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RECOVERY RENEWABLE ENERGY SYSTEMS FOR ROMANIAN PATRIMONIAL RELIGIOUS BUILDINGS

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Abstract. *The most beautiful cult buildings in Romania, some of which is heritage buildings, have some architectural, structural features, interior/exterior painting, which distinguishes them very much from most of the cult buildings in the world. In the current energy and environmental context, it is necessary to make energy-consuming buildings efficient to the performance of the NZBE. On the other hand, the heritage buildings should be conservated, mentened in function, and to ensure the conditions of heritage conservation, a healthy environment and a comfortable environnement. The paper describes briefly: a) characterization of these buildings; b) a review of the provisions of the regulations; c) an analysis of the specific problems of these buildings; d) ensure energy by harnessing renewable energies; f) a multi-criteria analysis of the proposed solutions.*

Key words: *passive strategy for NZBE heritage buildings.*

1. Introduction.

One of the major leaders of Moldova, trying to make people accountable for common and perennial values, states *„Moldova nu e a mea şi nici a voastră nu e, ci a urmaşilor urmaşilor voştri – Moldova isn't mine and neither yours but of the your followers followers"*. The phrase can be considered among the first positions in the field of attitudes regarding the inheritance of a people. Heritage buildings are part of the inheritance of a people or even of a whole human civilization, which is why they must be preserved with care and as long as possible maintained in continuous operation, according to the original purpose or new functions considered useful today.

The current energy and environmental context has prompted the promotion of policies aimed at drastically reducing energy consumption in general and in buildings in particular, restoring the ecological balance of the water cycle and CO_2 in nature and some of the major changes to the paradigm in the energy field, respectively at crossing to 100% renewable energy sources. Heritage buildings - buildings that include an important cultural heritage are also characterized by high energy consumption. The economic conditions, the overthrow of social needs in certain historical epochs, including the current one, often lead to a wrong justified by limited rationale, with a short-term analysis horizon, which in the long term run can lead to significant diminution in patrimonial values.

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Climate change (i.e. the increase of the hot episodes and of those with intense rainfall and winds, the thermal spells of *hot periods* - *cold periods*) lead to changes in the envelope's behavior and worsening impairment (plaster detached, condensation, molds, milling elements through repeated frost / thaw episodes). Increasing the requirements for hygrothermal comfort and the indoor environment quality in the premises belonging to the buildings of the patrimony with current human activity, simultaneously with the rising energy prices, can lead to mistaken human decisions regarding the heating of these spaces, respectively insufficient heating, with risk of condensation, mold, parasites, and, over time, abandoning them. On the other hand, the implementation of functional systems with agents prepared by the use of renewable energies presents a number of aesthetics disadvantages, the limited possibilities of integration of the energy generation systems in such buildings or even the reduction of the patrimonial value.

The two divergent aspects, *the aesthetic preservation*, *the diminishing of the heating* and *the abandonment*, respectively *the provision of the necessary heating* and *ventilation*, but *with aesthetic diminishments*, should be carefully analyzed and the solutions that will constitute the best long-term compromise between them and the social aspects. This problem is of a complex nature, the decisional context requiring multidisciplinary approaches and multivariable analyzes based on energy, economic, ecological, value, cultural, historical, social criteria, and the decisions must be the result of such complex analyzes (horizontally and vertically; qualitative and quantitative, ...). A structured approach to the decision-making process is needed. An appropriate method of analysis is Symbioses in development/SID that allows not only to ensure the sustainable development of these buildings but also to maintain functional resilience after some unforeseen events (earthquake, ...).

In this paper are analyzes: the decision-making mechanism in order to propose the most useful support for making the right decisions in the conditions of crossing from the use of classical sources of energy to the use of renewable resources for generating working agents and maintenance of patrimonial value; the renewables systems adequate for renovation/modernized romanean heritage buildings.

In ecological logical and energetically actual (2017) context is imperious necessary that in the modernization / refunctionalization / intervention works in the heritage buildings, interventions on the structure should be cumulated with interventions on the functional systems (ensuring a healthy, comfortable or adequate environment for the well-defined conditions of the space function by using 100% renewable energy resources), without affecting the value of heritage, based on the principles of sustainable and resilient development (Figure 1).

