ENERGY EFFICIENCY IN BUILDINGS FOR SEASONAL USE. CASE STUDY

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Abstract. Within the international context related to sustainable development, architectural design should focus on compliance with the following requirements: adaptation to specific environmental conditions, optimizing resource consumption with respect to the destination of the building, using environmentally friendly materials and alternative energy sources. All these criteria apply also for buildings with seasonal exploitation, respectively summer houses, the specificity of the architectural program concerning mainly the distribution of energy demand throughout the year. The present paper analyses a summer house model, located on a slope near the town of Iasi, overviewing the Ciurbesti lake. In order to achieve a sustainable solution and taking into account the limited operational period, solar radiation is used both to ensure the hot water demand, with relatively low costs, and as an electricity source. Solar panels produce thermal power with low temperature degree, thus the system efficiency is on average about 50% for ensuring the hot water demand. Due to the equipment's high costs, the system must be designed to be as efficient as possible. Therefore, it is of utmost importance the exposure optimization between the hours of maximum solar radiation intensity, by orienting the houses in compliance with the specific local conditions (Ozbalta *et al.*, 2009). As a result to preliminary studies it was concluded that, for the Iasi city, the most favorable orientation is southward, with variations of no more than 20 degrees towards south and the roof solar panels tilting should be 30 degrees. Also, in order to avoid the overheating was designed a ventilated facade system. The whole architectural concept is subordinated to the idea of traditional reinterpretation, the roof's slope and the ventilated facades patterns being site specific.
Keywords: renewable energy, ventilation systems, low energy demand.

Rezumat. În contextul preocupărilor actuale, legate de dezvoltarea de durată, proiectarea de arhitectură trebuie să urmărească adaptarea la condiţiile specifice de mediu, optimizarea consumului de resurse în raport cu destinaţia construcţiei, folosirea materialelor ecologice şi orientarea către surse alternative de energie. Toate aceste criterii se aplica si cladirilor cu exploatare sezoniera, respectiv case de vacanta utilizate in anotimpul cald, care prezinta particularitati in special in ceea ce priveste repartizarea necesarului de energie pe durata anului. Lucrarea de fata analizeaza un model de locuinţe de vacanţă, amplasate pe un versant în apropierea oraşului Iaşi, cu vedere către lacul Ciurbeşti, destinate în mod predilect turismului estival. În scopul de a obţine o soluţie ecologică şi ţinând cont de perioada de exploatare, radiaţia solară este folosită atat pentru asigurarea necesarului de apă caldă, cu costuri relativ mici, cât şi ca sursă de energie electrică. Panourile solare produc energie termică cu un grad scăzut al temperaturii, astfel, randamentul sistemului este în medie de 50% pentru asigurarea necesarului de apă caldă. Din cauza costurilor ridicate ale echipamentelor, sistemul trebuie să fie conceput pentru a fi cât mai eficient posibil. Este esenţială în acest sens, optimizarea expunerii, între orele în care radiaţia solară are intensitatea maximă, prin orientarea caselor respectând condiţiile locale specific (Ozbalta *et al.*, 2009). În urma studiilor preliminare, s-a concluzionat că orientarea cea mai favorabilă pentru zona oraşului Iaşi este către sud, cu variaţii de cel mult 20˚ faţă de acest punct cardinal, iar înclinaţia panourilor de acoperiş trebuie să fie de 30 de grade. S-a avut în vedere, de asemenea, evitarea fenomenului de supraîncălzire prin proiectarea unui sistem de faţade ventilate. Întreg conceptul arhitectural este subordonat ideii de reinterpretare a modelelor tradiţionale, panta acoperişului şi motivul elementelor pe faţadele ventilate fiind specifice locului.
Cuvinte cheie: energie regenerabilă, sisteme de ventilare, consum scăzut de energie.

1. INTRODUCTION

Ensuring optimal comfort conditions with low non-renewable energy consumptions constitutes a major concern for all stakeholders involved in the design, manufacture and exploitation of buildings. Same importance is granted to passive measures, as well as techniques for exploiting renewable energy sources by developing and integrating active systems into the building architecture.

