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Review paper

POTENTIAL SOLAR ENERGY USE IN A RESIDENTIAL DISTRICT IN NIŠ

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Serbia is a suitable place for solar energy exploitation with more than 2000 sunny hours per year over 80% of its territory. In the paper, the existing state is analyzed and the possibilities of solar energy use are examined by employing a combined approach. This relies on the following elements: an attached conservatory with remote heat storage for space heating in the period October-April; a canopy covered by flexible organic photovoltaic modules for electricity production in the period May-September, and a solar water heating system throughout the year. In addition to an analysis of energy performance of the proposed design solution, its economic aspect is also discussed, which suggests that investing in energy efficiency projects should be encouraged provided the state adopts an appropriate system of subsidies for the use of renewable energy sources.

Key words: Solar energy; attached conservatory; photovoltaic canopy; solar water heating system; family houses; case study.

INTRODUCTION

There is a common opinion in Serbia that "energy is not a trade good, but a tool for maintaining the population's economic status" (TE Nikola Tesla, 2009). This has a negative effect on the public's awareness of the need for increased energy efficiency. As a result, the current situation can be summarized as follows (Build Magazine, 2008):

- utilization of resources is extremely uneconomical;
- energy and transport systems are outdated;
- use of renewable energy sources and the application of energy efficiency principles are negligible, as the low price of electricity deters investment in energy efficiency projects.

The image of a typical facade from the 1960's and 1970's (Figure 1) best illustrates the condition of the majority of (multi-storey) buildings today.

The measures that have so far been undertaken by the state in order to enhance energy efficiency have proven to be insufficient and have not led to satisfactory results: there is, still, no adequate legislation, nor are there subsidies or supporting measures for projects in the field of energy efficiency. Consequently, the public is not sufficiently acquainted with all the advantages of energy efficient buildings and renewable energy sources. Over the last decade, a number of homeowners have invested in improved external insulation of their properties. Unfortunately, more frequently than not, these are only naive and partial attempts at solving a much bigger problem. Rare are those homeowners who decide to restore thermal bridges or replace the existing windows, doors and fittings in their homes.

Figure 1. The facade of a multi-storey building from the 1960-80 period

The aim of this paper is to estimate the energy gain and cost-effectiveness that could result from the use of solar energy. To this end, a combined approach is employed, which relies on the following design solutions: an attached conservatory for additional heating of space in

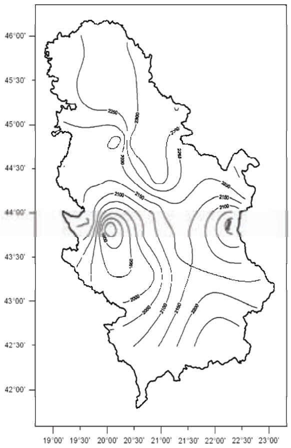

Figure 2. The annual number of sunlight hours in Serbia (Hydro-Meteorological Agency of the Republic of Serbia, 2009)

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winter, and a photovoltaic canopy on the conservatory roof for generating electricity in summer. The use of a solar water heating system throughout the year is also discussed as a possibility.

In this case study, an existing family house is analyzed, and the possibility of attaching a conservatory with a photovoltaic canopy is considered, along with the integration of solar thermal collectors. After the house structure, the location and functional arrangement of space are examined, and it is proposed to rearrange the rooms in the house, attaching a conservatory with a photovoltaic canopy, and integration of a solar water heating system. Energy gain is calculated for each component of the proposal; the conservatory is observed for the period October-April; the photovoltaic canopy for the period May-September, and the solar water heating system for the entire year. The economic aspects are also discussed, such as the cost-effectiveness of the attached conservatory, the photovoltaic canopy, and the installed solar water heating system, while taking into account the current price of electricity.

CLIMATE AND LOCATION

Climate

A clear division between four seasons characterizes the climate in Serbia. The winters are long and cold, and the summers are dry and hot. There are more than 2,000 sunny hours over 80% of the entire territory (Figure 2). For this reason, the majority of energy in residential buildings is consumed for heating in winter, and a somewhat lower amount for cooling in summer. As the number of sunlight hours during winter is not small, Serbia is a convenient environment for the application of techniques of passive solar architecture.

The house and its location

The analyzed house is one in the northern line of houses between Đerdapska and Ktitor streets in Duvanište district in Niš. The houses are mainly residential buildings, with some office space, consisting of ground floor, first floor and attic. They were built in the period 1995-2000, at a 13º angle westwards relative to the south (Figure 3 and 4). Their foundation is laid on flat terrain surrounded mainly by greenery and hedges. The streets are two-way asphalt streets with pavements. Between the northern and the southern line of houses, there is a concrete paved pedestrian zone with lamp posts in the middle. There are no paths for cyclists. During winter, the southern house line is not in the shade, and the wind usually blows from the north-east.

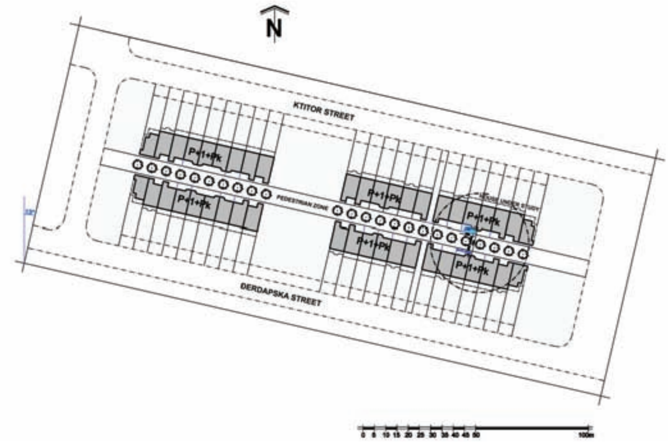

Figure 3. Orientation of the houses in Duvanište district in Niš

Figure 4. The orthophoto image of the houses in Duvanište district in Niš (source http://gis.ni.rs).

