UDC: 620.9(947.11)
Case Study
Recived: December 15, 2019.
Acceptee: December 28, 2019
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ECONOMIC AND ENVIRONMENTAL ASPECTS OF THE USE OF SOLAR ENERGY FOR THERMAL AND ELECTRICAL ENERGY IN THE CITY OF NIS

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Abstract: *The world is facing the depletion of natural fuels such as coal and natural gas for electricity generation and the increasing demand for electricity. In this situation, everyone is looking for unconventional, renewable energy resources such as solar and wind energy, etc. The Earth receives solar energy in the form of solar radiation, which contains ultraviolet, visible and infrared radiation. The amount of solar radiation that reaches any location depends on several factors such as geographical location, time of day, season, volume of land, and local time. The Republic of Serbia, compared to other European countries, has an average of 40% higher solar radiation during the year, while Nis, Kursumlija and Vranje have the highest potential for the use of solar energy in southern Serbia. Since the city of Nis belongs to the group of cities in Serbia that have the highest potential for solar energy use, the subject of this paper will be the economic and environmental aspects of using solar energy to generate thermal and electrical energy on the territory of the city of Nis.*

Keywords: *economic and environmental aspects, natural resources, solar energy, thermal and electrical energy*

1. INTRODUCTION

The reason why solar energy is preferred over other technologies is, among other things, its steep cost-cutting curve which continues to decline. Today, the cost of producing solar energy is much lower than the cost of not only new coal and nuclear power plants, but also of gas, and in the wind range, it depends on the region. In 2018, several supply cases were recorded, with solar energy prices of 2 cents per kWh. Such price levels have been reached in different parts of the world. The lowest solar energy price in 2018 was recorded in India at INR 1.38 (Indian National Currency) (1.86 cents) per kWh, although this was an escalating tariff, with a special business model for government roof premises.

The transmission of sunlight and its functioning is difficult because solar energy reaching the Earth is spread over a large area. The sun does not deliver the same amount of energy at any place at any time. The amount of solar energy an area receives depends on the time of day, the season, the cloud cover of the sky, and how close the area is to the Earth's equator. A solar collector is a way to capture sunlight and convert it to useful thermal energy. A closed car on a sunny day is like a solar collector. As sunlight passes through the windows of the car, it is absorbed by the seat covers, walls and floor of the car. The absorbed light transforms into heat. Two ways to produce electricity from solar power are photovoltaic and solar thermal systems.

In general, solar prices are much higher in developing countries than in economies with stable conditions and high credit ratings. However, with the support of international lenders, such as development finance institutions, project risks can be significantly reduced in developing countries. This paper will deal with the economic and environmental aspects of the use of solar energy in the territory of the city of Nis with a reference to the Republic of Serbia and the potential of our country for the wider application of this type of energy.

2. SUN LIGHT AS A NATURAL RENEWABLE RESOURCE AND THE SOURCE OF ENERGY

There are several unconventional methods of energy production, such as aeolian, hydroelectric and geothermal, and such methods comprise less than one percent in the world of energy production, but they can play a very significant regional role in terms of economy and availability. Chemistry has helped the development of solar panels to produce photovoltaic thermal and electrical energy, lightweight cells have been cured with carbon fibers for the use of wind energy, special cement and metal turbines are used for hydroelectric power plants, and stainless materials for the exploitation of geothermal sources (Djukanovic 2010: 25).

A wide range of chemical research and development had an impact on the construction of solar cells with high capacity for heat and energy production, carbon-fiber-reinforced wind turbines to exploit eolian energy, special cement and metal turbines used by hydroelectric power plants and various stainless materials used on geothermal sources. There are two types of energy sources, renewable and non-renewable (Markovic, 2013). Basic forms of energy that make civilization operate today are mostly electrical and thermal energy, but by means of further technological procedures, if certain converters were applied, they could be converted to other forms of energy. Today, a large percentage of thermal and electrical energy comes from non-renewable energy sources.

The renewable energy resources are, in fact, the inexhaustible, natural form of energy that is everywhere around us. The term renewable energy means energy sources that are found everywhere in nature and can be partially or completely renewed.