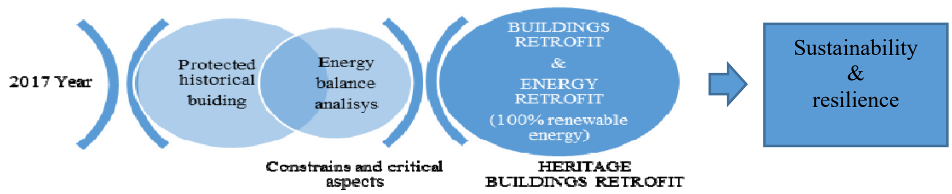


Fig. 1.

2. Possible Models for Sustainable Development

European specialists in this area have tried to propose appropriate tools for decision-making to modernize/renovate heritage buildings. Studies & other Projects have been developed on:

a) *Conditions for ensuring an indoor climate compatible with the functions of the spaces and, exigences of human/ special function, exigences of environnemental moyen:* the quality of the environment in the historic building can only be achieved by combining the diversification of energy production from different renewable sources along with the reduction of greenhouse gas emissions. The goal can only be achieved through an integrated analysis of historical, dimensional, functional, energy and environmental aspects. A profound knowledge of a real need allows the most appropriate modernization actions to be proposed. On the contrary, non-critical application of energy standards and general patterns disadvantages the building or its existing parts without gaining a real advantage in the overall energy balance.
b) *The increase of the energy efficiency*. Energy end indoor environmental quality in historic building can be achieved by use poligeneration system with combining a various renewable sources together with cutting greenhouse gas emissions. The goal may be obtained only by an integrate analysis of historic, dimensional, functional, energy and environmental matter. A deep knowledge of a real need permits to propose the most appropriate retrofit actions. On the contrary, non-critical application of energy standards and general models disadvantage the existing building or its parts, without getting a real advantage in the overall energy balance.
c) *The sustainable development solutions.* In order to bring them to the performance of NZBE buildings have used the Kohler model for building sustainability in a built environment, based on the three general dimensions of sustainability: Ecological values (embedded energy and the resource use of the building); Economic values (market value, running costs and revenues); Social values (functional values; cultural values/cultural heritage values: documentary value, experiential values). A very good analysis for necessary conditions for a sustainable heritage buildings is presented by Broström and Svahnström [1].

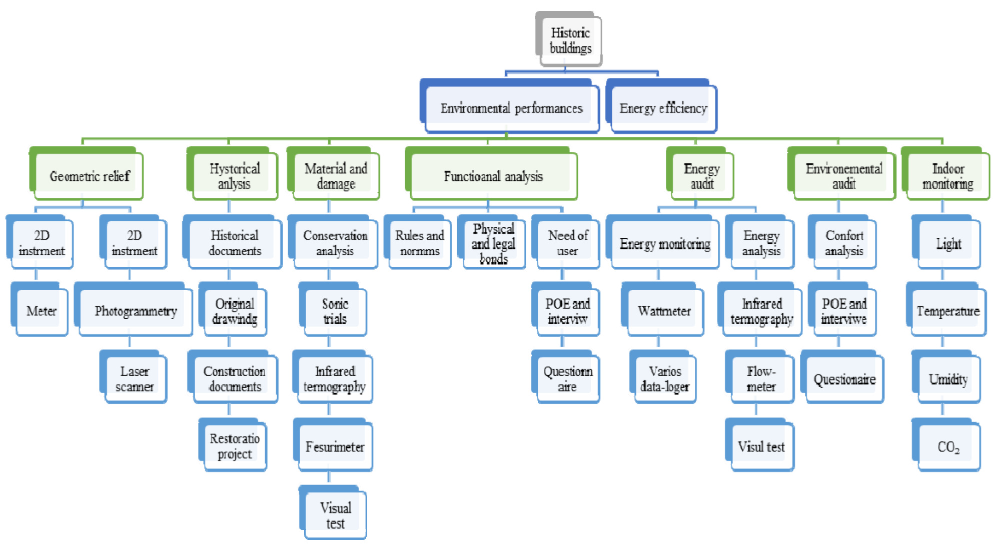


Fig. 2. *Method for analyzing energy and environmental performance of historic building.*

d) The solutions for the implementation of the renewable energy generation systems: Have been specifically addressed in various European projects focusing in particular on old, patrimonial housing buildings located in characteristic sites ("Old / Heritage Houses in Edinburg"). No studies have been carried out on the patrimonial buildings of worship in Romania that have many and important features that limit the integration of RES.

e) The revision/proposing standards in the field: very recent standards have been revised and new standards have been proposed. Design guides have also been developed (view Figure 3.).