FUNCTIONAL ORGANIZATION OF SPACE

The ground floor of the houses is used as an office space; the first floor comprises a living room, a kitchen and a dining room, while the bedrooms are located in the attic. The existing arrangement of space by level is given in figures 5a, 6a, and 7a.

The first floor of the houses in the southern line has its living room orientated to the south-west, and the staircase and the kitchen facing the north-east. The southern line is the mirror image of the northern house line, where the living room is in the north-east and the staircase and the kitchen in the south-west. As a first measure of passive solar architecture, a change in space function is proposed for houses in the northern line that involves switching the locations of the rooms on the first floor: the living room takes the place of the kitchen and the staircase, thus referencing its position to the south to provide more sunlight. Provided a conservatory is attached, and the balcony doors on the first floor are open towards the conservatory, the sun-lit living room will also seem lighter and its overall aesthetics improve. In addition, the living room is now acoustically more comfortable. On one side, it faces the more quiet pedestrian area and, on the other, the conservatory functions as an acoustic barrier. The proposed rearrangement of space, together with the attached conservatory is presented in Figure 6b. As can be seen, particular care was taken to avoid unnecessary dismantling and to preserve as many walls as possible.

The proposed reconstruction is based on two possibilities, each of which supports a different functional scheme: change inside the existing space and change by attaching a new volume, i.e. a conservatory (Krstić-Furundžić, 1997).

