578.54	646.60	747.28
El. Appliances	1101.63	1416.37	1416.37	1416.37	1416.37
Lighting	729.43	748.89	748.89	748.89	748.89
HWS	0.00	1095.00	1095.00	1095.00	1095.00
Total	17001.53	6891.15	6487.27	6114.50	5721.66

5. From Energy Mix to Renewable Energy Supply

Locally available biomass forest wastes, geo - groundwater, as well as solar radiation availability at the area on which the house is located, offers reliable prospects for design and construction of sustainable energy supply system. Hence, main energy demand of house heating and cooling system can be satisfied combining biomass utilization, groundwater heat pump use and electricity production by the building integrated photovoltaic (PV) panels.

A. Solar and Geo - Hydrogeological Data

Fig. 10 displays the annual solar radiation profile for the city of Ćuprija that was used for the calculation of solar PV equipment, and Fig. 11 displays groundwater temperature oscillation profile on the groundwater measuring station located about 1 km from Ribare village.

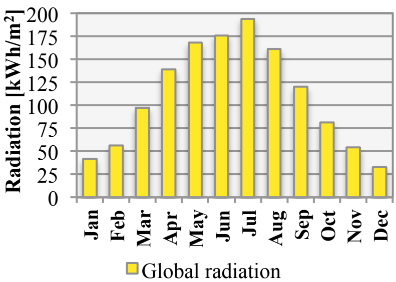

Fig. 10 Annual solar radiation profile, Ćuprija

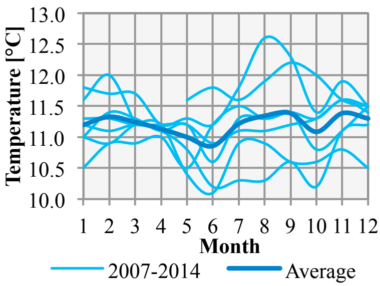

Fig. 11 Groundwater temperature oscillation profile, RI bare

For the territory of Jagodina (Pomoravlje county), yield value is $Q = 785\ l/s$ (3.45 l/s per capita), with small microbiological inadequacy of 8.8% and partially acceptable physicochemical regularity with 13.1% inadequacy (muddiness, nitrates) [14].

B. Zero Fossil Energy House as Final Result

"Energy consumption in buildings, including residential ones, accounts for the highest percentage of the total energy consumption in many countries. On average, this consumption is between 40 and 60%, and in Serbia it is approximately 50%. Dissipation i.e. distributional character of solar energy and other renewable energy sources is very similar to scattered buildings in rural, but also in urban environments, with green interspaces. Therefore, the most natural way to increase the use of solar energy is primarily by the energy conservation implementing buildings passive solar/bioclimatic design and then by the application/integration of appropriate solar thermal collectors, PV panels and PV/Thermal systems, primarily in building facades and roofs. Naturally, in dense urban areas with many high-rise buildings, it is much more difficult to satisfy all buildings energy needs by solar and/or other renewable energy technologies, than in rural areas with much more available space to install solar thermal or solar PV equipment" [2]. Characteristics of PV modules used in calculations are given in Table 7.

Table 7. PV modules characteristics

STC 250 W P PV Panels Characteristics	
Power output	250 W
Short circuit current	8.65 A
Open circuit voltage	37.85 V
Current at P_{max}	8.3 A
Voltage at P_{max}	30.12 V
Temp. coeff. at SC current	+0.04%/°C
Temp. coeff. at OC voltage	-0.35 mV/°C

Electric power inverter losses are set to 15%, and all modules are oriented to south with 30° pitch angle.

C. Biomass for Heating and PV Panels for Electrical Loads

According to ([15], [16]), the value of 4.800 kWh/t of pellet was used for the calculation of necessary pellet for satisfying needed heating demand. The results are displayed in Table 9.

Table 8. Annual Biomass needs for heating

Biomass needs for heating					
Model	MO1	MO2	MO3	MO4	MO5
Biomass [kg/year]	2936	648	552	460	358

For air-conditioning (AC), particularly summer cooling regime is foreseen by the PV electricity powered heat pump REHAU AQUA type 7.

It has a vertical open circuit system that uses groundwater from production well as the heat sink (its working fluid to reject condensation heat to it). After realizing cooling process ground water returns to the injection well.

As stressed earlier, in addition to powering the selected heat pump PV electricity is foreseen to supply all other electrical loads water heating (HWS), lighting, electronics and appliances. Determined numbers and corresponding area of PV panels sized to satisfy total electrical energy needs (AC, lighting, electronics and appliances are given in Table 9}. In that table data given in the column PVmin correspond to sizing PV area with an aim to satisfy electricity needs when the largest PV produced power is (August), and PV max column data relate to sizing PV area to satisfy electricity loads when PV produced power is smallest (December).