The buildings intended for seasonal use have certain specific features regarding the components of the energy balance and energy demand distribution throughout the year. Such constructions require energy especially for cooling, lighting and hot water,

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during the summer. The designer's main goal must take into account minimizing the energy demand through: architectural measures (spatial configuration, envelope elements composition), exploitation of renewable energy resources, passive measures (harnessing natural sources for cooling - nocturnal ventilation, air cooling using Canadian shaft, etc.) (Okba, 2005). Furthermore, to these measures, are added both user behavior modification over time and use of electronic and computerized devices in order to achieve a smart building under the domotics revolution framework (home automation - application of computers and robots for domestic appliances) in constructions (Omer, 2008).

Significant results for reducing energy demand and maximizing comfort through practical application of these principles are set out in the paper "*Passive cooling in a low-energy office building*" (Breesch *et al.*, 2005). Thus, for an office building, were applied nocturnal ventilation and a heat exchanger soil - air, which have significantly decreased energy requirements in order to ensure optimum comfort conditions.

Development and improvement of technologies for capturing and capitalizing on solar radiation represents an international concern, due to the advantages this inexhaustible source of energy offers. The average amount of solar radiation that reaches the earth's surface is about 2,5 kWh/m^2/day, also counting and recording the variations during day and night (Dunster *et al.*, 2008). If it were used photovoltaic solar cell systems for capturing this energy with an efficiency of 12%, then, installing panels to just 0.75 of a percentage of the earth's surface would be enough to effectively respond to global energy demands (fuel, gas, oil, nuclear energy, etc.). Considering these aspects, solar energy, compared to other unconventional energy, is extensively exploited worldwide, with great potential for further development (Reyes *et al.*, 2007).

2. CASE STUDY

The applied methodology in this case study will be defined by the following elements: experimental summer houses architecture - morphology; constructive structure - envelope components, materials, thermo technical characteristics; location, climatic conditions - solar potential, prevailing winds, summer temperature regime.

2.1. Architecture

On the Ciurbesti lakeshore, Iasi, is proposed the design of a holiday village that comprises of 9 houses, as shown in Fig. 1. The plan of a single holiday house is compact, a rectangle with dimensions of 8.40 x 6 meters interaxis.

From a functional point of view, the interior spaces distribution concept, presented in Fig. 2, tries to offer a favorable orientation of the living room and master bedroom towards the lake. From a volumetric standpoint, the roof's slope has an inclination of 30 degrees to the south.

The facades facing the lake have a ratio of opaque – glazed in favor of the glazed surfaces, as observed in Fig. 3. The external paneling, which creates an overall image of a parametric surface, represented by variable geometric patterns, is used to define the ventilated facades system, aspect that contributes to maximizing comfort both during the summer and the cold season.

2.2. Envelope constructive structure

The holiday houses have a "platform framing" wood structure, the external walls being made with sandwich panels, as in Fig. 4.

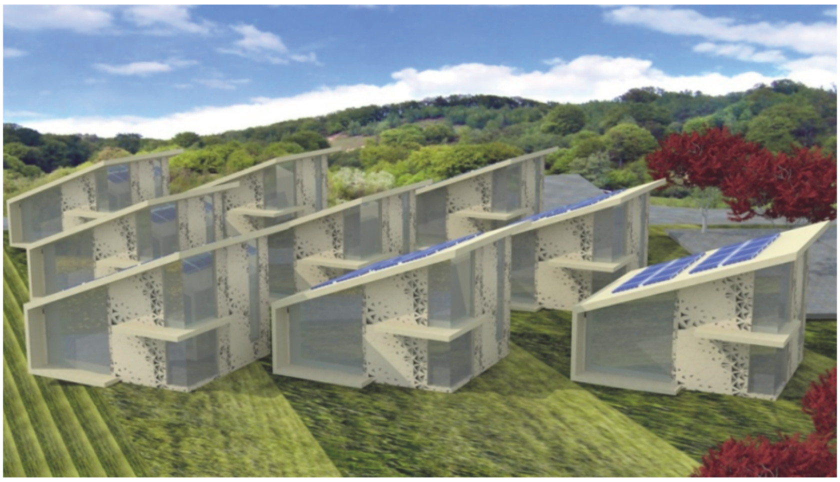

Fig. 1. Aerial perspective of the holiday village at Ciurbesti,– Iasi.