Aspects of form

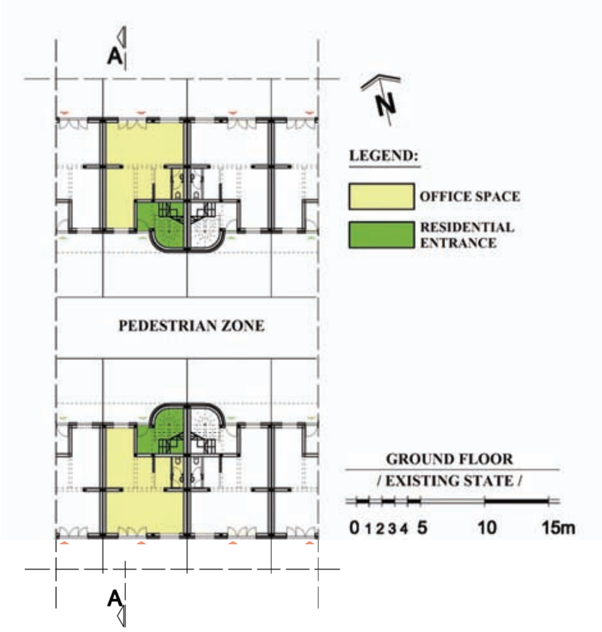

Figure 5a. The existing ground floor

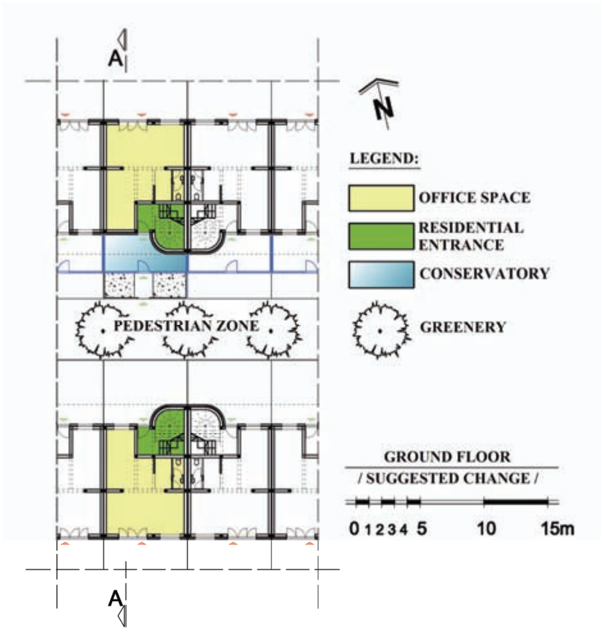

Figure 5b. The reconstructed ground floor, with the attached conservatory

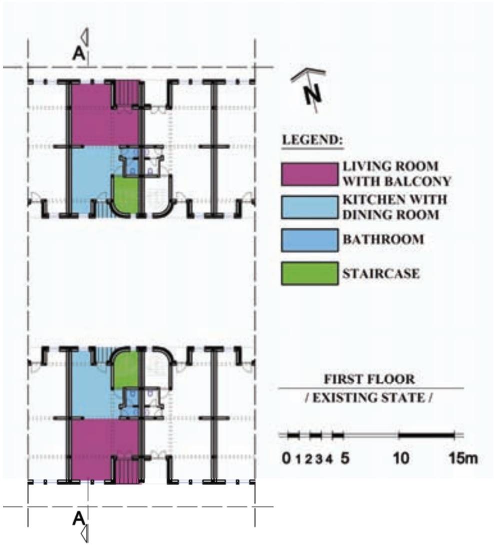

Figure 6a. The existing first floor

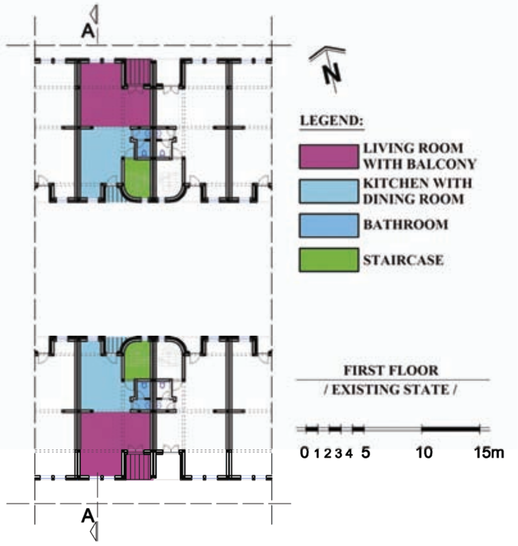

Figure 6b. The first floor with the attached conservatory

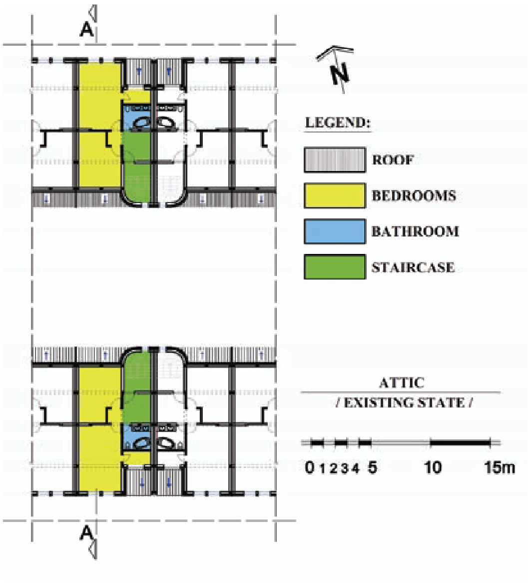

Figure 7a. The existing attic

Figure 7b. The attic with the attached conservatory

PROPOSED SOLAR ARCHITECTURE MEASURES: THE PASSIVE AND ACTIVE APPROACH

One of the basic principles of designing energy efficient facilities is the passive use of solar energy (Pucar, 2006). To apply this principle to the houses discussed herein, the balcony of the southern line house can be glass-paned, and a conservatory can be attached to the house in the northern line. Irrespective of the house location, solar thermal collectors can be installed in the south-west pitch of the roof. The proposed solutions are given in Figure 8.

The glass-paned balcony in the southern house line

A conservatory attached to the house in the southern line is not a practical solution, as the entry to the office space is south-oriented. The glass-paned balcony on the first floor captures solar energy, which is used for heating the living area (living room, kitchen, dining room). It turns into a useful space throughout the year, even in late autumn and early spring when outside temperatures are still low. It also functions as an extension of the living room and, due to the glass panes, improves the aesthetics of both the exterior and the interior.

Glass panes should be as neutral as possible, so as not to significantly affect the appearance of the facade. In this respect, wide glass doors are the preferred choice. When wide open, they allow the balcony to regain its primary function and prevent the overheating of space. In addition, the glass-paned balcony reduces the area of the house envelope, as well as transmission and ventilation loss, thereby improving the house's efficacy and resolving the problem of cold bridges. The acoustic comfort of the house is also enhanced, as the balcony functions as a sound insulation space.

A further proposed measure implies planting short deciduous trees in the grounds to the south of the house. Leaves reduce heat in summer and their absence on branches in winter allows sunlight to enter the space, contributing to the solar gain. It has been estimated that deciduous trees planted in the southern and western grounds can lower electricity consumption in summer by up to 5% (Donovan, Butry, 2009). While deciding on tree sorts, it is necessary to select those that can be grown in urban areas and are at most 7m high.

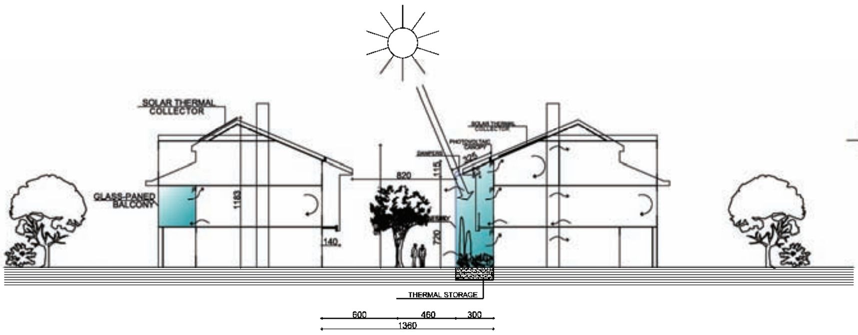

Figure 8. The cross-section of houses with glass-paned balconies, attached conservatories and installed solar thermal collectors in the roof

The tree height is relevant, if the shading of the photovoltaic canopy, and solar energy collectors installed in the upper roof part is to be avoided and their malfunctioning prevented. The appropriate tree types include the apricot tree (Prunus armeniaca), cornel (Cornus mas), hazel tree (Corylus avellana), Japanese maple (Acer palmatum), whitebeam (Sorbus aria), etc.

The attached conservatory in the northern house line

The conservatory attached to the house in the northern line contributes to reduced heat loss, better energy performance and higher energy efficiency, as collected solar energy is directly transmitted into the space. The conservatory is so designed as to represent a link between the living area and the natural ambiance. It is attached to the southern facade and is erected to the level of the roof crown, so the impression created is of the conservatory roof as an extension of the house roof. The distance from the southern facade is large enough to provide sunlight to the conservatory surface area and the windows in winter months. Functionally, the space of the conservatory directly attached to the living area is the space of the balcony on the first floor, which makes it convenient for use in late autumn and early spring, as well as on sunny winter days. The useful space of the living area is enlarged in this way. Moreover, the exterior structure of the conservatory is significantly distant from the balcony that when one is on the balcony, one gets the impression of a larger open space, than when one is on a glass-paned balcony alone, with no surrounding conservatory. The garden inside the conservatory can also be used during the low-temperature period, but as it is functionally detached from the living room by the staircase and the entry hall, it is reasonable to expect that more time will be spent on the balcony inside the conservatory.