It is to be drawn attention to the colored values light blue (PV power less than needed) and house is to use electricity from the grid, and light rose colored data (house integrated PV will produce more than needed and the refurbished house will send electricity to the grid).

Table 9. Electricity demands and PV electricity production

MO2-MO5 – Total electricity demand and PV electricity production [kWh]					
Month	Demands	PVmin		PVmax	
		[kWh]	[%]	[kWh]	[%]
Jan	219.60	107	48.7	284	129.3
Feb	195.91	146	74.5	391	199.6
Mar	214.35	247	115.2	659	307.4
Apr	204.22	256	125.4	683	334.4
May	216.34	306	141.4	815	376.7
Jun	226.07	309	136.7	824	364.5
Jul	243.87	330	135.3	879	360.4
Aug	245.95	314	127.7	838	340.7
Sep	211.94	250	118.0	665	313.8
Oct	214.19	211	98.5	563	262.9
Nov	211.52	134	63.4	357	168.8
Dec	221.11	86	38.9	229	103.6
Total	2625.06	2696.00		7187.00	
PV panels power production					
Number of modules		9		24	
Installed PV power [kW]		2.25		6.00	
Total panels area [m^2]		13.14		35.04	

With more detailed analysis has been shown that the PVmin sized PV resulted in so called net Zero fossil fueled house, and that PVmax is clearly Energy Plus house – producing more electrical energy and sending it to the grid than its electrical energy demand is.

Residual life assessment “For a typical aged/existing building, residual service life prediction/planning is a process which seeks to ensure, as far as possible, that remaining service life of building will equal or exceeds performance requirements, while taking into account sustainability and (preferably optimizing) the remaining life cycle costs of the building. Sustainability has been considered as an implicit performance requirement rather than additional criteria.” [17]

In this case, it’s especially important to analyze the current condition of the building: its functionality, condition of structural elements, level of damage, need for rehabilitation and the amount of work. It is necessary to make an assessment - whether the costs of repair are higher than the costs of demolition of old and the construction of a new house; are the repairs cost-effective and if so, what is the value of structures residual life. If the analysis shows that the building is functional and that the rehabilitation costs are lower than the construction of a new home, the conditions for the thermal refurbishment of the building are acquired.

6. Conclusions – Deep Energy Refurbishment Economy

The results of the analysis show that, if the house condition and its residual life value are satisfactory, house thermal refurbishment gives notable and favorable results that will affect the energy use for heating and cooling of the building in its present condition, and that is essential from the aspect of energy efficiency because it contributes to less energy consumption, and therefore less fossil fuel use, CO_2 emission and energy cost expenses. The possibility of setting a renewable energy sources is taken into the account, with the prerequisite that the house has a satisfactory remaining life span.

Conducted research encompassed total BPS (Building Performance Simulation) and energy efficiency optimization of the reconstructed building for local TMY obtaining its zero fossil energy and healthy IEQ status. Study crucial result is that implemented approach and methodology enable all systems loads to be enough minimized with the reference to the local climatic conditions, that deep renovated house, in addition to the significant improvement of IEQ raised it status to the status of net Zero fossil fuels and potentially to become Energy+ house.

The case study house was constructed of wooden skeleton and cob–a mixture of mud, straw, wood chips and sand. Determined was strategy, reconstruction means, appropriate RES (Renewable Energy Sources) technologies and whole integrated sustainable building design to turn the building status to the contemporary living conditions, and environmentally conscious status preserving local architecture, construction traditions and culture.

The results of the analysis are imposing some additional questions that should provide the basis for further research. This raises the question of justification of the building renovation, which should be considered through the analysis of the current state of the building and its residual life, the total cost of rehabilitation and refurbishment, as well as the overall impact of the process on the environment through CO_2 emission. In Table 10 are presented preliminary calculated quantities: total investment costs (construction materials, components and works; all technical systems components and installations including biomass utilization unit and PV power plant); total energy saving values; and investment simple payback periods.

Table 10. Investment costs, annual energy costs, annual energy saving valuec and simple payback period

Model	Total investment costs [€]	Annual energy costs [€/year]	Annual energy costs savings [€/year]	Simple payback period [year]
MO1	0	1061	0	0
MO2	10408	142	920	11.31
MO3	10892	123	939	11.60
MO4	11735	104	957	12.26
MO5	14183	84	977	14.51

In terms of the preservation of traditional architecture and environmental sustainability, it is necessary to consider the construction method of new houses and renovation of existing ones, by use of the material with similar composition and properties, and that is accessible on-site or near the settlement. Primarily, this is the reference to the walls, made from earth material.

The above mentioned procedures are entailing the necessity of further analysis of possibility of transition to the use of fully "green" energy sources, as well as its consequences on a household and its surroundings in a long term, particularly taking in account the highest impact on CO_2 emission reduction of MO5 model.