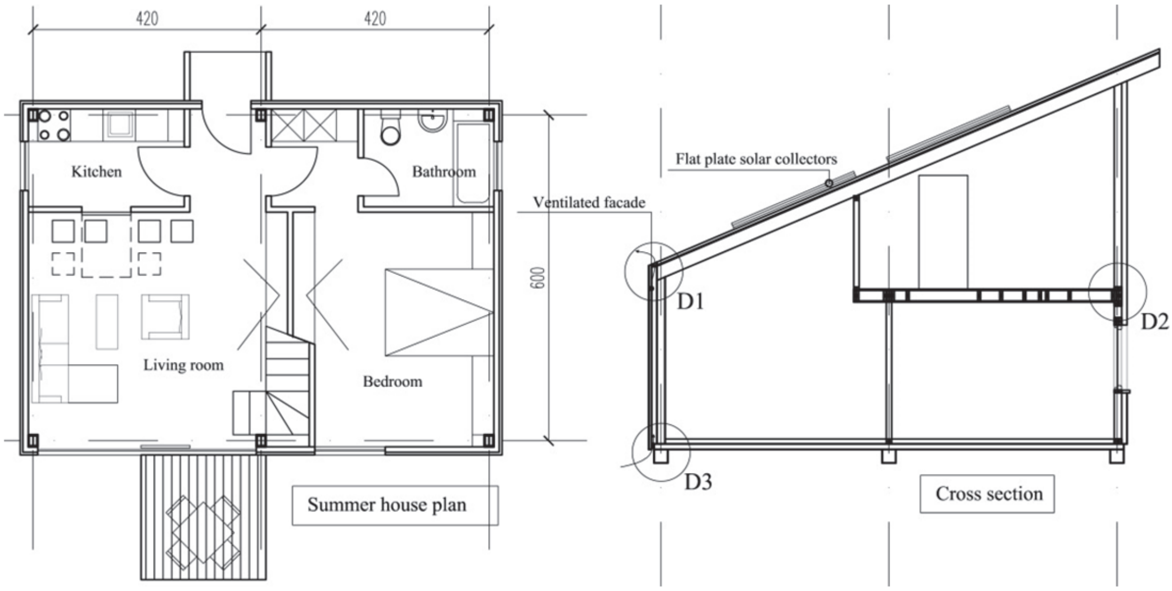

Fig. 2. Summer house architecture - plan and cross section.

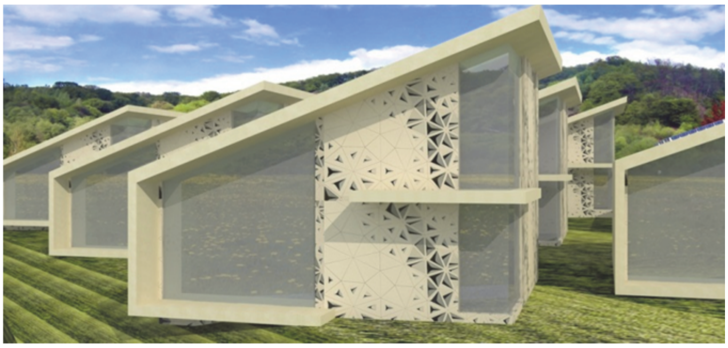

Fig. 3. The facade facing the lake.

