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THE VALIDITY FOR THE APPLICATION OF SOLAR ENERGY IN IRRIGATION OF PERENNIAL PLANTS IN FRUIT GROWING IN THE REPUBLIC OF SERBIA

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Abstract:
Constant increase in the number of people in the world today imposes the need for constant increase in food yield on the one side and energy on the other. The presented survey compiles two technological processes that use solar energy for their functioning. These are solar panels that produce electricity and agricultural production (seen through the irrigation process) which develops herbal mass (weight) by the means of photosynthesis.
The aim of the research was to investigate the validity of applying solar energy in irrigation of perennial plants in fruit growing in the Republic of Serbia. This paper will explore the energy obtained from solar panels for irrigation purposes for the period (April-October) in which the requirements of plants for water are the highest. The justification for the application of solar energy in irrigation of perennial plants is compared, with the prices of diesel fuel and electricity from the network.

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Solar panel, energy, irrigation, sun, agriculture

1. INTRODUCTION

In the Republic of Serbia today about 40% of land is arable, while the region of Vojvodina in which area is the location that is the subject of the research in this paper has 1.78 million hectares of fertile arable land, of which only 28% is irrigated [1]. Also, due to varying amounts of precipitation per year, the yield of agricultural crops varies from year to year at a very high level. Deficit of the rainfall in the last 20 years is expressed, which caused yields reducing up to 100% compared to the optimal amount of rainfall or irrigation [2]. The given issue is an enormous research task, which consists of increasing the surface area that would be irrigated, and that the energy that drives these systems is renewable. Irrigation in the fruit growing is a very important measure, particularly in the areas where rainfall does not exceed 600 mm of precipitation. The needs for water are greater on sandy, windy and southern positions than on structural soils of northern exposure [3]. In Serbia, the apricot is planted on a total of 5,290 ha, with an average production of 23,504 t/ha in the last four years which places Serbia to the sixth position in Europe [4].

The European Commission has proposed a five-point action plan for European energy security and solidarity through [5]: construction of infrastructure and the diversification of energy supplies, international energy relations, creation of oil and gas reserves and the mechanisms of response to emergencies, energy efficiency and best use of domestic resources within the EU.

Solar energy is identical to agricultural production, primarily because geographical position is the most important criterion, then the length of the solar light, the intensity and the angle of the sun's rays, etc [6]. An accurate knowledge of solar radiation distribution at particular

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geographical locations is of vital importance for surveys in agronomy, hydrology and ecology, for applications such as photovoltaic cells and solar thermal systems [7]. Number of sunny hours in Vojvodina is a bit lower than 2,000 hours (west part) up to 2,100 hours (east part). According to Valentin software Energie Software -TSol Pro 4.5, an average value for global radiation per year for horizontal surface is between 1,294 kWh/m^2, in the north of Vojvodina and 1,335 kWh/m^2 in the south of Vojvodina, and 1,281 kWh/m^2 in the west up to 1,294 kWh/m^2 in the east of Vojvodina. This shows that the average value of solar radiation for horizontal surface-for territory of AR Vojvodina is about 1,300 kWh/m^2 [8-10].

The most attractive way of using solar panels in agriculture is surely to drive pumps for irrigation of crops [11]. Instead of expensive fossil fuels a solar pump uses clean and inexhaustible energy of the Sun. When the irrigation is needed most there is the most sunny hours, in the summer months [12]. Besides irrigation, this energy can be used for fan operation in air conditioning of livestock buildings, the performance of machine milking on pastures, to drive the kiln, operation of electric fences, etc.

Solar Energy that could, in principle, fulfill the world's energy requirements with clean procedures and low prices [13]. Solar energy is one of the few renewable energy sources, which does not have a limited use in agricultural production [14]. Its use is not limited/related? to the size of the estate, the configuration of the terrain and the branch of agricultural production. Unlike biodiesel biomass, it is in the true sense renewable, because the only thing it requires is a sunny day. Solar photovoltaic plant have found their application in every branch of agriculture, cattle-breeding, vegetables growing, viticulture, farming, to veterinary medicine, agricultural techniques and melioration.

