INFLUENCE OF CLIMATE AND AIR POLLUTION ON SOLAR ENERGY DEVELOPMENT IN SERBIA

by

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The paper introduces basic information on the geographical location, climate and solar radiation in Serbia. It focuses particularly on the air pollution in Serbia and its influence on the solar cells energy efficiency. Moreover, detailed information on the development of solar energy in Serbia and the examples of the application of the low, medium and high temperature and photovoltaic conversion of solar radiation is provided. The paper also gives an overview of the installed greater capacity solar power stations related to the electricity network and the smaller capacity solar power stations as the independent sources of electricity in Serbia. In conclusion, the paper stresses Serbia's favourite climate and other conditions for the prospective successful development of solar energy.

Key words: *solar energy, climate, air pollution, thermal solar energy conversion, photovoltaic, photovoltaic plants*

Introduction

The Sun is the most important source of renewable energy; its age estimated to be about five billion years centres it in the middle of its life cycle. Worldwide solar radiation has been increasingly used for heating and electricity generation. Main reasons for the research, development and utilization of the solar energy in the world are to preserve the existing ecological balance and restore it where disturbed; more efficient use of the country's own potential in the electricity and heat generation; reduction of the *greenhouse gases* emission, reduction of the import and fossil fuels use; development of the economy and local industry, *etc*. [1-5].

In 2008 the European Parliament adopted a legislative package on climate changes with the aim of reducing the greenhouse gases emission by 20%, improving energy efficiency by 20%, and increasing a share of the renewable energy to 20% of the total EU energy consumption by 2020 as compared to 1990. In October 2014, after long negotiations, the European Union

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decided to increase the use of the renewable energy sources to 27% by 2030; it also planned energy savings by 30% and obligated every country to build an infrastructure enabling 15% of its electricity production to be exported to the neighbouring countries [2, 3, 6, 7].

Republic of Serbia in 2009, became a member and a founder of the International Renewable Energy Agency (IRENA) as the first international (intergovernmental) organization focusing exclusively on the renewable energy [3]. A detailed overview of the current state, perspectives and regulations concerning the use of the renewable energy sources in Serbia and the Republic of Srpska is presented in [2].

This paper focuses on the climate and air pollution influence on the solar energy development in Serbia.

Geographical location and climate of Serbia

Serbia is located between 41°46’40" and 46°11’25" north latitude and 18°06’ and 23°01’ east longitude.

Serbia belongs to the continental climate area divided into a continental climate in the Pannonian Plain, temperate continental climate in the lower parts of the mountain region and the mountain climate in the high mountains. Relief significantly affects the climate in Serbia. The belt of the Dinaric Mountains in the west and south-west prevents the penetration of moist air masses from the Atlantic Ocean and the Adriatic Sea to the territory of Serbia. On the other hand, through the Pannonian Plain, the territory of Serbia is wide open to the climate impacts from the north and east. The valleys of the Kolubara and the rivers Velika and Juzna Morava facilitate the penetration of air masses in the north-south direction and *vice versa*. The climate of Serbia is under the influence of the large geographical areas with certain physical characteristics air masses. Air masses formed over Siberia, the Arctic, the Atlantic Ocean, the African mainland, and the Mediterranean exhibit major influence on the climate in Serbia, forming higher air pressure over these areas. Cold air from Siberia and rarely from the Arctic often penetrates the territory of Serbia [2, 3].