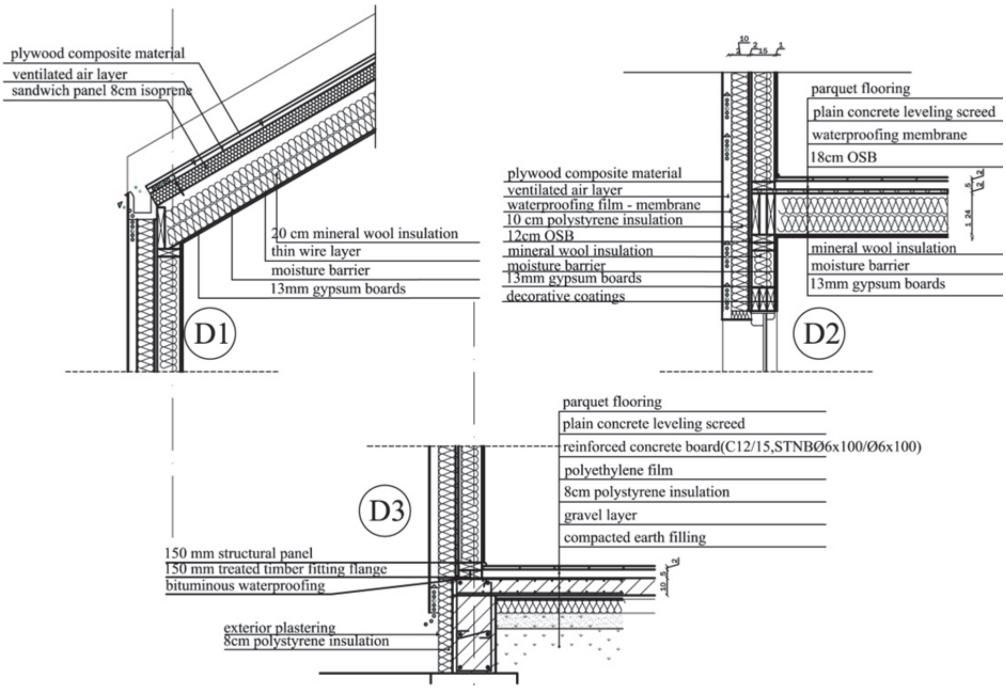

Fig. 4. Construction details for the exterior wall:
D1 – roof detail; D2 – interior slab detail; D3 – ground floor detail.

The "framing" system, known as lightweight wood-frame construction, uses a constructive technique that is based on bearing wooden walls, with pillar being the characteristic element. This is a vertical element which ensures structural stability, due to wood's good behavior to compression and because the slab redirects its loads towards several vertical elements that work together as a whole. The structural frame walls have modulated pillars, currently being used wooden pillars with the section of 100x150mm (4x6in). The pillars' spacing is made at 400 mm (16in) and, for constructional reasons, in practice, this becomes 415 mm, while respecting the paneling dimensions in order to optimize the material consumption. Vertical loads are taken over by pillars, while side loads are supported by the external panels (Năstase & Secu, 2009). Modern lightweight structures gain resistance by strengthening of panels (bracing method) using plywood. "Technological developments regarding the OSB and its performance have made it the main plywood used in structural applications, gradually replacing, in the past 20 years, the veneer plywood (Ross *et al.*, 2010)."

2.3. Climate data

2.3.1. *Solar potential*. During the years 2001-2005 it was developed a database in the European Union and the candidate countries regarding the potential use of solar energy, by employing a solar radiation model and climate data integrated into the Photovoltaic Geographical Information System (PVGIS). Romania has favourable climatic conditions for solar energy use, hovering, according to this report, in the same category of potential with regions such as Northern Italy and before Central European countries (Suri *et al.*, 2007). Iasi is located within an area that benefits from an annual average of solar energy flows between 1350-1450 kWh / m^2 per year. Thus, it was calculated the specific sunshine level by using Meteonorm 7 program and applying the PVGIS system. The resulting data shows a good potential for solar energy use, especially during summer, Fig. 5a, 5b, 5c. By using the same calculation software, it could be concluded that the optimum inclination of the roof's slope, for a maximum irradiation, is 30 degrees, with a small deviation to the absolute south.