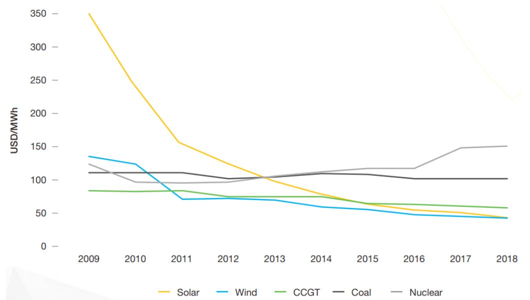

Fig. 1. Changes in the price of using renewable resources in the period from 2009 to 2018

Sun energy or solar energy is a renewable energy source. Being a star closest to our planet by distance, the sun is, directly or indirectly, the source of almost all the energy available on our planet (Tomovic 2002: 76). Solar energy is generated as a result of nuclear reactions in the center of the sun, with temperatures as high as 15 million ° C. It is a fusion, when hydrogen atoms are combined to produce helium, and hence a huge amount of energy is released. Therefore, according to this principle, about 600 million tonnes of hydrogen is converted to helium, whereas hydrogen, whose mass is almost 4 million tonnes, is converted to energy.

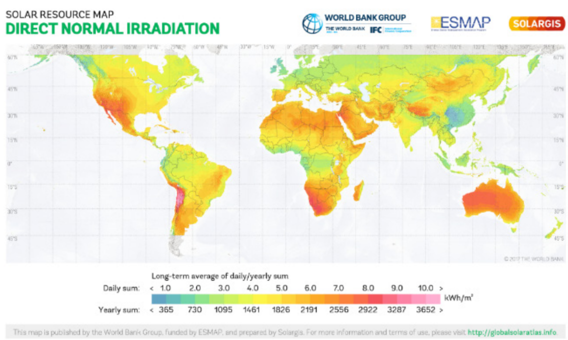

Fig. 2. The average annual energy of global solar radiation on the horizontal surface in the world

For five billion years, the Sun has been a major energy producer and it is currently estimated that the generation of this energy will continue for the next five billion years (Pavlovic and Carbic 2007: 142). Solar energy is the part of energy that is generated in the sun but that radiates onto the Earth.

Solar energy has the potential to be directly converted to thermal energy or electricity, and these are considered useful forms of energy. Electricity is the most exploitable form of energy for humanity today, because it can very easily be transformed into useful work. Solar energy is the "engine" for almost every renewable energy source. Most renewable energy sources on Earth are wind, wave, hydropower and biomass, and they represent secondary energy sources whose main drive is solar energy. Geothermal energy, as well as ebb and high tidal energy, are not secondary to solar energy, as they would still exist even without the sun's rays, (Gevorkian 2008: 267-272).

During the night and when the sky is overcast during the day, solar energy is not fully available, so it is necessary to have structures to store the energy which will be charged when solar energy is available (Djukanovic 2010: 29). It can be stored in various forms, but the most popular types are conversion to heat, storage in batteries and accumulators, then a pumped storage system, which means that water is pumped in several places when there is sufficient energy, and used when solar energy is unavailable.

Solar energy is a renewable energy source because it cannot be consumed as fossil fuels can. Also, solar energy is a very clean source of energy after installation, because there is neither emission of pollutants or pollution resulting from the use of a solar panel or a solar cell (Lepotic-Kovacevic and Lazarevic 2015: 33).

2.1 Conversion of solar energy into electricity

Quantum physics states that light has a dual nature, because it represents both a particle and a wave. A photon is the name used for light particles, which have no mass and their motion is equal to the speed of light. The energy of a photon depends on its wavelength or frequency. Einstein's law is used to calculate photon energy (Markvart & Castaner 2005: 24).

Electrons can exist as valence or free, both in metals and generally in matter. There is a bond between valence electrons and atoms, and free electrons can move freely (Jovancic 2009). For a valence electron to become free, it must obtain an amount of energy that is greater than or equal to the binding energy. Binding energy is the energy by means of which an electron binds to an atom in some atomic bonds. When a photoelectric effect occurs, the electron receives the energy it needs through a collision with a photon

The photon consumes a part of the energy so as to free the electron from the influence of the atom to which it is bound, and the rest of the energy is then converted into kinetic energy, which is now generated by free electrons. These free electrons obtained by photoelectric effect are also called photoelectrons. The operation of the output represents the energy required for the valence electron to be freed from the influence of the atom and it depends on the type of material in which the photoelectric effect took place. The conversion process is based on the photoelectric effect. Heinrich Rudolf Herz, 1887, was credited for its discovery, but it was first explained in 1905 by Albert Einstein, who was awarded the Nobel Prize for it in 1921 (Radosavljevic et al. 2004).