Content
1. Introduction Why do we need Standards & Guidelines? What is Conservation?
2. Conservation Treatments:
Preservation;
Restoration;
Rehabilitation
3. The Guidelines for the Conservation of the Places …..
4. The Guidelines for the Conservation of Historic Buildings in Saskatchewan: Exterior Form;
Roofs Exterior;
Walls Windows;
Doors & Storefronts Entrances;
Porches & Balconies Structural Systems.

Fig. 3. *Conservation in the umbrella* [2]

The issue of conservation is treated differently from one patrimonial objet from another, from one country to another.

Proposal Model: *Symbiosis in Development (Sustainable development and resilient).*
Is an update & completion of the Kohler model, proposed by the authors (Figure 4.). The sustainable development model require additions measures to ensure the resilience of heritage buildings after unforeseen events (earthquakes, floods, ...). These measures are extremely important for heritage buildings in Romania, which have suffered major damage at the earthquakes. The use of renewable energies is a measure that can be integrated in ensuring the resilience of functional systems.

3. Renewable Energy Recovery Systems

3.1. Energy Refurbishment Methodology Proposed in European Project

Under the European project ENBAU "Energie und Baudenkmal", the energy renovation methodology was proposed. The methodology contains procedures for analysis, of potential solutions and priorities, by quantification the potential advantages and disadvantages of the solutions. Selection of the solution is done in relation to the environment, energetically performance and other aspects of the solutions to be executed (conservation needs, functional needs,...). The proposed measures can vary according to different degrees of priority and feasibility.

Regarding the organization of activities within a project it was proposed:

1. Diagnosing the current status of the building and analysing the energy balance;
2. Developing the project proposal - Energy upgrading solutions and tools for assessing improvement measures and improving the current situation;
3. Evaluating modernization, management and planning and maintenance measures.

Each stage was associated with a simple model of evaluation, summarized in diagrams, considering all aspects, the macro areas of interest and subjects, as detailed in Figure 5.

Each chart is conceived in relation to aspects of interest grouped together in the macro-development area. The general matrix of the included / targeted information may be synthetic in some situations, and in others it is much broader. A macro-area may focus on: building cultural value, architectural and constructive features, local environment and climatic conditions, improving comfort and passive conditioning, state of the art systems (Heating systems, hot water systems, air conditioning systems, systems Ventilation) for thermal conditioning.