2.3.2. *Prevailing winds*. In general, the Iasi city and its surrounding areas benefit from a normal circulation of air masses, especially conducive to maintaining a relatively stable atmosphere. The dominant winds during all seasons are those from East (21.2%), followed by West (16.3%), North-east (14.2%) and Southwest (11.2%).

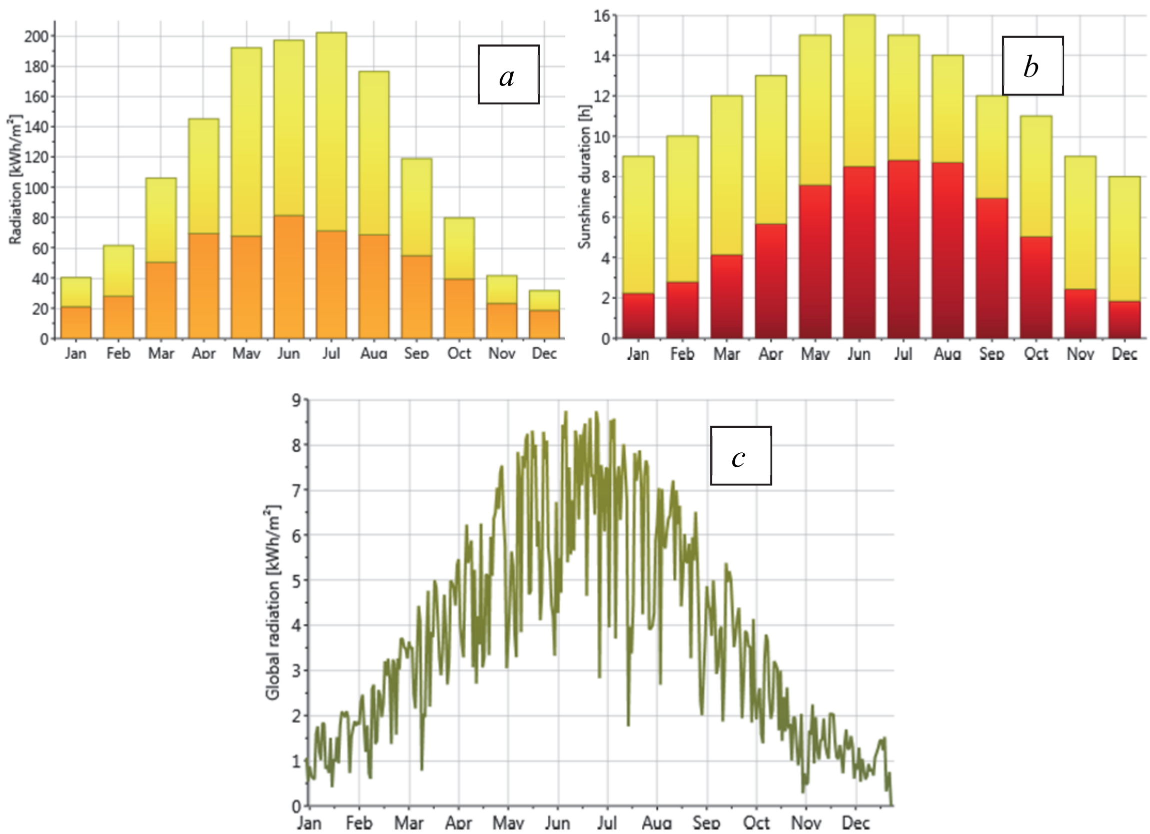

Fig. 5. Calculated data with Meteonorm 7 for Iasi city, by applying PVGIS system:
a – average monthly level of solar radiation; *b* – sunshine duration; *c* – average daily solar radiation.

2.3.3. *Temperature regime*. The climate of Iasi is moderate continental, with an annual average temperature of 10-11°C. The lowest monthly temperature is registered in January, with an average of -3°C. The summer is very hot, in July the average temperature is 23°C, sometimes even reaches 35-40°C. Amid the general climatic variations, specific to the region, there are a number of local thermal changes generated by the structure and functioning of the city, aspect that emphasizes differences between the city's climate and that of its surrounding areas.