2. SOLAR ENERGY IN THE REPUBLIC OF SERBIA

According to the National Action Plan for the use of Renewable Energy (according to Directive 2009/28/EC), The Republic of Serbia has committed to reduce the level of greenhouse gas emissions by 20% and increase the share of energy from renewable sources by 20% by 2020 [15]. Fig.1 gives a share of each source of energy production in Serbia in 2013. Also, Fig. shows that thermal electricity participates in the amount of 71.16%, 28.59% hydro, and renewable energy from privileged producers account for only 0.25%.

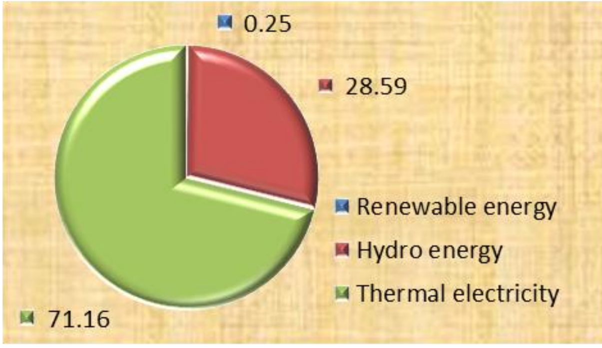

Fig. 1. The share of each source of energy production in Serbia in 2013 [16]

According to the Ministry of Mining and Energy resp. Department for renewable energy Register of Privileged Producers of renewable energy sources in the Republic of Serbia is made, so that now as of 28/11/2014. 33.4 MW of energy is produced from small hydropower plants, 10 MW from solar power plants, 36 MW of energy from wind power plants, 4.9 MW power plant on biogas and 9 MW of energy and high-efficiency cogeneration. The share of each source of renewable energy in the privileged producers and energy production in Serbia are shown in Table 1.

Table 1. Total installed capacity and number of facilities built by privileged producers of energy in the energy production in Serbia in 2014 [17]

Privileged Producers of Energy	Number of Built Premises	Power Installed (kW)
Hydro power plants	45	33,415.7
Solar Plants total:	152	10,000.2
- Solar Plants on the Ground	15	6,000
- Solar Plants on the building up to 30kW	120	2,000.2
- Solar Plants on the building from 30kW to 500kW	17	2,000
Wind Plants	7	35,950
Biogas Plants	5	4,862
High-efficiency cogenerations	5	9,007

The total installed capacity and number of facilities built by privileged producers of energy in the energy production in Serbia in year 2014 [17].

Before considering cost-effectiveness of solar installations, it should be noted that the total amount of global solar radiation in the areas of the Republic of Serbia ranges from 1,300 to 1,600 kWh/m^2 per annum [18,19] which is 40% more than the average which applies to countries of the European Union [20]. Technically exploitable potential of renewable energy sources in Serbia is about 4.3 ten (millions of tonnes of oil equivalent) per year, out of which 14% or 0.6 ten goes to solar energy [21].

3. MATERIALS AND METHODS

The aim of the research was to investigate the validity of applying solar energy in irrigation of perennial plants in fruit growing in the Republic of Serbia. The paper the energy obtained from solar panels for irrigation purposes for the period in which the water requirements of plants are the highest (April-October). The validity of application of solar energy in irrigation of perennial plants in fruit growing (apricot) is compared with the prices of diesel fuel and electric energy from the Network.

The mentioned solar plant would be used to irrigate plots under 6 hectares of apricots. It is specific that apricot needs 260 mm of precipitation, which can be performed in several occasions, but in larger amounts. Water would be drawn from the channel by the solar pump and distributed further into the system in which the irrigation would be performed in drop by drop system or sub-irrigation. The above experiment was conducted in the wider locality of Novi Sad, (location Irmovo: 45° 20' 13'' North, 19° 42' 34'' East, Elevation 79 m a.s.l.).

The energy produced from solar panels would be used to drive pumps in irrigation of perennial plants in fruit growing. The tested solar panel has the mono-crystalline silicon cells. The basic characteristics of the solar panel were:

- efficiency coefficient of 16%,
- panel surface 7m^2, or 0.50m^2 per module,
- angle of inclination of the panel 45°.

For this particular location in Novi Sad (Irmovo), after defining the average duration of solar radiation per month and the average duration of solar radiation during the day by months:

- the total amount of solar energy with 1m^2 surface of the panel which may be obtained for irrigation in the period April-October,
- dependence of a lifetime of the solar panels and the generated electric power in solar plant for irrigation,
- dependence of the usage period of solar panels and energy obtained in equivalent amounts of diesel fuel,
- dependence between the surface of the solar panel (m^2) and the generated electric energy (kWh) were explored.