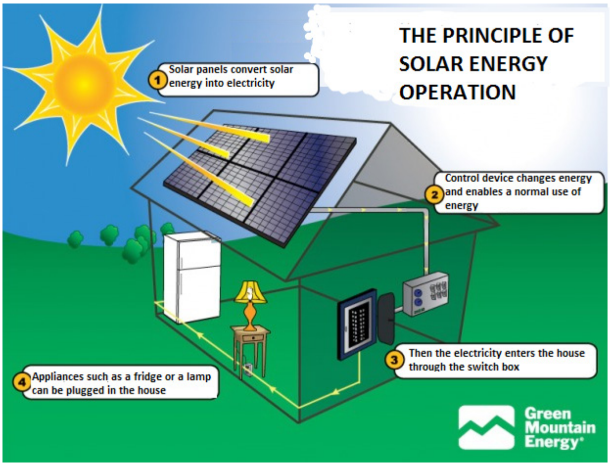

Fig. 3. Conversion of solar energy into electricity

The operation of the solar collector is designed for open space during all weather conditions. Solar collectors do not often break down because they do not have rotating parts, but it is necessary to maintain them at a specific period of time in order to prolong the exploitation and efficiency of the entire system (Ilic and Stanojevic, 2018).

The basic procedures for preventive maintenance of collectors are:
- basic maintenance performed by the manager,
- preventive examinations over a fixed period of time,
- technical diagnostics,
- identifying and removing weaknesses,
- preventive replacement of parts,
- preventive repairs over a period of time,
- repair and renewal of collector parts and others

2.2 Energy potential of solar energy in the Republic of Serbia

In our country, the number of hours of solar radiation is between 1,500 and 2,200 hours per year. It has an average of 1.1 kWh / m2 a day in the northern part, up to 1.7 kWh / m2 a day in the southern part, during January, while in July it is from 5.9 to 6, 6 kWh / m2 a day. Radiation energy has an average value of 1,200 kWh / m2 a year in the area of northwest Serbia, up to 1,550 kWh / m2 a year in the area of southeast Serbia, whereas in the central part of the country it is about 1,400 kWh / m2 a year (Ilić, Stanojević 2018: 572- 578). There is a significantly greater number of hours of solar radiation in Serbia compared to many countries in Europe, the best conditions being in the area of southeast Serbia (Jovanovic 2009: 72-75).

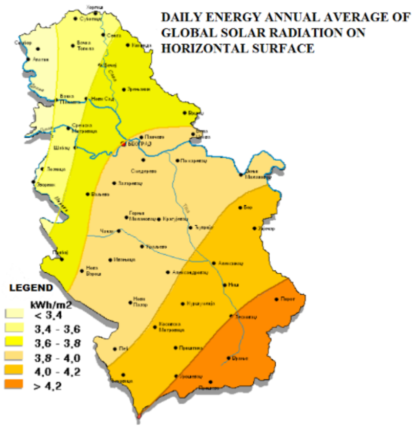

Fig. 4. Daily energy annual average of global solar radiation on horizontal surface (kWh / m2) in the territory of Serbia

When compared with other European countries, it was concluded that Serbia is very rich in solar energy**.** For instance, in Germany there is an average of only 1050 kWh / m2 of solar energy a year, which is 38% less than in Serbia. The European countries such as Greece, Italy and Spain that are rich in solar energy and annually have more than 1600 kWh / m2 are located in southern Europe, (Ilic, Stanojevic 2018: 572-578).

It is the reason why numerous solar collectors have been installed in these countries to prepare hot water. Such devices pay off in five to nine years, when considering tourist places in southern Europe, where hot water consumption (around 40 ° C) is high during the summer months (more than 60 liters per capita per day). Even in Germany, with 1050 kWh / m2 a year, there are numerous companies producing solar collectors and PV modules. Moreover, the Germans have shown that modern collectors can generate from 500 to 600kWh / m2 of thermal energy a year. even at their latitude.