Considering all these aspects, to which is added the architectural program's specificity (comfort should be ensured especially during the summer months by cooling the interior spaces), the location and orientation of the holiday houses are established for achieving maximum daylight intake. The house's long side is aligned with the north - south axis, with a deviation towards East of 18° - 20°.

3. THERMO – ENERGETIC ANALYSIS FOR THE SUMMER HOUSE MODEL

The analysed summer house falls under the category of buildings for seasonal use (small touristic units), whose architectural and constructive characteristics are to provide indoor comfort with minimal energy consumption. In this regard, the strategies that can be adopted to reduce the energy consumption include: designing the building envelope so that it meets the heating, cooling, ventilation and natural lighting demands throughout the year; exploitation of natural cooling resources; use of hybrid cooling systems; lifestyle adaptation.

3.1. Passive cooling measures (applied to case study)

In the table below are denoted the architectural measures and passive systems that can be provided for projects of buildings for seasonal use. Starting from the assumption that such constructions operate mostly during the warm season, will be outlined only measures to ensure the cooling demand.

3.2. Assessment of comfort level and cooling energy demands – CASAnova software

For the thermo - energetic analysis Casanova v.3.3.08a (An Educational Software for Heating and Cooling Energy Demand as well as the Temperature Behavior in Buildings) was used. Energy Simulation results (Fig. 6, 7, 8) were obtained introducing general data such as: building geometry (plan and cross-section), ratio of windows per each facade, window type, insulation degree (walls, roof, ground floor), thermal transmittance value (U) for each element, structure type, ventilation degree, heating system, climate data.

Table 1

Measures provided by envelope design

Envelope components	Measures to reduce the energy demand	Applied to case study
Walls and roof	Architectural project (volume, space distribution and orientation)	x
	Shading for walls and roof	-
	Use of reflective materials and light colours	x
	Use of insulating materials with adequate thermal resistance	x
	Use of solar control devices in roof's structure	-
Windows and doors	Architectural project (form, dimensions and orientation)	x
	Avoidance of negative impact on the indoor temperature because of the door opening - the design of "windfangs" (buffer spaces)	x
	Protection through insulation	x
	Shading devices for doors and windows	
	Watertight doors and tripan windows (three glass sheets)	x
Constructive details	Use of construction materials and details that reduce the heat transfer	x
	Elimination of thermal bridges	x
Landscaping	Reduction of paved areas in order to diminish the heat build-up around the building	x
	Planting of trees, lawn	x
Passive measures	Green roof	-
	Nocturnal ventilation	x
	"Canadian shaft" cooling system	x

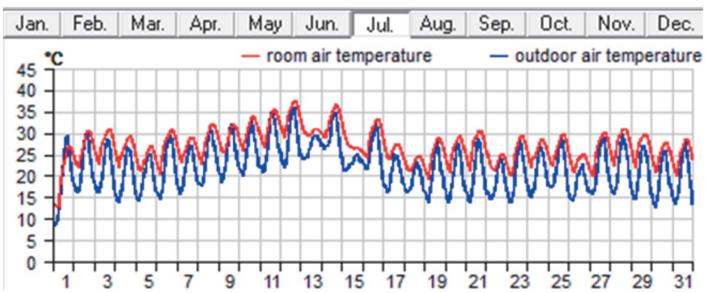

Fig. 6. Indoor temperature variation compared to the outdoor temperature.

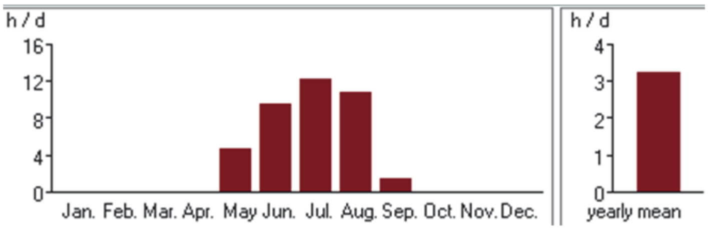

Fig. 7. Monthly average of overheated hours per day.