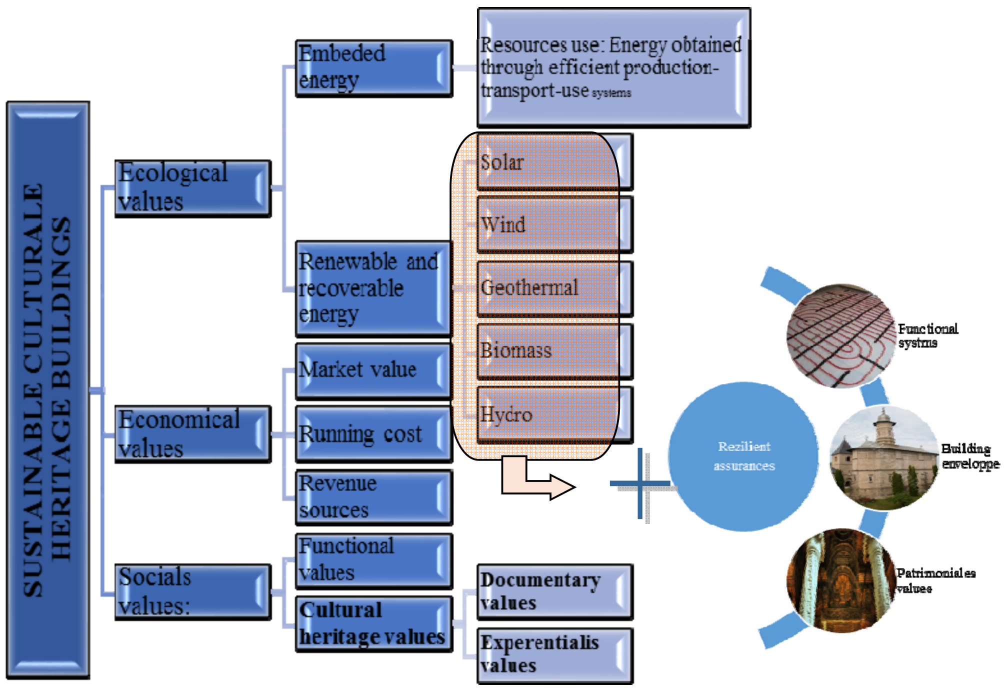


Fig. 4. *The sustainable & resilient cultural heritage buildings model*

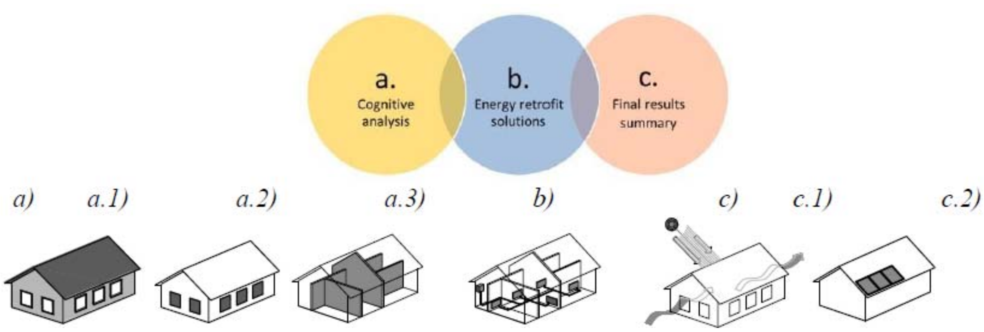


Fig. 5. *Symbols are used to identify the areas involved in retrofitting measures: (a) Building envelope: a.1_ façade and roof/ground floor enclosure; a.2_ transparent enclosure; a.3_ Internal enclosures; (b) Equipment systems (electrical / thermal / ACS); (c) Solar Energy solutions: c.1_Solar passive solutions; c.2_Renewable energy sources (photovoltaic / solar thermal /; heating pump, wind generator, biomass boiler)*

The integration of solar energy resources and each of the listed aspects can be detailed / subdivided. The impact of the proposed measures on each aspect of the macro-area is quantified by an analysis that takes into account the potential, the solution, the limits and the levels of action of the building's energy performance. For this purpose, the final energy balance is compared to the initial situation so that the benefits obtained can be verified immediately. The methodology provides solutions that can be compared to their level of feasibility and impact on building significant heritage (high, medium or low). This chart system allows for the overall quality of the patrimony buildings undergoing interventions.

A set of main parameters has been proposed: ***"Color code: (***green, yellow and red dots) for categorized the energy efficiency renovation's measures (standard is color-coded green, the follow-up actions for any improvement are encoded yellow or red; ***Symbols***: are used to identify the involved areas; ***Indicators:*** to assess energetically refurbishment measures in relation to each historical building**;** ***Scoring system:*** to evaluate these key parameters."

3.2. Renewable and Recoverable Energy Resources Available from Romania

The main renewable energy resources available on the Romanian territory are: solar, wind, geothermal, biomass and even hydro power. Only some of these may be used efficiently in relation to site and neighborhood particularities. Appropriate inventory systems for use in heritage buildings are much more limited than other types of buildings and their integration into buildings and its associated site often requires a good compromise between conservation, energy performance and sustainable development.

The potential of renewable energy resources is extremely different in Romania (relative to latitude, altitude, site neighborhoods) and extremely variable in time.