In our country, solar energy is used mainly to generate thermal energy (in very rare instances), and in those cases it is quite cost-effective. Therefore, solar collectors have gained some popularity in households and are used to heat water (Ilic, Stanojevic 2018: 572-578). Both the use of solar energy to generate electricity and the photovoltaic module is scarce, although all the conditions are met. For instance, the data obtained from the Ministry of Energy of Serbia say that in our country, the number of sunny days is more than 2000 hours.

3. ECONOMIC AND ENVIRONMENTAL ASPECTS OF USING SOLAR ENERGY FOR GENERATING THERMAL AND ELECTRICAL ENERGY IN THE CITY OF NIS

The application of solar energy implies its conversion into thermal or electrical energy, whereby the thermal energy is obtained by means of a solar collector while the electrical by means of a photovoltaic (solar) cell and through solar radiation focusing. Nis is one of the hottest and sunniest cities in Serbia, so it could take advantage of such a renewable energy resource in an intelligent way and thus make a contribution to generating energy from renewable sources. Figure 4 shows average temperatures in this city on annual basis.

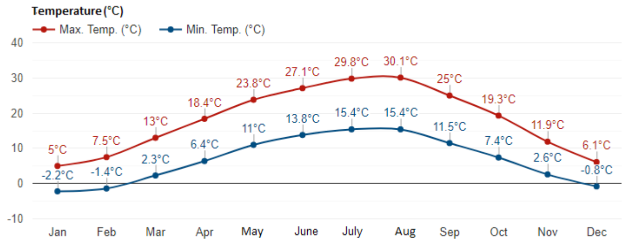

Fig. 5. Average annual temperature - Nis

As Figure 5 shows, the average daily temperature in Nis during the summer period is almost 30 degrees. Daytime temperatures are above zero throughout the year, and only during the winter period, during January and February, do these temperatures drop below zero.

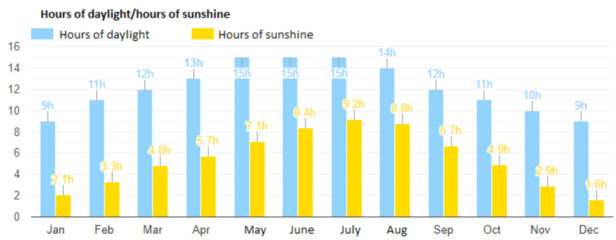

Fig. 6. Average hours of daylight / Average hours of sunshine - Nis

Figure 6 shows the average hours of daylight and sunshine in Nis. The average daylight does not go below 9 hours, and the number of hours of sunshine is the lowest during the winter, which is quite logical. However, from April to October, the number of hours of sunshine is not fewer than 10 hours during the day (Djukanovic 2010: 33).

According to the data regarding average temperature and average hours of both daylight and sunshine during the day, it can be concluded that the average inflow of global solar radiation energy per square meter, on a horizontal surface in the city of Niš in January is between 1.50-1 , 60 kWh/m^2; whereas during July it is from 6.40-6.50 kWh / m2. Throughout the year the daily average inflow of the level of radiation energy on the horizontal surface in the territory of the city of Nis is from 4.00 - 4.20 kWh / m^2, and this annual inflow of energy and orientation towards the south results in 4,600 solar rays on the surface which has a slope of 304.8 kWh/m^2.

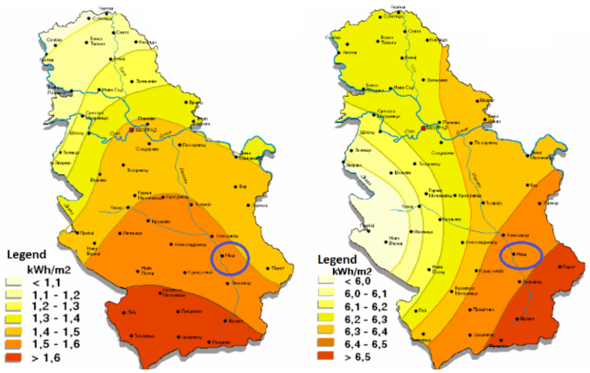

Fig. 7. Average daily energy of global radiation on the horizontal surface in January (left) and in July (picture on the right) (kWh/m^2)