Continental (Pannonian) climate

In the northern part of Serbia there is a spacious wide open Pannonian area exposed to the north and east climate influences. The Pannonian Plain exhibits continental climate including Vojvodina and its rim up to 800 m altitude. Continental climate is characterized by the extremely hot, low humidity summers. Winters are long and severe and springs and autumns are moderate and short. Mean annual air temperatures in the Pannonian area increase from west to east and from north to south. Sombor city at the western end has the mean annual temperature of 11.1 °C and Jasa Tomic sity in the east, 14.4 °C. The mean annual temperature of Palic sity in the far north is 10.6 °C and Belgrade in the south is 11.6 °C. The warmest month in the Pannonian area is July. However, there are some differences in the whole Pannonian area. The summer temperatures rise from west to east. For example, the mean July temperature in Sombor (Backa region) is 21.2 °C and in Vrsac (Banat region) it is 23.3 °C. The highest summer temperatures range from 35 to 44.3 °C (Stari Becej), and in sands they reach up to 60 °C. Winter is extremely cold in the Pannonian area exhibiting lowest winter temperatures in the east of the regions Banat and Backa, and slightly hotter on the rim of the Pannonian basin. January is the coldest month with an average temperature of –1.9 °C in Palic and 0.3 °C in Smederevo city. The Pannonian Plain precipitation is insufficient and unevenly distributed throughout the year. The territorial distribution of rainfall also differs with Vojvodina receiving the least precipitation over the year. On average, Banat and Backa receive annually about 500-600 mm and in some years less than 400 mm of rainfall. Therefore, droughts are frequent. Precipitation increases from the central parts of the Pannonian Plain to the south, west, and east. There is about 600-800 mm of precipitation per year around Vrsac city. The precipitation is slowly increasing towards the south, thus Pozarevac city annually receives 609 mm and Smederevo 650 mm of rainfall [2, 3].

Moderate-continental (mountain) climate

Moderate-continental climate dominates the mountain belt of Serbia from 800 to 1400 m above the sea level. It is characterized by moderately warm summers, autumns longer and warmer than springs and cold winters. The mountain climate dominates the belt over 1400 m above the sea level. On the territory of Serbia it is most pronounced in the Sar-Planina, the Prokletije, Kopaonik, Stara Planina, *etc*. This type of climate is characterized by long cold and snowy winters and short and cool summers.

In the high karst fields and valleys of the mountain area of Serbia climate varies from the continental to mountainous one. Due to the temperature inversion winters are harsher; summers are pleasant and even cool in the higher areas. Heat peaks are rare and short during summer. Warm climate dominates the valleys that are closed and wind protected. These valleys are warmer than their surroundings both in winters and summers. Mean monthly and mean annual air temperatures in the mountain area of Serbia decrease with the increase of latitude and altitude the lowest being recorded on the Sar-Planina, Stara Planina, and Kopaonik.

The mountain area of Serbia is also characterized by the warm variant of temperate-continental climate typical for the Aleksandrovac, Metohija, and Vranje valleys. This variant occurs as a consequence of the greater protection of the mentioned valleys from the north cold air. The temperature inversions are also characteristic for the mountain area of Serbia. During winter high valleys and karst fields get cooler than their surroundings, particularly at night when a cold air descends from the surrounding mountains and retains there for long. Cloudiness in a mountain area ranges from 55-60% per year. The duration of sunshine in the mountain area of Serbia is 1500-2000 sunshine hours per year. Smaller insolation is caused by high cloudiness, especially during winter time of the year. The duration of sunshine is the smallest in the mountains. On the Tara mountain the Sun shines 1700 hours per year or 4.9 hours per day. On the Kopaonik mountain the annual duration of sunshine is 1741 hours or 5 hours per day. Precipitation is abundant in the mountain area. On average, the mountain area of Serbia receives 1700 mm of rainfall per year [2, 3].

Solar radiation in Serbia

Serbia's solar radiation intensity is one of the highest in Europe, with the average of 272 sunshine hours, *i. e*. annual average of 2300 sunshine hours. The average solar radiation intensity on the territory of Serbia ranges from 1.1 kWh/m^2 per day on the north up to 1.7 kWh/m^2 per day on the south – during January, and 5.9-6.6 kWh/m^2 per day – during July. Annually, average global solar radiation energy on the territory of Serbia ranges from 1200 kWh/m^2 per year in the northwest Serbia, up to 1550 kWh/m^2 yearly in the southeast Serbia, whereas in the middle part it is around 1400 kWh/m^2 per year. Consequently, Serbia exhibits favorable conditions for the use of solar radiation and its conversion into the thermal and electrical energy [1-4, 8, 9].