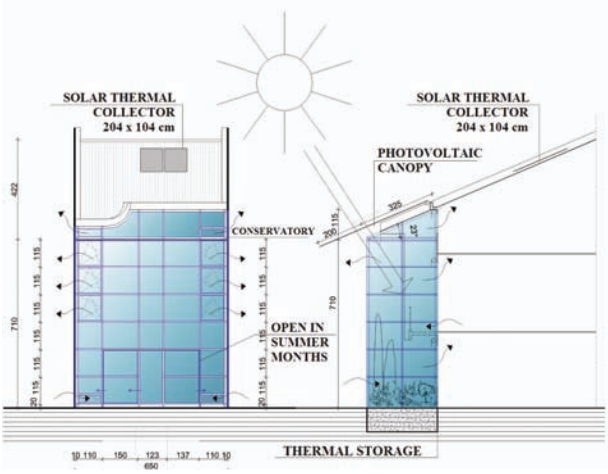

Figure 9. The conservatory

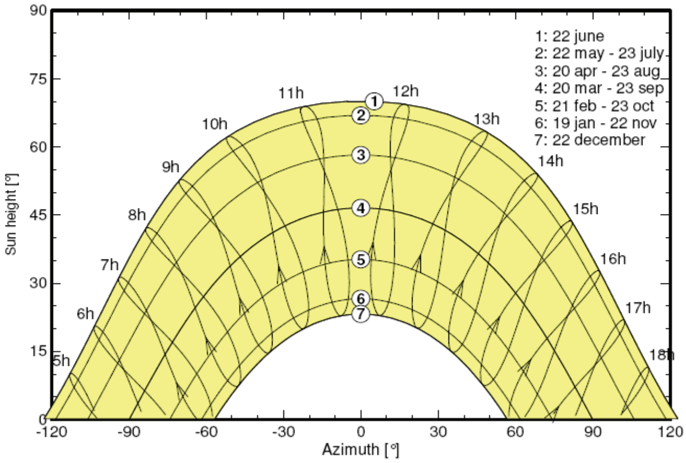

Figure 10. The Sun path in Niš (source: PVSYST v. 4.37 softwar

Table 1: Thermal mass- dimensions and characteristics

Accumulation element	House Walls	Balcony	Total
Material	brick	concrete	
Density (kg/m^3)	1700	2300	
Thickness (m)	0.08	0.12	
Exposed area (m^2)	47.56	4.30	51.86
Exposed mass (kg)	6468.16	1186.8	7654.96
Specific heating capacity (J/kgK)	0.20	0.29	
Heating capacity (J/m^{3}K)	1293.63	344.17	1637.80

The attached conservatory, as a transparent addition to the existing house volume, makes the southern facade of the house visually lighter and brighter, whilst at the same time increasing the dynamics of the south-western façade, due to the various hues of shadows cast by trees planted in front of the conservatory, and the reflection of light inside the conservatory in daytime.

As can be seen from the cross-sections of the conservatory (Figures 8 and 9) and the Sun path in Niš (Figure 10), the grounds are not sunlit in the period October 23-February 21. For this reason, the primary thermal mass of the conservatory should consist of the house walls and the balcony on the first floor (Table 1). The house walls are composed of a mortar layer, a 12 cm thick brick layer, a 6 cm thick mineral wool layer, a 20 cm thick gitter panel, and an additional layer of mortar. The balcony is made of 12 cm thick fortified concrete panels and is paved with terrazzo. For the estimate of the heating capacity of the primary thermal mass, it is assumed that the effective thickness of the brick is 8 cm and that of concrete and terrazzo 12 cm (Pucar, 2006).

As the area of the southern glass-paned (collector) surface of the conservatory is 67.92m^2, the heating capacity of the available primary thermal mass is sufficient for up to 10% of the heating needs of the house. The low accumulation capacity of the primary thermal mass, as well as the fact that a thermal insulation layer behind the bricks is an additional obstacle to convection of heat into the secondary thermal mass, will result in a quick overheating of the conservatory on sunny days and a high fluctuation between day and night temperatures. For this reason, the conservatory should primarily be used as a solar collector, allowing the major part of heat to be transferred into the inside space. In case extra heat is needed inside the house, the balcony doors and bedroom windows in the attic are opened. If the conservatory should be isolated from the house, the balcony doors and bedroom windows can be shut. As the glass in the balcony doors and windows is heat-insulated, it acts as a thermal barrier between the conservatory and the rest of the house.

In order to increase the conservatory efficiency and to lower indoor temperature fluctuations, a heat storage should be constructed and placed in the conservatory under the garden. This allows an extra amount of heat, generated in daytime, to be stored and used during the night or on days with insufficient sunlight. Warm air circulating in the conservatory is collected in the channels, and by means of a fan, is conducted into the stone-layered thermal storage. The storage is designed as a structured pile made of graded stone, primarily shingle, 3-10 cm in size. The storage is heat- and hydro-insulated on all its sides, except for the bottom which is covered with a concrete panel. In order to raise the level of heat accumulation in the storage, warm air from the conservatory should be led through the system of drainpipes dug in the shingle layer and evenly spread throughout the storage.

Warm air is transferred from the conservatory to the shingled storage by thermostatically controlled fans and air channels. When night temperature is below the temperature of the shingled storage, recirculation is activated automatically, and the fan is turned off. The heat is released inside the conservatory by passive radiation convection from the concrete panel on the ground. Warm air rising from the storage maintains the conservatory temperature during the night, reducing temperature oscillations. When extra heat is needed, warm air from the shingle pile can circulate upon reactivation of the fan, thereby providing neighboring rooms with a higher percentage of heat from the storage.