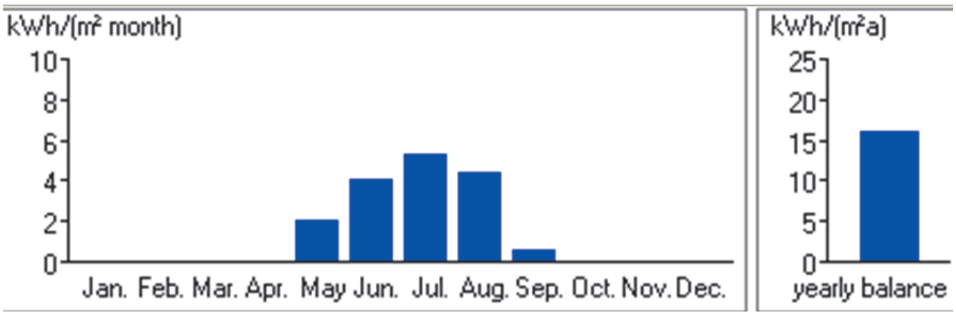

Fig. 8. Cooling demand for the summer months.

It is ascertained that, in July, at a maximum outdoor temperature of 31°C, the indoor temperature value increases to 33°C (Fig. 6). Considering that the comfort temperature is ensured within the range of 23°C - 27°C, this is surpassed with up to 6°C.

Also, simulation results reveal that the annual average of overheated hours per day is approximately 3.25 h/day, the maximum being recorded for the months from May to September. In July it reaches its maximum of 12 h/day (Fig. 7). These measurements lead to the calculation of an annual demand for cooling of about 16kWh/(m^2a). The cooling necessary for the indoor space is at maximum level in July, approximately 5.5 kWh/m^2 (Fig. 8), cumulating the lowest values in September – 0.5 kWh/m^2.

In conclusion, for the analysed house model, the charts emphasize that, during summer, the comfort can be provided through indoor air cooling. In this regard, besides the architectural and constructive measures (Table 1), it is necessary to implement passive cooling systems.

4. SYSTEMS ENSURING INDOOR COMFORT DURING SUMMER

4.1. Passive systems

For ensuring the comfort during summer and in order to reduce the energy demand will be exploited the natural cooling sources (implementation of a nocturnal ventilation system, cooling air by using Canadian shaft). The equipped ventilation system is made with galvanized steel piping, inside the house, and air valves for recirculating air, a heat recovery and fresh air piping such as the "Canadian shaft" system.

The "Canadian shaft" system is made with special antimicrobial polypropylene piping (the antimicrobial system is obtained through the integration of silver particles in the inner lining of the tubes), manufacturer Rehau. The "Canadian shaft" uses the heat and thermal inertia of the soil, so that the outdoor air is preheated during winter and cooled to a comfortable temperature in the summer.

This system is relatively easy to implement and can reduce the indoor temperature by 5 to 8°C in the hot days, with very low power consumption. The shaft's pipeline is buried underground at a depth of 2.2 - 2.5 meters. The tubes system has a length of 40 meters and a diameter of 200 mm. The outside air is aspirated by the outer piping through a suction tower, equipped with filters that absorb and retain dust and pollen from the air.

4.2. Active systems

Exploiting the potential of solar radiation during summer season could significantly reduce the costs for domestic hot water. For the holiday houses presented thus far, ariston flat solar panels will be used. The solar panels will be installed on the the south orientated roof slope (**Kairos CF 2.0** – www.ariston.com).

5. CONCLUSIONS

By analysis of the summer house model, the exploitation potential of passive cooling measures was observed. The approach followed architectural optimization of the final volumetric form, convenient site location, south orientated roof slope, east orientated glazed facade and exterior finishing solutions that prevent overheating. These architectural measures were accompanied by implementation of passive systems to avoid overheating, reducing the power consumption and providing indoor comfort during summer.

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