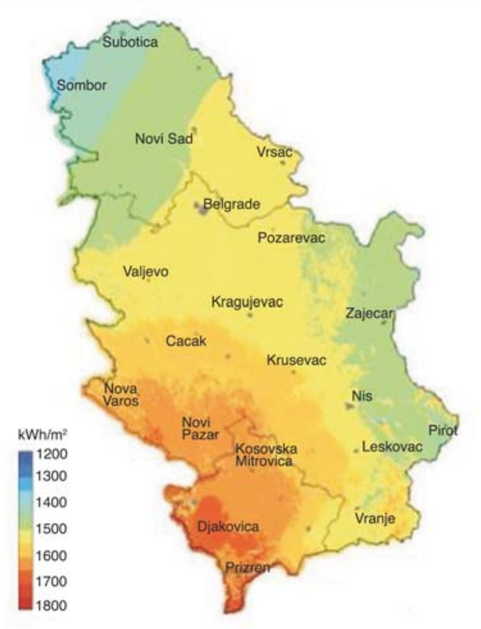

Figure 1. Yearly sum of the total solar radiation incident on optimally inclined south-oriented PV modules in kWh/m^2 for the territory of Serbia. Adapted for Serbia from PVGIS © European Communities, 2001-2008, http://re.ec.europa.eu/pvgis/.

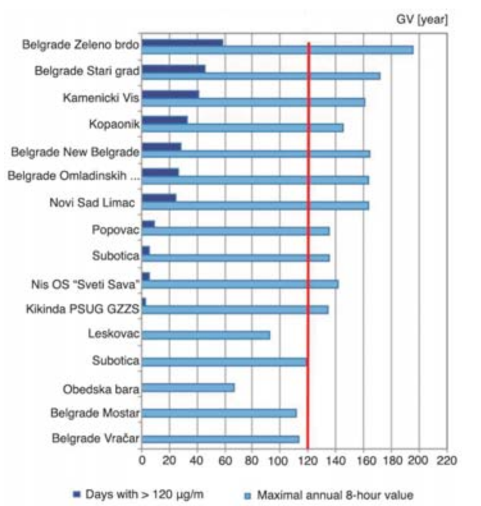

Figure 2. Comparative representations of the maximum annual eight-hour concentration of ground-level ozone (O_3) and the number of days in excess of limit values in 2013 in Serbia

Yearly sum of the total solar irradiation incident on optimally inclined south-oriented photovoltaic (PV) modules in kWh/m^2 for the territory of Serbia obtained by PVGIS is given in fig. 1.

Air pollution in Serbia

Global solar radiation consists of direct and diffuse radiation. Diffuse solar radiation occurrence is affected by the presence of the natural and anthropogenic (artificial) air pollution. The diffuse radiation intensity in the troposphere depends on the solar radiation absorption by the dust, smoke and H_2O, O_3, CO_2 molecules. Water vapour absorbs a part of the infrared radiation of the wavelengths up to 2.5 μm and carbon dioxide absorbs radiation of the wavelengths higher than 2.5 μm. Ozone completely absorbs ultraviolet radiation with wavelengths less than 0.3 μm. Ultraviolet radiation with wavelengths between 0.3 μm and 0.4 μm is almost fully dispersed over the air particles. There is no systematic and continuous measuring of the carbon dioxide concentration in the air in Serbia. Comparative representation of the maximum annual eight-hour concentration of the ground-level ozone (O_3) and the number of days in excess of limit values in 2013 in Serbia is shown in fig. 2.

In 2013 exceeding of the annual limit values for ozone (120 μg/m^3) were recorded at most measuring points (Belgrade, Novi Sad, Kamenicki Vis-Nis, Kopaonik, *etc*.).

In the urban areas of Serbia chemical composition of the suspended particles and sedimentary dust in the air depend on the industrial processes, fossil fuel and biomass combustion, emission of the exhaust fumes, *etc*. It is determined by the natural resources activities in the surrounding area and the specific weather conditions.