The conservatory's energy performance is highly dependent on the properties of glass. These include total transmissivity, which is the percentage of sunlight transmitted into the conservatory, and the U-value, which is heat transmission per area unit that determines the amount of heat passing from the warmer conservatory to the cooler areas through glass walls. Naturally, the best combination is high transmissivity and low heat transmission. One example from Western Europe consists of a 4mm thick external glass pane, a 16mm space 90% filled with argon, and a 6mm K Glass internal pane of a 78% total transmissivity, and 1.5W/m^{2}K U-value (*see Notes 1*). However, this glass type is not available on the Serbian market, and data about available products are difficult to obtain. One Serbian product offers heat insulated low-E glass of 4-15-4 type, with the space filled with dry air (dew point of -30°C), and with the properties comparable to the type mentioned above i.e.: 73% total transmissivity, 1.42W/m^{2}K U-value (*see Notes 2*). The price of this glass (including VAT) is approximately 33**€**/m^2, which means that the cost of the overall glass area of the conservatory of 103.08m^2 would be slightly below 3400**€**, excluding the costs of transportation and installation.

System for prevention of overheating

For the prevention of overheating in the period May-September, a UV protected roll-on canopy is installed that covers the entire roof surface of the conservatory. It has a 2m overhang down the vertical wall, and is positioned as high as the trees. This provides shading to the vertical south-west surface of the conservatory during summer. Between the canopy and the conservatory roof, there is a 30cm empty space to allow free air circulation. Fresh air is supplied to the conservatory through the external door and dampers at the bottom, while warm air is conducted away through the dampers on top of the conservatory.

To maximize the use of solar energy in the period May-September, when sunlight is most intense, the canopy is covered with organic photovoltaic modules of the third generation technology based on photo-reactive polymer. These modules are composed of several layers: flexible plastic substrate, primary electrode, photo-reactive printed material, transparent electrode, and transparent protective packaging (see Notes 3).

Due to the flexibility of this type of material, the conservatory can make use of solar energy at any time. In the period October-April, the canopy can be rolled up to allow generation of thermal energy inside the conservatory. When unrolled, the canopy dims the inside of the conservatory, and electrical energy is produced that is directly distributed to the electric grid.

As these photovoltaic modules are made of conductive organic polymers, they weigh only 0.9kg/m^2. This means that the system installed on the conservatory roof will contribute an additional 31 kg (excluding the canopy weight). The power of the solar cells is 16.7Wp/m^2. The main disadvantage of this photovoltaic technology is its considerably lower efficiency, compared to that of the first and second generation photovoltaic modules based on silicon cells, cadmium-indium-selenium cells or cadmium-tellurium cells. The advantages include the possibility of rolling up/down the flexible photovoltaic canopy and its relatively low end price. It is expected that within a few years photovoltaic modules of the third generation will have a higher efficacy and lower price (Green, 2003).

Installation of a solar water heating system

For the purpose of water heating, a solar water heating system is installed that consists of solar thermal collectors, a tank of 300l volume, an electric water heater, and the attendant devices (Figure 11). Two solar thermal collectors, 2040 mm x 1040 mm in size, are integrated in the south pitch of the roof, at a 23° angle parallel to the roof pitch (Figure 9).

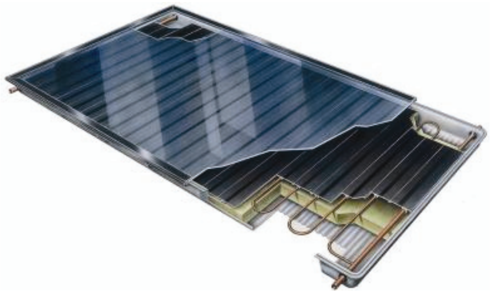

Figure 11. Solar thermal collector (see Notes 4)

ANALYSIS OF SHADOWS

An analysis was carried out regarding the position of shadows that fall onto the northern line of houses, where the conservatories were attached. In this article, a presentation is given for the 22nd December, when the Sun is the lowest on the horizon. At the same time, this is the most unfavorable day in the year, when the level of shadowing of the conservatory is the highest. Almost half of the glass-paned vertical surface of the conservatory is in the shade during most of the day, while the slanting parts of the conservatory onto which the photovoltaic canopy is installed are sunlit during the greater part of the day. Only at 15h, they are in the shade (Figure 12, 13, 14). Part of the roofs in which solar thermal collectors have been placed are sunlit throughout the day. Around 16h the sun already sets, which is evident on the diagrams (Figure 10).

In this work, it is interesting to illustrate the shadow positions on the 21st March and 23rd September at 17h. Based on the analyses illustrated in the figures 15 and 16, it can be concluded that the vertical surfaces of the conservatory are sunlit almost throughout the entire day. Only at 17h, on the 23rd September, the greater part of the vertical surfaces are in shadow, while on the slanting