The cost-effectiveness of investment in solar plant depends on the work life of solar modules. If we observe in theory, the solar modules have unlimited service life, but , in practice, usability depends on the weather conditions (hail, storms) and maintenance. For mathematical calculations of application validity of solar energy in this research, the average lifespan of the panel of 20 years is taken into account.

4. RESULTS AND DISCUSSION

The total temperature, resp. Solar radiation directly correlates with the amount of water needed for irrigation of agricultural crops. So, the higher the temperature is, the higher are plant water requirements (transpiration coefficient is higher) and the amount of energy obtained by the solar panels, on the other side the lower the temperature the lesser are needs to water the plants and the obtained amount of solar panels energy is lower. The total water loss on transpiration at an average solar radiation is up to 75%. Insolation duration in the area of Novi Sad by months is given in Fig. 2 and totalled for the year 2012 to 2,462 hours, and for the period April-October 1,912 h, that is on average by months 205 h ie. for the period from April to October 273 h. From Fig. 2, it can be concluded that the duration of summer insolation is significantly higher than in the winter months. Therefore, the energy obtained from the Sun is larger and more justified is the use of solar energy in the summer months.

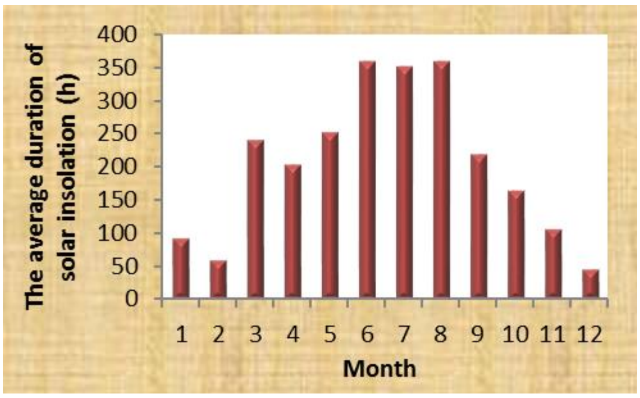

Fig. 2. The average duration of solar insolation per month for the city of Novi Sad [22]

The average duration of solar radiation during the day, by months in Novi Sad is shown in Fig.3. The average length of solar radiation in the year 2012 was 6.71 h/day.

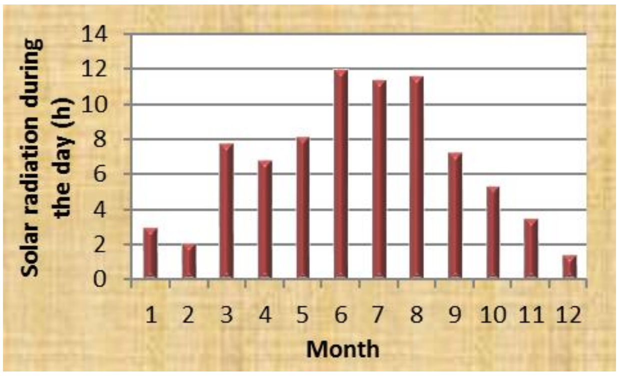

Fig. 3. Average length of solar radiation during the day by months, for the city of Novi Sad in 2012

The total amount of solar energy that falls on the panel surface of 1m^2 leaning 45° to the south for the city of Novi Sad is 5,225.90 MJ/m^2, or 1,451.64 kWh/m^2. Since irrigation period lasts from April to October, we obtain a theoretical amount of energy per 1m^2 which is 3,856.14 MJ/m^2 or 1,071.15 kWh/m^2. This value is equivalent to the energy required for burning 89.68 kg diesel fuel, (H_d=43.00 MJ/kg). Fig.4 gives the average daily amount of solar energy by months for the city of Novi Sad (Irmovo), for the panel facing south to 45°. The presented average daily amount of solar energy on Fig.4 was obtained using a software program (PVgis - Photovoltaic and thermal software) [24].