In our research has identified several heating, cooling, lighting and hot water preparation solutions, which uses renewable energies that could be efficiently applied to serving heritage worship buildings, respectively:

- *Passive*: sun shading zone; plaster with PCM; tiles and Smart glasses bricks (where is possible); passive smart windows; passive radiator system cooling for roof; natural ventilation cooling; thermal mass; wind protection; etc.
- *Active*: smart glasses (electrochromic; heat and light control); CPV-T systems placed in the site; Micro-wind turbines; Heating pumps with GeoColumn storage (eventually modified in special mode and for cooling with solar systems); heating/cooling of biomasses; trigeneration energy systems; thermo-activation of the envelope elements (floor, roof, vertical opaque elements).

3.3. Analyzing the Impact on the Indoor Environment Quality (Hygrothermal Comfort) of Possible Passive Heating / Cooling / Lighting Strategies

Analysis of the effect of passive strategies can be achieved with a high level of accuracy based on time climatic data (direct, diffuse, global solar, albedo, wind speed and direction, global wet / dry thermometer, humidity, wind pressure, ...) using the Climate Consultant software. The Climate Consultant will determine the best set of Passive Design Strategies displayed on the Psychrometric Chart for the selected weather site. This is the smallest set of strategies that maximizes the number of comfortable hours without using conventional heating or cooling (Figure 7).

Strategies & parameters for different models comfort Tabel 1

No.str.	**Confort model & strategyes**	**UM.**	**Value**		
1.	COMFORT MODELS*:		1.***	2.****	3.*****
	Confort Low –Min, Confort Effective Temp @ 50 % RH (ET)	^0C		1	20
	Confort High –Min, Confort Effective Temp @ 50 % RH (ET)	^0C		20.0	23.9
	Max. Wet Bulb Temperature	^0C		23.3	18.9
	Min. Dew Bulb Temperature	^0C		17.8	
	Summer comfort shifted by this Temperature	^0C		2.2	
	Winter Clothing Indoor (1.Clo=long pant, sweater)	clo		2.8	
	Smmer Clothing Indoor	clo		**1**	
	Activity level Daytime	met		**0.5**	
	Max. relative humidity	%			50
	Min. DewPoint Temperature	^0C			-2.8
2.	SUN SHADING ZONE: (Defaults to Comfort Low)			**1.1**	
	Min. Dry Bulb Temperature when Need for Shading Begin	^0C		22.8	20.0
	Min. Global Horiz. Radiation when Need for Shading Begin	Wh/m^2		315.5	315.5
3.	HIGH THERMAL MASS ZONE				
	Max. Outdoor Themperature Diference above Comfort High	^0C		8.3	8.3
	Min. Nightime Themperature Diference belov Comfort High	^0C		1.7	1.7
4.	HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE				
	Max. Outdoor Themperature Diference above Comfort High	^0C		16.7	16.7
	Min. Nightime Themperature Diference belov Comfort High	^0C		1.7	1.7
5.	DIRECT EVAPORATIVE COOLING ZONE: (Defining by Comfort Zone)				
	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb	^0C		**20.0**	**20.0**
	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb	^0C		**11.0**	**6.6**
6.	TO STAGE EVAPORATIVE COOLING ZONE: (Defining by Comfort Zone)				
	Efficiency of indirect stage	%		50	50
7.	NATURAL VENTILATION COOLING ZONE:				
	Terain category to modify wind speed (2=suburban)	type		2	2
	Min. Indoor Velocity to Effect Indoor Comfort	m/s		**0.2**	0.2
	Max. comfortable velocity (per ASHRAE std. 55)	m/s		1.5	**1.5**
	Max. Relative Umidity	%		90	90
	Max. Perseived Temperature Reduction	^0C		**3.7**	3.6
	Max. Wet Bulb Temperature	^0C		**22.8**	**22.8**
	Procentage Acceptability Limits (80%-90%	%	90		
	Min. Montly Outdoor DB Temperature (10^{0}C or less)	^0C	10		
	Max. Montly Outdoor DB Temperature (33.5^{0}C or less)	^0C	22.6		
	Comfort Low – Min. Operative Temperature in this Climate	^0C	18.4		
	Comfort Hight – Max. Operative Temperature in this Climate**	^0C	27.3		
8.	FAN-FORCED VENTILATION COOLING ZONE				
	Max. Mecanical Ventilation Velocity	m/s	0.8	0.8	0.8
	Max. Perseived Temperature Reduction (Min Vel, Max RH, Max WB match Natural Ventilation)	^0C	3.0	3.0	3.0
9.	INTERNAL HEAT GAIN ZONE				
	Balance Point Temperature below witch heating is need	^0C	12.8	12.8	12.8
10.	PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:				
	Min. South Window Radiation for 5.56 ^{0}C Temperature Rise	Wh/m^2	157.7	157.7	157.7
	Thermal Time Lag for Low Mass Buildings	hour	**3.0**	**3.0**	**3.0**
11.	PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:				
	Min. South Window Radiation for 5.56 ^{0}C Temperature Rise	Wh/m^2	157.7	157.7	157.7
	Thermal Time Lag for Low Mass Buildings	hour	12	12	12
12.	WIND PROTECTION OF OUTDOOR SPACES:				
	Velocity above witch Wind Protection is Desirable	m/s	8.5	8.5	8.5
	Dry Bulb Temperature Above or Below Comfort Zone	^0C	11.1	11.1	11.1
13.	UMIDIFICATION ZONE: (Defining by and below Comfort Zone)				
14.	DEZUMIDIFICATION ZONE: (Defining by and below Comfort Zone)				