Spatial distribution of the particles emission in tonnes, in 2013, on the territory of Serbia is given in fig. 3.

In 2013 the PM_{10} limit values were exceeded on the territory of Valjevo (63 μg/m^3),

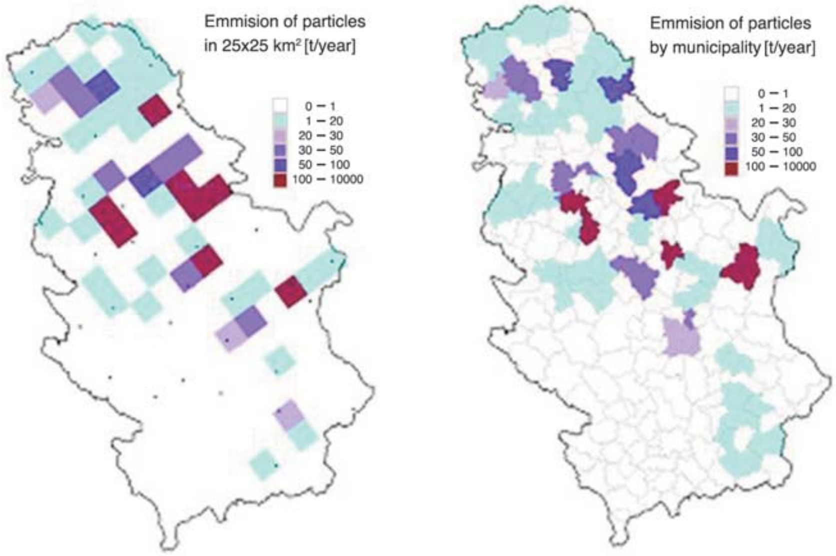

Figure 3. Spatial distribution of the particles emission in tonnes in 2013 on the territory of Serbia

Uzice (61 $\mu g/m^3$), and Belgrade (55 $\mu g/m^3$). In 2013 the largest number of days with exceeding limit values for soot particles was recorded in Leskovac, Uzice, Nis and Ivanjica. In Serbia there are no data on the impact of the air particles on the occurrence and intensity of diffuse solar radiation [10].

In 1960 worldwide research on the effect of air pollution on the solar cells performance began. Studies have shown that most negative impact on the solar cells performance have the particles less than 10 μm (PM_{10}), sedimentary particles and dust [11-13].

A study concerning the reliability of solar water heating systems implies that dust and dirt on the solar collectors surfaces are, in a great extent the reason for the systems performance degradation [13,14].

Influence of the presence of different particles on the reduction of solar cell power is shown in fig. 4 [12].

Reduction in PV voltage and power strongly depends on pollutant type and deposition level. The highest reduction in PV voltage (25%) is recorded when the ash pollutant is used [12].

Analysis of the impact of various factors on the solar modules efficiency in Serbia have shown that impurities on solar modules surface during the year reduce their efficiency by 10-20%. Therefore, it is necessary to regularly maintain solar modules or to clean them during the year [15].

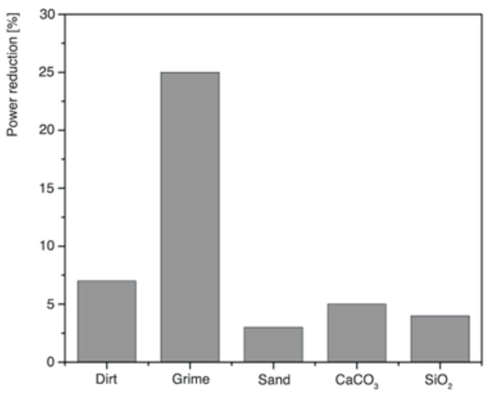

Figure 4. Influence of different particles on solar cells power reduction

Based on these findings it can be concluded that air pollution as well as the increasing concentrations of the ground-level ozone in Serbia could lead to the reduction of the solar radiation intensity and solar cells efficiency.