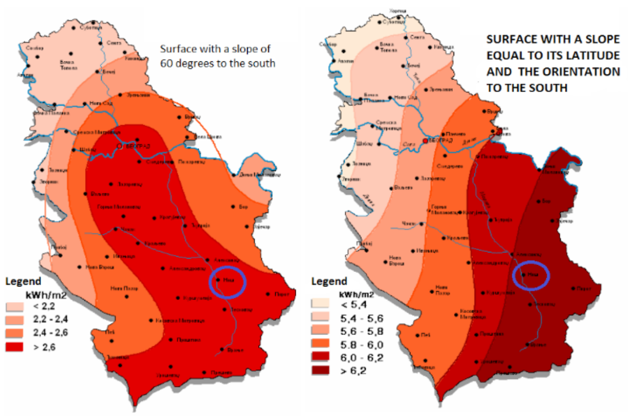

Fig. 8. Average daily global energy radiation to the surface with a slope equal to its latitude and south orientation in January (left) and July (right) (kWh/m^2)

According to the data presented above, it is concluded that there are available solar radiation energy resources in the territory of the city of Nis, which provide the possibility to apply “passive” and “active” solar systems (in accordance with the Study of Energy Potential of Serbia for Utilizing Solar Radiation and Wind Energy).

Solar collectors are used in Nis to heat sanitary water, that is, they are a support for conventional heating in which boilers are used. Unfortunately, solar systems are only applicable to individual residential buildings. Exact data on the number of systems installed in the municipality are not yet available, but photovoltaic systems are being used to generate electricity by means of which public lighting facilities are supplied. However, there is no widespread use of solar panels in Nis, the main reason being the poor economic power of the population, since it is primarily necessary to invest significant amount of money in order to have them installed (Ilić and Stojanović 2018: 572-578).

3.1. Possibilities of using solar energy in industry

Solar technology is expected to grow in the 21st century. An increasing number of architects and contractors are beginning to see the value of passive solar energy and are realizing how they can apply it effectively when designing objects. There is economic competition between solar water heating systems and conventional systems, and due to the possible tax exemptions in some countries, they are becoming even more affordable. Prices of solar panels continue to decline, so they are expected to be installed in larger projects. In Europe, North Africa and the Middle East, concentrated solar energy (CSP) is a commercially available technology that uses direct sunlight, water-heating mirrors and conventional steam turbines.

The MENA region has not taken full advantage of the opportunities to use concentrated solar energy, which could solve major energy problems. The question is not whether it is possible to produce concentrated solar energy, but whether programs such as the MENA Initiative will be operational enough to halt climate change in time, which otherwise could have catastrophic consequences. Such programs are a revolution in the massive use of renewable energy resources, and efforts should be made immediately to devise a plan and secure stable funding of the projects (Kuka 2010: 73).

3.2 Possibilities of using solar energy in homes

Residential facilities use two types of solar thermal energy systems, also called combined systems. They are used only to heat water, thus providing heating. The design of solar thermal energy systems for water heating is such that during the warmer part of the year, they function only to heat the water, and during the colder months, hot water is provided from boilers operating on a different propulsion, such as oil, gas or wood, and during sunny days, the solar thermal energy system remains active (Ilic and Stojanovic 2018: 572-578).

Passive solar energy can play a very important role in reducing electricity consumption in both private and public buildings, because the difference in heat movement is perceived in their architecture, so the buildings themselves begin to collect solar energy, absorb heat and become systems by means of which heat is distributed. Passive solar projects would significantly reduce energy demand in buildings, and in certain situations, if combined with solar photovoltaic panels, resulting in a building with zero energy. A solar thermal energy system for home water heating implies collectors, solar tanks, water heaters, solar stations and hot water consumers, for instance, a shower. Active solar power systems also use additional devices and energy sources to run the fans, pumps, and other equipment needed to collect, store and convert solar energy to heat or electricity. By absorbing solar energy, energy is stored, which can be used later (Lepotic-Kovacevic and Lazarevic 2015: 37).