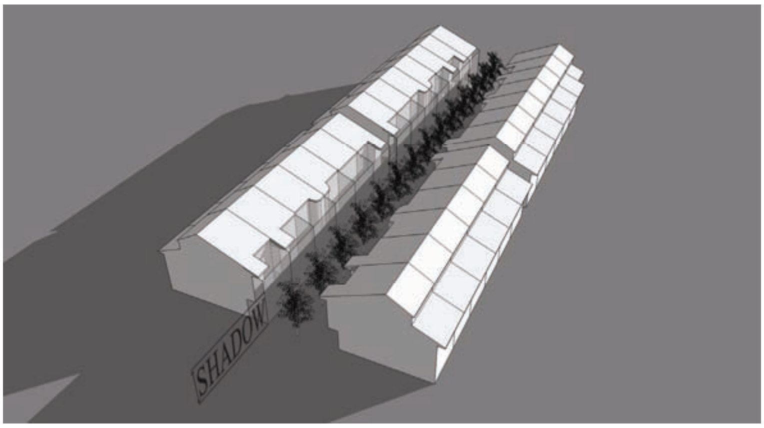

Figure 12. Position of shadow on the 22nd December at 9:00h

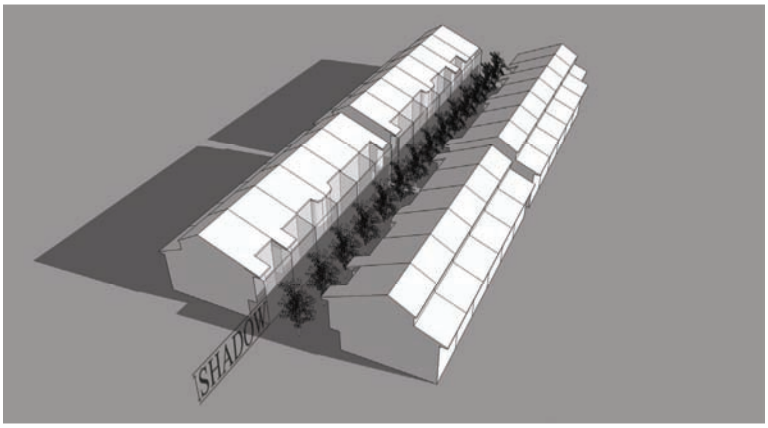

Figure 13. Position of shadow on the 22nd December at 12:00 p.m.

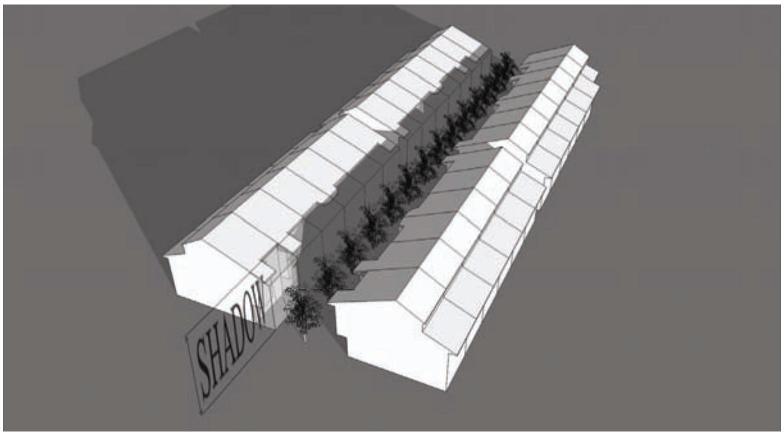

Figure 14. Position of shadow on the 22nd December at 15:00h

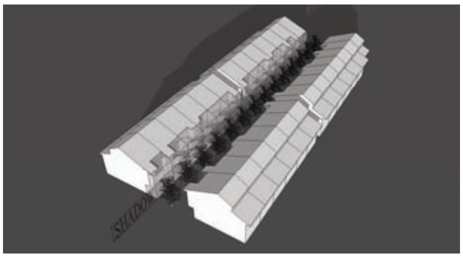

Figure 15.Position of shadow on the 21st March at 17h

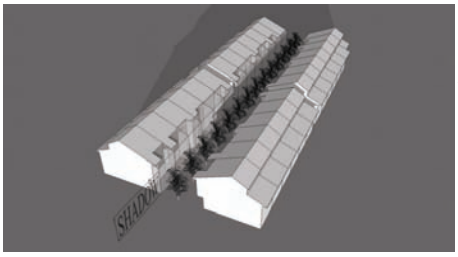

Figure 16. Position of shadow on the 23rd September at 17h

surfaces of the conservatory and on the roof of the house there are no shadows.

In the program PVSYST v.4.37, which has been used in this work, the given values have been calculated for the current situation – orientation and spatial organization.

ENERGY GAIN FOR THE CONSERVATORY IN THE PERIOD OCTOBER-APRIL

The amount of collected solar energy on the various conservatory surface areas by month is shown in Figure 17. The following surface areas are taken into account:

H = solar energy collected on the horizontal surface

K = solar energy collected on the southwest surface (193°) at inclination (23°)

J = solar energy collected on the southwest (193°) vertical surface

I = solar energy collected on the southeast (103°) vertical surface

Z = solar energy collected on the northwest (283°) vertical surface

The energy of solar radiation on the horizontal surface was measured at Davis Automatic Meteorological Unit of the Laboratory for Solar Energy, Faculty of Science, University of Niš, every 10 minutes during the year 2008. As the September of 2008 was exceptionally cloudy for Niš, the amounts for this month were smaller than expected.

The size of the respective surface areas of the conservatory are as follows:

$PK = 21.125\ m^2$, $PJ = 46.80\ m^2$,
$PI = 11.70\ m^2$, $PZ = 23.45\ m^2$

Energy gain by month inside the conservatory is the sum of all individual energy gains for each characteristic surface area of the conservatory (K, J, I and Z) represented as the product of their areas (m^2), solar energy collected on them by month, and glass transmissivity, according to the formula:

$$E = (\sum\nolimits_{\text{on conservatory surface}} \text{P}\ x\ \text{collected energy})\ x\ \text{glass transmissivity} \quad (1)$$

For glass transmissivity, the value of insulated low-E glass used was 73% (0.73). The values of energy gain by month in the conservatory are given in Table 2. Total energy gain in the conservatory for the period October-April is 29.39 MWh.