Acknowledgment. Authors of this paper are expressing their gratitude to the Republican Institute for Protection of Cultural Monuments - Belgrade [6] and its employees on the literature, consultations and the assistance provided, during this study performance.

References

[1] Todorović, M. S., BPS, energy efficiency and renewable energy sources for buildings greening and zero energy cities planning: Harmony and ethics of sustainability, *Energy and Buildings, year 2012*, vol. 48, Pages 180–189

[2] Todorović, M. S., Harmonious Integrated Rural And Urban Sustainable Development - Solar Decathlon Europe, A Milestone For Energy Plus New And Deep Energy Refurbished Buildings, *45th HVAC International Congress*, Belgrade, Republic of Serbia, December 2014.
[3] Todorović, M. S., Regional Programme for the Cultural and Natural Heritage in South-East Europe – LDPP, 2013-14.
[4] Republički zavod za zaštitu spomenika kulture Srbije, Narodno graditeljstvo kao arhitektonska vrsta i spomenička vrednost, http://www.atlas.heritage.gov.rs/node/139
[5] Republički zavod za zaštitu spomenika kulture Srbije, http://www.atlas.heritage.gov.rs/
[6] Republički zavod za zaštitu spomenika kulture - Beograd, http://www.heritage.gov.rs/
[7] T. Popović, E. Radulović, M. Jovanović, "Promena klime u srbiji i očekivani uticaji", The Environmental Protection Agency, Ministry of Agriculture and Environmental Protection, Republic of Serbia, Fifth Regional Conference "EnE09 - Životna sredina ka Evropi", Belgrade June 2009.
[8] Bojić, M., S. Djordjević, A. Stefanović, M. Miletić, D. Cvetković, Decreasing energy consumption in thermally non-insulated old house via Refurbishment, *Energy and Buildings, year 2012.*, vol. 54, pg. 503–510
[9] Miletić M., I. Miletić, E. Dolićanin, V. Nikolić, Influence of New and Old Regulation Standard for Energy Efficiency on Thermal Insulation in Serbia, *Sci. Publications of University of Novi Pazar,* Ser. A: Appl. Math. Inform. and Mech., *year 2014*, vol. 6, 2, pg. 131-145.
[10] Goodhew, S., R. Griffiths, Sustainable earth walls to meet the building regulations, *Energy and Buildings, year 2005*, vol. 37, pg. 451–459, Table 2
[11] Bentley AECOsim Building Designer V8i
https://www.bentley.com/en/products/product-line/building-design-software/aecosim-building-designer
[12] Bentley AECOsim Energy Simulator V8i
https://www.bentley.com/en/products/product-line/building-design-software/aecosim-energy-simulator
[13] EnergyPlus Software http://apps1.eere.energy.gov/buildings/energyplus/
[14] Republic hydrometeorogycal service of Serbia, Republic of Serbia,
http://www.hidmet.gov.rs/
[15] Glavonjić, B., *Drvna Goriva: Vrste, Karakteristike I Pogodnosti Za Grejanje*, SNV Montenegro, Podgorica, Crna Gora, 2011.
[16] The Biomass Energy Centre - UK government information Centre for the use of biomass for energy in the UK
http://www.biomassenergycentre.org.uk/
[17] Shah A., A. Kumar, Challenges In Residual Service Life Assessment For Refurbishment Projects, *CRC Construction Innovation Conference*, QUT Digital Repository: http://eprints.qut.edu.au/27206 , year 2009
[18] Krnjetin, S., V. Mrkajić, Nepečena stabilizovana zemlja – Građevinski materijal budućnosti, *KGH, year 2008,* BI-BLID 0350–1426 (206), 37:3, pg. 45–48
[19] Todorović, M. S., Harmonized Rural And Urban Sustainable Development To Preserve Natural And Cultural Heritage - Via Renewable Energy Sources, Energy Efficiency, *3rd International Conference "Energy in Buildings 2014",* Athens, November 2014.
[20] Todorović, M. S., O.Ećim, I.Martinović, An Approach To Advance The Energy Efficiency And Sustainability Of Masonry Buildings, *Journal for Research of Materials and Structures, year 2010*, Vol. 4, LIII, pp. 5-27
[21] Todorović, M. S., P. Vasiljević, Integrated Residential - Municipal Refurbishment & Modeling Predictive Smart Control For Zero Co2 Emission Cities, MT kgh-2013.
[22] Todorović, M. S., O.Ećim, Renewable Energy Sources And Energy Efficiency For Building's Greening – From Traditional Serbian Village Houses Via High-rise Residential Buildings BPS and DHS Measurements to the National Energy Efficiency Action Planning, *AIIR 43th Conference of Installations*, Sinaia, Romania, 2010.