* The comfort criteria considered are presented in Appendix 1; **(Air velocity is controlled by oening/clousing windouws); *** 1.Adaptive Comfort model in ASHRAE 55/2010; **** 2.ASHRAE Handbook of Fundamentals Confort Model, Through 2005); ****** 3.California Energy Code Comfort Model, 2013

3.3.2. Obtained Results

3.3.1. Working Hypotheses.

In the analyzing were considered the comfort models, strategies and parameters shown in Tabel 1.

The sites considered in the analysis were: Constanța, Miercurea-Ciuc & other. The related climatic data was extracted from Meteonorm 7. For analysis were used the software: *Trnsys*; Climate Consulte.

The results obtained were represented as:

- graphs with hourly / daily / monthly variations and average values (maximum averages, minimum averages) and monthly and hourly averages of the main climatic parameters: dry and wet thermometer temperature; direct, normal, diffuse, global sun radiation, reflected by soil with different coatings, inclined; the degree of coverage of the sky; direct normal illumination; hours of sunshine, soil temperature at different depths, wind speed and direction. An extract of these data is shown in Figure 6.
- psychrometric charts with comfort zones and the impact of comfort (passive and active) comfort strategies on indoor comfort (Figure 7).

An analysis of the represented sizes allows the selection of the heating / cooling strategies to be analyzed, respectively the appropriate heating / cooling systems.