Solar energy use in Serbia

Development of solar energy in Serbia is marked by the works of Prof. Dr. Lalović (1928-1988) in Belgrade and Prof. Živojin Ćulum (1911-1991) in Novi Sad.

Since 1973 solar energy in Serbia has been the main research topic of several symposia and scientific meetings, first being held in 1978 in Belgrade (*The International Solar Energy Symposium on Technical, Economical and Organizational Aspects*), *etc*. Apart from the above-mentioned scientific meetings our experts have presented their papers on solar energy at the international conferences featuring the topics of energy, technics, environment protection, *etc*. Likewise, solar energy in Serbia was the research topic of several doctoral dissertations, master thesis, specialist and BA thesis, and a large number of books [2].

Figure 5. PV solar plant installed on the roof of the Faculty of Science and Mathematics in Nis

Faculty of Sciences and Mathematics (FSM) in Nis features a sopfisticated state-of-the-art solar energy laboratory which investigates physical characteristcs of the thermal and hybrid solar radiation collectors, solar cells and PV solar power plants (fig. 5).

Faculty of Mechanical Engineering in Nis features modern laboratory for thermotechnique, thermoenergy and processing technique investigating the characteristcs of the flat and parabolic solar radiation collectors.

Faculty of Electronic Engineering in Nis features modern laboratory for electronics realizing and investigating rotating PV systems for optimal solar radiation incidence [2, 4].

Faculty of Technical Sciences in Novi Sad features modern Renewable Energy Laboratory investigating among others also photovoltaic solar energy conversion.

Solar radiation low temperature conversion

Previous research on solar radiation low-temperature conversion in Serbia focused on the development of flat-plate collectors with a spectrally selective absorber (B. Lalović, T. Pavlović), air collectors (M. Lambić), hybrid collectors (B. Lalović, T. Pavlović), *etc*.

Spanning the period from 1978 to 1985 there were several manufacturers of solar radiation flat-plate collectors in Serbia: *Nissal* in Nis, *Sinvoz* in Zrenjanin, *Petar Drapsin* in Novi Sad, *Gosa* in Smederevska Palanka, *Jugoterm* in Gnjilane, *etc*. However, after 1985 the manufacturers' decline of interest seriously affected the production of solar collectors. Nowadays flat-plate collectors with water are produced by the following companies: *Termovent* in Belgrade, *El-Sol* in Pozarevac, *Jugoterm* in Nis, *etc*.

Today the companies *Energo Pro-Teh* in Zrenjanin, *Termogas* in Senta, *Conseko* Ltd. in Belgrade, *El-Sol* in Pozarevac, *CIM Gas* in Subotica, *etc*., are designing and installing solar energy systems. Solar water heaters and differential thermostats are produced by several private companies in Serbia.

Solar flat-plate collectors with water are used to heat sanitary water (Domestic Hot Water, DHW) in households, hotels, hospitals, military and other facilities in Serbia.

Serbia got installed large number of solar systems with flat-plate collectors for water heating: on the building of the *General hospital* in Pozarevac (210 collectors), near Petrovac na Mlavi (80 collectors), on the building of the *Youth home in* Kragujevac (20 collectors), on the building of the *Special hospital for mental illnesses* in Kovin (30 collectors), on the building of the *Special hospital for mental illnesses* in Vrsac (30 collectors), on the building of the *Special hospital for mental illnesses* in Novi Knezevac (30 collectors), on the building of the *Sports center* in Kikinda (40 collectors), *etc*.

In the period from 2006 to 2009 flat-plate solar collectors for DHW heating were installed on the buildings of the *Food and Catering School* and the kindergartens *Sunce, Bambi* and *Lugovi* in Cacak. The project was successfully implemented by the *Centre for Renewable Energy Sources of Greece*–CRES/KAPE (Athens), ECONET (Athens), and the town of Cacak. The project was financed by the Ministry of Foreign Affairs of the Republic of Greece through the Hellenic Aid program, with a partial subsidy participation of the project partners. The project coordinator was the *Centre for Renewable Energy Sources* (Athens).