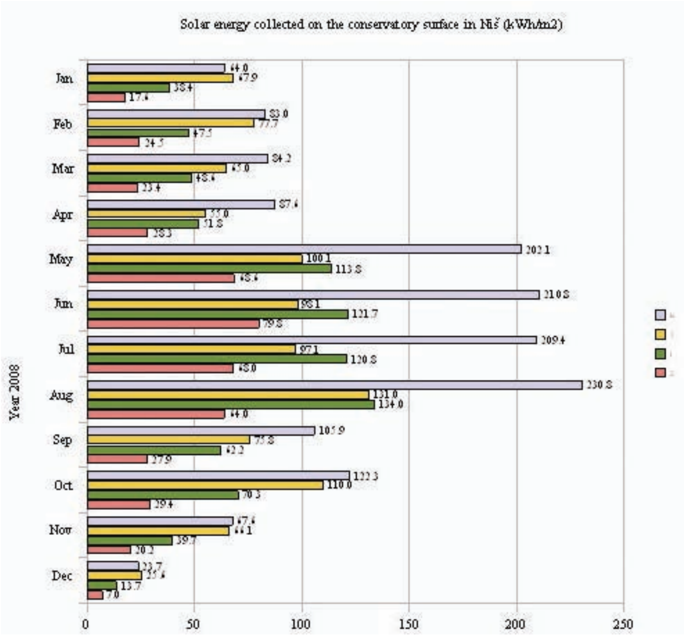

Figure 17. Solar energy collected on the conservatory surface area (K, J, I and Z)

Table 2. Energy gains by month in the conservatory (kWh).

Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
3 933	4 758	4 335	4 156	8 682	9 006	8 744	10 274	5 230	6 748	3 985	1 478

Table 3. Energy gain for the photovoltaic canopy

	PVWatts (kWh)	Approximate estimate (kWh)
Jan	33.42	36.46
Feb	46.11	47.30
Mar	51.67	47.98
Apr	47.66	49.92
May	108.60	115.19
Jun	113.52	120.13
Jul	112.49	119.36
Aug	119.88	131.54
Sep	54.37	60.33
Oct	70.69	69.71
Nov	41.67	38.54
Dec	10.28	13.53
Annual	810.34	850.00

ENERGY GAIN FOR THE PHOTOVOLTAIC CANOPY FOR THE PERIOD MAY-SEPTEMBER

When unfolded, the canopy has the area of 6.5m x 5.25m = 34.125m^2. Therefore, output power of the photovoltaic canopy is Pmax = 34.125 m^2 x 16.7Wp/ m^2 ≈ 0.57 kWp.

As shown in Table 3, in the column „PVWatts“, the software PVWatts Version 1 (PVWatts, 2009; Mennicucci, 1986) was used for the first calculation of the canopy energy gain. For the approximate calculation of energy gain, a simple formula was applied:

$$E = \frac{\text{collected energy x Pmax}}{1000} \tag{2}$$

where Pmax = 0.57kWp, and collected energy is the monthly collected energy on the surface inside the pitch of the roof for the year 2008 (K in Figure 17).

Both calculations of energy gain give similar results, so it can be expected that the photovoltaic canopy during May-September will generate 500-550 kWh of electrical energy. The average monthly consumption of electrical energy was 390.2 kWh in Serbian households in 2008 (Serbian Electric Power Industry, 2009), so it is anticipated that the energy output by photovoltaic canopy would provide about 25% of the electricity consumed in households over the same period.

ENERGY GAIN OF THE SOLAR WATER HEATING SYSTEM

Computer simulations were done using Polysun 4.3 software under the assumption that a four-member family consumes a daily average of 200l of hot water at 45 C°. Based on the obtained simulations, it can be concluded that the proposed solar water heating system has the potential to meet fully their needs for hot water in the period May-September. Of the average annual needs for hot water 80% are met by using the solar thermal system, and the lowest monthly percentage (approx 30%) is recorded in January and February. A total of 2,317.9 kWh of thermal energy can be generated annually. In Figure 18, the ratio is presented between the monthly generation of thermal energy by the solar system and the energy used for water heating per household.

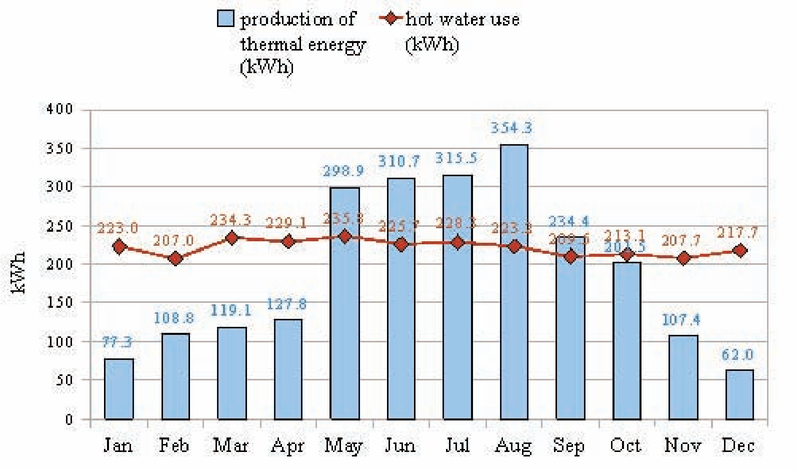

Figure18. Thermal energy produced by the solar system per month and hot water consumption

ECONOMIC ASPECTS OF THE ATTACHED CONSERVATORY, THE PHOTOVOLTAIC CANOPY, AND THE SOLAR WATER HEATING SYSTEM

The price of 3400**€** for the proposed low-emission insulated glass (excluding transportation and installation) suggests that the price of the entire conservatory (including the supporting structure), the active heat storage system and the canopy (without the photovoltaic cover) would be approximately 14,000 **€**. The price of the photovoltaic cover is still unknown, given that its mass production has just begun. It is expected that the price of the system will be 200**€**/m^2, which gives a final price of about 7,000 **€** for the photovoltaic cover of the canopy.