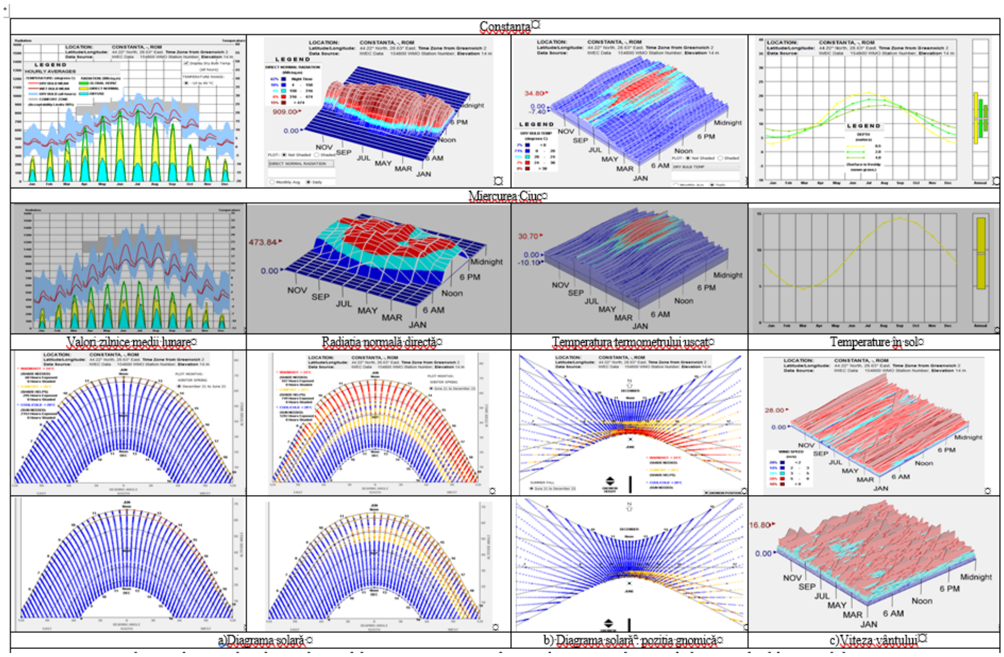
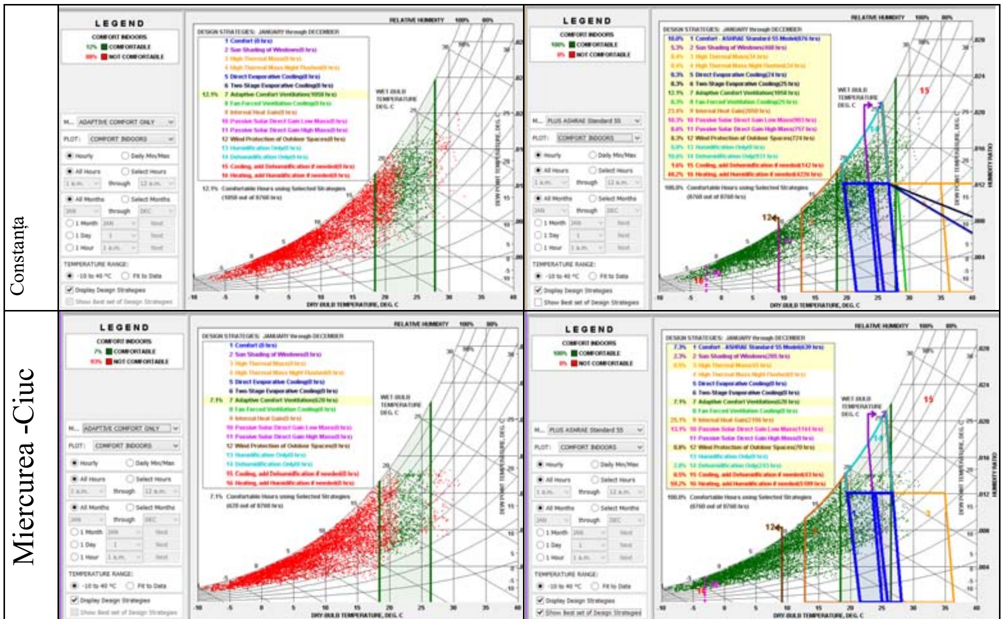


Fig. 6. Climate data used in the analysis of the passive strategies for purchasing comfort inside heritage buildings with human activity



a)Confortul adaptive | b) Confort ASHRE 55-PMV

Fig. 7. *The impact of passive strategies to ensure indoor comfort - psychrometric charts with comfort zones*

4. Conclusions

The paper investigated various mechanisms useful in deciding on the right solutions for intervention works on increasing energy performance and ensuring sustainable development for heritage buildings. Romania is proposing to use the procedure presented in the European project ENBAU "Energie und Baudenkmal", with the following addition: it is necessary to diversify the passive strategies and analyze thoroughly their impact on global performances, namely: it is proposed to identify the most suitable passive strategies with the Climate Software Consultancy, by considering an extended set of climatic time parameters extracts from the Meteonorm database and solutions for the active utilization and use of renewable energies are proposed.The analysis of solutions can be done under the same dynamic local climatic conditions using software (Trnsys, Polysun, ...). For serving the Romanian heritage buildings with renewable energy, possible and efficient solutions are: a)**Passive:** plaster with PCM; tiles and Smart glasses briks (where is possible); passive smart windows; passive (i.e. free**)** radiator system cooling for roof; b)**Active:** smart glasses (electrochromic; heat and light control); CPV-T systems placed in the site; Micro-wind turbines; Heating pumps with Geocolumn storage; heating/cooling of biomasse; trigeneration energy systems; Thermo-activation of the envelope elements (floor, roof, vertical opaque elements).

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