In Obrenovac solar collectors for DHW heating were installed on the building of the *Culture and Sports center* (27 collectors), on the building of the swimming pools (40 collectors) and on the building of the *Disabled youth daycare* (5 collectors).

In early 2009 the Provincial Secretariat for Energy and Mineral Resources in Vojvodina signed with *the Slovak Agency for International Development Assistance* (SAIDA) an agreement on the implementation of *Solar Energy Projects in Vojvodina*, involving the Slovak state and the company *Thermo Solar Ziar* from Slovakia in donators. By virtue of this project in late October 2009 solar collectors for DHW heating were installed in the *General hospital "Dr. Djordje Jovanovic"* (200 collectors, fig. 6) and the *Boarding school Angelina Kojic-Gina* in Zrenjanin (80 collectors, fig. 7).

Figure 6. Solar collectors in General hospital *Dr. Djordje Jovanovic* in Zrenjanin

In late 2009 the *Cradle (Kolevka)* the disabled youth home in Subotica undertook a major project of replacing the conventional forms of energy utilized by the local power and heating systems with the solar energy prospective use in the coming decades. On the building of the *Cradle – disabled youth home a solar system with 160 collectors for DHW and industrial water heating and the facility reheating in the spring and autumn when central district heating system is inactive, was installed.*

In 2010 the donation of the Kingdom of Spain enabled a psychiatric hospital in Toponica near Nis to install the 10 flat plate collectors solar system for DHW heating.

In 2011 on the rooftop of the general hospital in Pirot 96 flat-plate collectors were installed for the kitchen water heating, sterilization and the laundry running [2, 4, 16].

Figure 7. Solar collectors on the roof of the *Angelina Kojic-Gina* boarding school in Zrenjanin

Figure 8. Vacuum collector at Vojvodina hotel in Zrenjanin

Figure 9. Prototype of solar power plant in Badnjevac

Solar radiation medium temperature conversion

Vacuum collectors for water heating are being used in Serbia in several places such as hotels and residential households.

On the roof of the Vojvodina hotel in Zrenjanin there are ten tube-vacuum collectors total surface of 33.3 m^2 (fig. 8). The mentioned solar system serves for the heating of 3000 l of the sanitary water in the hotel.

Solar radiation high temperature conversion

The first project on the high temperature solar radiation conversion in Serbia was realized in Badnjevac, a village near Kragujevac. The project was implemented according to the design of Prof. Dr. Vladan Petrović and solves two major solar energy problems, the efficient conversion of the solar radiation into the thermal energy and the thermal energy storage for a longer period of time (fig. 9).

The system consists of a concentrator which reflects sunlight towards the absorber in which high temperatures are reached and the working fluid (air) is heated. The concentrator is automatically directed towards the Sun by rotation around two axes, vertical and horizontal.

Concentrator of a diameter D = 10 m and useful area A = 66.7 m^2 can provide 40-54 kW thermal power depending on the solar radiation intensity incidence (600-800 W/m^2).

Maximum measured temperature during the summer months in the focus was 1650 °C. Due to high temperatures materials resistant to high temperatures were used to produce the absorber.

Besides concentrator and absorber a very important component of the system is a high temperature heat storage battery which consists of the heat storage and heat exchanger. Thermal energy is air transmitted from the absorber to the battery. Due to high quality isolation materials annual battery heat losses are 12%. Heat capacity of the maximum heated battery t_{max}= 800 °C is Q = 40000 kWh. The whole system runs automatically and is software monitored [2].

Solar radiation photovoltaic conversion

The PV conversion of solar radiation studies were conducted by M. Mihailović, Lj. Pesić in the Institute of Microelectronic Technologies and Monocrystals (ICTM) in Belgrade, B. Lalović and M. Stojanović in the Vinca Institute of Nuclear Sciences in Belgrade, T. Pavlović in the Faculty of Sciences and Mathematics, University of Nis, Nis, *etc*. First solar cells were made of monocrystalline silicon having efficiency of 8% at the ICTM in Belgrade in 1963, whereas the satellites solar cells had an efficiency of 10%. In the period from 1978 to 1981 the company *Radio cevi Ei (Radio tubes)* in Nis manufactured monocrystalline silicon solar cells of low efficiency and low power solar modules.