The average price of electricity in Serbia in 2008 was 4.322RSD/kWh (Electric Power Industry of Serbia, 2009). If electricity were used for house heating, the annual use of 12.50MWh would cost 54,000RSD, which is slightly below 600**€**. So, even if the active system of remote storage had the required capacity and efficacy to heat the entire house, it would take as long as 24 years for the investment into the conservatory to pay off. The truth, however, is that this investment can never pay off. If, rather than investing in a conservatory, a household deposits 14,000**€** with a bank in Serbia, at the interest rate of 7-8% per annum, their balance at the end of the year will be 815-930**€**, which is more than sufficient to cover the annual expenses for heating by electrical energy, assuming the current electricity price.

The economic aspects of investing in a photovoltaic canopy seem to be even worse: by generating 550 kWh electrical energy per year, approximately 25**€** are saved, which even by a simple division of the amount shows that the installation of the photovoltaic canopy would take as long as 280 years to pay off! It is obvious from this that the low electricity price in Serbia makes any investment in energy efficiency or renewable energy sources a mere enthusiasm.

The estimated payback period for solar water heating system for water heating is 10 years for a single house, assuming the investment price is 1500**€**, and there is no support by the state. This could be a good economic investment if the entire row of houses obtained a central system for thermal energy storage, because the repayment period would be even shorter (Kosorić, 2009).

It should be stressed that the technologies considered in our analysis have not, as yet, been put into wide use. Photovoltaic systems in the world still have a long payback period, as they are generally characterized by low efficiency and high price. Their cost-effectiveness in Serbia is even lower, given the price of electricity. If a standard conservatory were used, with ordinary glass panes and without special systems, the final price as well as the conservatory's overall operation would be very different. The feasibility of solar water heating system is stronger. Solar water heating system is more available on the market, their technology is known, and the price of the system is decreasing, which in addition to the ecological and energy benefits, increases their economic feasibility.

The price of electricity in Serbia, tailored to the consumers' living standards, should not be used as an excuse by the Energy Efficiency Agency to limit its promotion of energy efficiency to only a few projects. A much better way for the continuous raising of public awareness of energy efficiency and renewable energy sources would be a comprehensive program to subsidize the utilization of energy efficient techniques and technologies in the building sector. With a payback period of 15-20 years, which is the average longevity of the majority of energy efficiency technologies, investment can be made a more realistic option.

CONCLUSION

Although the potential exists for using solar energy in the building sector, its application, in both the design of new buildings and the reconstruction of old ones, is still rare. One of the ways to reduce the amount of energy for heating and cooling residential buildings is to employ bioclimatic principles of architectural design, as well as renewable energy sources, in particular solar energy. The analysis of the residential district in Niš presented in this paper is only a part of a broader research carried out within the doctoral program at the Faculty of Civil Engineering and Architecture, University of Niš, in cooperation with professors and experts in the field. This model can be applied to similar residential districts in other cities and regions in Serbia, taking into account the location-specific parameters (climate, location, building structure, etc.) Passive and active systems were proposed that would reduce energy consumption and improve comfort and functional conditions. An important role in the improvement of functional, energy and formal conditions in the house is given to the conservatory, which protects the house from direct external impacts, whilst connecting it with its surroundings. As an element of passive solar architecture, the conservatory does not use expensive technology, as it is tailored so as to maximize the collected solar energy. The most recent technology of glass manufacture provides various possibilities, as discussed earlier. A relatively new technology was proposed here, which relies on a photovoltaic and solar thermal system for generating electric and thermal energy. In addition to analyzing the performance of passive and active systems of photovoltaic canopies, the economic aspects of the proposed measures were also discussed. As pointed out earlier, some of the proposed measures, especially those relying on new technology, considerably increase the cost of conservatory building, but there are other options of building reconstruction as well.

In conclusion, the application of the principles of bioclimatic architecture and introduction of passive and active solar systems in the building practice require the fulfillment of a series of organizational, educational, economic, and technological prerequisites. The extent to which the needs of house residents can be met depends largely on their economic status. It can be expected, therefore, that projects offering higher energy efficiency will gain more importance with a change in regulations and market criteria, including the price of electricity (Pucar, Nenković-Riznić, 2007).

Notes

During their research the authors used examples and data from the following commercial sources:

1 Pilkington (2006), The Glass Range for Architects and Specifiers, CI/SfB (41) Ro3.

2 Vujić Valjevo (2008), Tipovi termoizolacionih stakala http://www.vujic.rs/_new/content/view/22/70/lang,ser/, pricelist http://www.vujic.rs/_new/_cenovnici/Cenovnik_IZO_stakla.doc, accessed 26.08.2009.

3 Konarka Power Plastic photovoltaic material (source: http://www.konarka.com/index.php/technology/our-technology/)

Konarka Power Plastic, Converting Light to Energy – Anywhere, http://www.konarka.com/media/pdf/konarka_info_sheet_BIPV.pdf, accessed 26.08.2009.

4 Solar thermal collector TS 300 by ThermoSolar AG, Slovakia (source: www.thermosolar.sk)

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Pucar, M., Nenković-Riznić M. (2007), Legislative and policy in energy efficient designing and renewable energy sources: Application in Serbia, *Spatium - International Review*, No 15/16, IAUS, Beograd, pp. 66-71.

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