3.3 Cost-effectiveness of solar energy projects

Solar power plants produce “clean” electricity, and when there is a large roof area in certain buildings, solar power plants are an ideal solution to reduce both electricity consumption and bills. This kind of clean energy reduces the amount of energy that would be paid if it were taken from the electrical grid, thus saving a lot. In Nis, although not in Serbia, there has been no subsidy for several years to transfer electricity from the solar power plant to the grid. But due to the gradual fall in the prices of solar panels, 15- to 150kW- solar power plants have become economically viable, as the investment returns after six years (Mihajlovic 2010: 103).

The expected production of electrical energy of such a solar power plant would be 14800 kWh per year, which, at an adopted purchase price of electricity of 0.23 euros / kWh, would bring an annual profit of 3404 euros.

Solar power plants located in Niš can provide 15-70% of electricity for their own consumption if the facility consumes electricity during the day. Solar power plants are a very cost-effective solution for legal entities and businesses (Jovanovic 2009: 72-75).

There is a great interest in installing panels wherever there is a good place to do so, because there is a significantly greater number of hours of solar radiation in Serbia which is annually between 1,500 and 2,200, depending on the location (Jovanovic 2009: 72-75) than in most European countries,. The southeast part of our country has the best conditions, in which the average value of radiation energy during one year is up to 1,550 kWh/ m^2 (slightly lower in the central part and the lowest in the northwestern part of the country) (Kuka 2010: 110).

Table 1. Expected production of electrical energy in kWh by using a 10kWp solar vertical rotating system for the Nis area

Month	Ed	Em	Hd	Hm
Jan	19,80	610	3,23	77,4
Feb	25,60	699	4,41	92,3
Mar	39,10	1240	5,51	156
Apr	44,60	1400	5,98	177
May	51,70	1565	7,22	221
June	52,60	1740	8,31	240
July	63,40	1800	9,21	255
Aug	52,30	1770	6,54	251
Sep	41,90	1510	6,32	205
Oct	37,20	1151	4,66	157
Nov	21,40	690	2,15	94,8
Dec	14,20	540	2,20	69,7
Average	38,65	1226,25	5,49	166,35
Annually	14800kWh		1960	

Ed - Average daily electrical energy production (kWh)

Em - Average monthly electrical energy production (kWh)

Hd - Average daily amount of radiation per square meter received by panels (k \ Vh / m2)

Hm - Average monthly amount of radiation per square meter received by panels (kWh / m2)

In the city of Nis, it is worth investing in solar power plants, because these facilities have extremely low maintenance costs, there is no need for additional employee engagement, and the state can contract feed-in tariffs for a period of 12 years (Jovanovic 2009: 72-75). Investments in solar energy are promising, stable over the long-term period and can certainly generate revenue. However, it depends on the state how developed this area will be, that is, whether it will give new investors the status of privileged producers in the future (Ilic and Stojanovic 2018: 572-578).

3.4 Advantages and limitations

The main advantages are that it is a clean technology for generating electricity, modules can be installed in locations of poor utility value, such as poor soil, sloping terrain, sites where slag or other waste is deposited, wetlands which first need to be restored and then turned into a usable area and so on. Installation is relatively quick and easy at a minimal cost for the construction of special facilities (Ilić and Stojanović 2018: 572-578).

Everything is all ready, there are even special containers that house larger inverters or control rooms. Maintenance is very easy, they just need washing and, provided the systems are installed on the ground, grass needs mowing between the rows of solar panels when necessary. There are no mechanical parts for fixed systems, so the cost of depreciation and maintenance is minimal. No noise is produced and there is no pollution of the environment during exploitation, regardless of whether they are single crystalline, polycrystalline or amorphous panels. The same is true of inverters (Kuka, 2010: 142).

As far as the limitations are concerned, there are natural and technical ones, that is to say, one of the limitations is that solar fields do not produce electricity at night as there is no sun. Likewise, power plants do not always produce nominal power, the power is actually slightly lower since the nominal power is declared for the laboratory conditions. In addition, the longer the power plant runs the more the efficiency of solar cells declines.