Solar cells and solar modules are not manufactured in Serbia. In Serbia solar modules, battery chargers, batteries and inverters are sold by several private companies such as *Telephone engineering* in Zemun, *Elvet* in Pirot, *etc*. Designing of PV systems are performed in Serbia by the following companies: *Alfatec* (Nis), *Netinvest* (Belgrade), *Conseko* Ltd. (Belgrade), *etc.* [2-4].

Solar PV power plants in Serbia

In the village of Matarova near Merdare municipality of Kursumlija, on the 26th of April, 2012, the Italian company *Gascom* in co-operation with the local company *Multienergy Consulting* began the construction of 2 MWp solar PV power plant. The plant was put into operation in early 2013. It is located on an area of 4 hectares, has 8500 solar modules and the investment value amounted to € 4 million.

In mid 2013 the company *Solaris Energy* from Kladovo started the construction of 1 MWp solar power plant *Solaris 1* near Kladovo. The plant was completed in a few months and is covering 2 hectares area. It consists of 4232 solar modules the area of 1.6 m^2 and individual power of 245 W. The investment value amounted to € 1.6 million [17].

Other applications of solar cells

In Serbia solar cells are used in the *Republic hydrometeorological institute* for the hydrometeorological devices charging, traffic signalization (traffic lights, car speed meters, *etc*.), private households electrical energy generation, *etc*.

Serbia has up to now installed more than 200 independent PV systems power of 50 W-4 kW for different purposes.

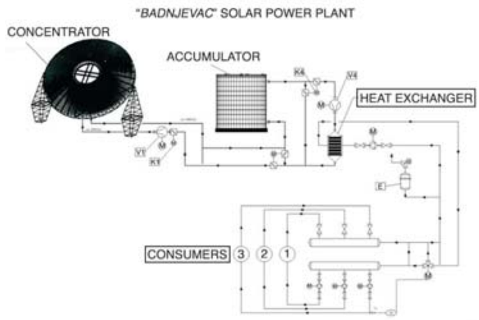

Figure 10. Schematics of solar power plant in Badnjevac

Moreover, Serbia has installed several small PV solar power plants connected to the grid: on the building of the primary school "*Dusan Jerkovic" in Ruma (3 kWp, in 2004), on the building of the secondary school in Varvarin (5 kWp, in 2010, Netinvest Co.*), on the building of the secondary electrotechnical school "*Rade Koncar"* in Belgrade (5 kWp, in 2010, *Netinvest Co.*), on the building of the secondary technical school "*Mihajlo Pupin"* in Kula (5 kWp, in 2010, *Netinvest Co,*), on the building of the Faculty of Technical Sciences in Novi Sad (8 kWp, in 2011), on the building of the Faculty of Electronic Engineering in Nis, (1.2 kWp, in 2011, *Alfatec Co.*), on the building of the Faculty of Sciences and Mathematics in Nis (2 kWp, in 2012, *Alfatec Co.*), on the building of the private house in Blace (10.44 kWp, in 2012, *Netinvest Co*.), on the building of the private companies in Leskovac (30 kWp, in 2012, *Alfatec Co.)* and in Cacak (55 kWp, in 2012, *Electrowat Co*.), on the building of the private houses in Merosina (10 kWp and 20 kWp, in 2012, *Telephone Engineering Co*.), on the building of the private houses in Zajecar (10 kWp, in 2011, *Telephone Engineering Co*.), in Cacak (5 kWp, in 2012, *Telephone Engineering Co*.), in Zemun (2.5 kWp, in 2012) and in the village of Cortanovci (10 kWp, in 2012, *Telephone Engineering Co*.). Solar PV power plants in Varvarin, Belgrade, and Kula were installed as a donation of the Spanish Government, with the help of the Energy Efficiency Agency, Belgrade, within the project *Development of Installations for the Promotion and Use of Solar Energy in Serbia* [2-4].

Students of technical sciences, University of Belgrade have won the first place at the Sustainable Europe contest in April, 2011 in Brussels for their invention of the public solar mobile phones charger called *strawberry tree*. Public solar mobile phones charger shaped as a tree comprises aluminum construction with a shade, two solar modules made of polycristalline silicon total power of 500 Wp, battery, four sitting benches and charging sockets for different types of mobile phones. For the first time a prototype of this tree was installed in October, 2010 downtown of Obrenovac. In Belgrade in the autumn of 2011, a public solar mobile phones charger was installed in front of the municipality building Zvezdara, and somewhat later in Novi Sad on the platoe in front of the Sports and shopping moll SPENS. Afterwards, the public solar mobile phones charger was installed in Kikinda, Vranje, Bor, Valjevo, Belgrade (Tasmajdan, Slavija), Bjeljina (Center, city park), Bogatic, *etc.* [17].

Solar architecture

Solar architecture was the main research focus of B. Lalović, M. Lambić, M. Jovanović-Popović, M. Pajević, M. Pucar, M. Lukić, and many others in Serbia. In this connection Serbia has up to now built several houses with passive solar incidence in Boljevci, Kac, Mladenovac, Belgrade, Sombor, Zajecar, Ljig, Novi Sad, *etc.* [2, 4].

Figure 11. Solar house in Boljevci

In Boljevci (Srem region) there is an ecology glass dome shaped house diameter of 18.5 m, front side glass covered and back side earthbased. The ecology house is constructed as a double shell enabling air circulation through the house interior and the heat battery. Maximal solar radiation incidence is realized by the combination of the active system (solar collectors) and passive (solar radiation incidence on the south, glass covered side of the house). At the bottom of the house there is a battery heat of 600 tons of stone and concrete. Ground floor locates residential area and the swimming pool with the water heated by the solar radiaton falling on the glass facade and the heat battery. The house is heated by the air circulation from the basement heat store. The house saves around 50% of the energy needed for its heating [17].

Conclusions

To sum up, by geographical location and climate conditions Serbia appears to be a very favourable country in Europe to utilize solar energy for water heating, electricity generation and houses and other buildings heating by passive solar energy.

In Serbia mainly industrially developed cities and places locating thermal power plants suffer heavily from air pollution while other places are much less affected. Air pollution to some extent exhibits adverse effects on the solar radiation reaching the soil and thus the development of the solar energy.

Solar energy development in Serbia traces back in 1973 following the first oil shock or energy crisis in the world. Solar energy is being researched in Serbia in several university centres of Nis, Novi Sad, Kragujevac, and Belgrade. Several private companies produce solar radiation flat-plate collectors with water. Serbia does not produce vacuum tube collectors and solar cells. The flat-plate collectors for water heating of the domestic or foreign production, vacuum tube collectors and the solar cells of the foreign production are to be found on the Serbian market. Solar radiation flat-plate collectors with water and a small number of vacuum tube collectors have been installed on the buildings of the private houses and community facilities in Serbia. First high temperature system (1650 ºC) with dual axis solar tracker was installed in the village of Badnjevac near Kragujevac.

So far two solar PV power plants of high capacity have been installed in Serbia *Matarova* of 2 MWp in the village of Matarova near Merdare and *Solaris 1* of 1 MWp in Kladovo. Over recent years a number of smaller solar power plants power of 0.5 to 40 kW have been installed in the residential areas and other facilities in Serbia.

Moreover, several houses with passive solar incidence were built the latest being the solar house in Boljevci (Srem region).

Over recent years Serbia has issued several regulations in compliance with the regulations of the European Union concerning the use of the renewable sources of energy thus stimulating a more intensive development of solar energy.

Taking into account the research findings it can be concluded that Serbia exhibits favourable climate and other conditions for prospective and successful solar energy development.

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