The efficiency of a solar power plant in Nis depends on the following; topography of the terrain, the slope of the terrain, the shadows of the surrounding hills, trees and other objects, the climatic conditions in a particular site (related to the number of sunny days, the intensity of the sun and the temperature fluctuations during the year), as well as on the latitude of the site, but to a lesser extent on its altitude. When looking for a place for some larger solar fields, it is necessary to consider the parameters above, because with them it is precisely determined not only how many kWh will be produced during one year, but also the time when the money will be returned. The goal is that the investor reaches break-even point as soon as possible and begins to profit from the plant.

Similarly, it also depends on the nearby distribution grid, or the capacity of the transmission grid. The information whether a nearby power substation, if there are any, can receive and distribute the planned energy is very important for both small and large projects. Otherwise, the investor has to build all the missing facilities, which puts an additional burden on the investment.

In the city of Nis, there are no accurate data on the installed flat solar collectors, but there are a number of visible examples that are installed on the roofs of private, individual houses. There is an increased need for hot water at the Clinical Center in Nis, student dormitories, and at Nis Gerentology Center. Each of these facilities could represent a future location in the implementation of such systems (Jovanovic 2009: 72-75).

3.5 Environmental Impact

Solar energy systems (photovoltaics, solar thermal, solar sources) provide significant environmental benefits compared to conventional energy sources and thus contribute to the sustainable development of human activities. However, sometimes their wide scale must face potential negative environmental impacts. These potential problems appear to be a strong obstacle to the further dissemination of these systems to some consumers (Framework for the Sustainable Development Strategy of the City of Nis).In order to understand the positive and negative impacts of solar energy on the environment, it is important to understand what it means to produce a functional solar panel. Firstly, the raw material (predominantly quartz that is processed into silicone) must be mined, Aluminum, copper, or silver are also key materials that must be mined or obtained from recycled sources, but are largely extracted due to the increased expansion of the PV industry during the last 10 years.

After digging the raw materials, the quartz must be processed into electronic grade silicone. This process involves heating the quartz in a furnace at high temperatures and reacting with various chemicals (Lepotic-Kovacevic and Lazarevic 2015).

Solar panel production requires more energy to produce than other forms of energy production. This is due to the production process required to convert the raw minerals into photovoltaic armchairs. Quartz must be processed, cleaned and then produced with other components (aluminum, copper, etc.) that may originate from different facilities to produce one solar module, while coal is mined, cleaned and burned on a mass scale, usually in one location.

A very high temperature is necessary to heat quartz during the processing phase. Production demands combining multiple materials with incredible precision to produce high efficiency panels. All this requires a lot of energy (Tomovic 2002: 89).

Although recycling solar panels has not yet become a major issue, solar panels will need to be replaced in the forthcoming decades. However, technology is still keeping pace with demand. The recycling car industry has not started because the automobile industry hasn't started it yet. The same can be attributed to other recycling industries, such as bottle storage, biofuels and electronics.

4. CONCLUSION

In 2018 solar 'took a bit of a break' from the enormous growth rates seen in previous years. Although the solar market grew modestly by only 4%, it was enough to outperform any other energy generation technology. There were more solar panels deployed than all the fossil and nuclear fuels combined. Solar also increased its capacity more than all renewable energy altogether - including large hydro energy and it had twice as much the installed power as the wind energy. Relatively speaking, the share of solar energy reached 36% of all newly increased energy capacity in 2018 compared to 38% a year earlier.

While impressive at first glance, the "stagnation" in both solar and wind energy in 2018 meant that renewable capacity only contributed 63% to the total power increase. When looking at the share of total installed capacity for electricity generation, in 2018 renewable sources of energy contributed 33% and 26% in terms of electricity generation. All solar power plants together produced only 2.2% of the world's electricity. This shows that, despite the

Sun's recent dominant role in annual power generation additions, there is a huge untapped potential for both solar energy and its renewable sources.

Regarding the city of Nis, it is noticeable that the citizens realized the need for the greatest possible saving in electricity. On its territory flat solar collectors are, due to their cost-effectiveness, but also their lower cost of installation, the most frequently installed, mainly on family homes. Finally, public institutions may be urged to start installing solar panels to properly harness the potential of solar energy.

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