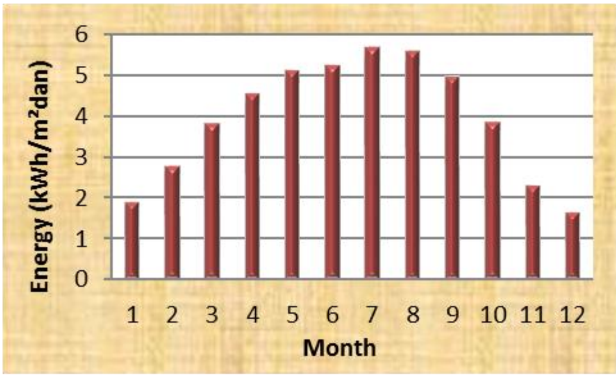

Fig. 4. Average daily amount of solar energy received from 1m^2 of panel at an angle of 45° in Novi Sad (Irmovo)

For the tested mono-crystal silicon solar panel which has a maximum efficiency coefficient of 16%, the total amount of the obtained energy was: 616.98 MJ/m^2 or 171.38 kW/m^2. This energy is equivalent to an amount of 14.35 kg of diesel fuel which could be saved from 1m^2 panel. For twenty-year operating life of the plant and the total area of 7 m^2, one can get energy from 86,375.52 MJ or 23,993.20 kWh – Fig. 5a. That is the equivalent amount of energy obtained from the combustion of 2,008.73 kg of diesel fuel.

Oil prices have to be above US$ 100 per barrel for alternative sources of energy to be profitable [23]. Assuming 1 kWh from the network costs € 0.054, while a liter of diesel fuel is € 1.2, the result is that the price of 23,993.20 kWh of energy is € 1,295.63, while the price of 2,008.73 kg ≈ 2,377.20 l (Fig.5b) diesel fuel is € 2,852.62. If you consider that the price of photovoltaic equipment in Serbia is ~ €2.8/W (without the price of irrigation equipment), we get that the total funds invested in its construction amount to € 3,136. Economically, the plant would be profitable if its price was lower than the prices of other energy sources (electricity and diesel fuel). Based on the presented results and obtained energy for 20 years (for the period from April to October), it can be concluded that the price of electricity from network is 2.42 times cheaper than solar photovoltaic installations, resp. 1.1 times cheaper than diesel fuel. Given that the paper analyzed only the period of operation of photovoltaic installations for the irrigation period, which lasts from April to October, it can be concluded that for the rest of the period the remainder of the produced energy should be used for other purposes in agriculture. For these purposes, outside the irrigation period, the produced energy could be used in the fan drive while air conditioning livestock buildings, to perform machine milking on pastures, to drive kilns, electric fences operation, etc.

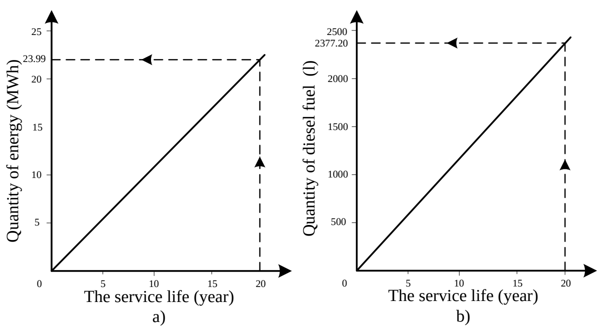

Fig. 5. a) Dependence of the service life and the obtained electricity in solar plants for irrigation; b) Dependence of the service life of solar panels and energy that can be obtained in equivalent amounts of diesel fuel

The interdependence between the service life (year) and the generated electric energy (MWh), which lasts from April to October is given in Fig. 6. For a period of 50 years, the studied solar plant could provide 59.98 MWh for irrigation of perennial plants in growing fruit.

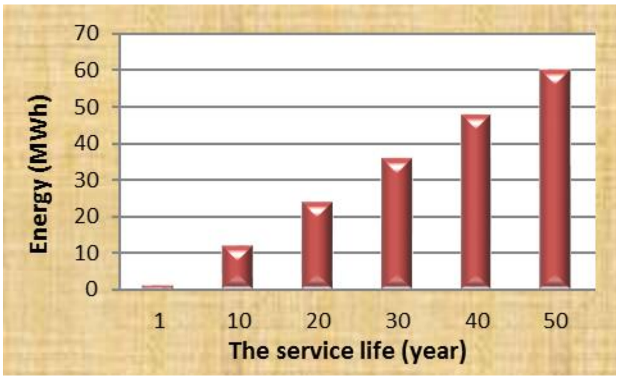

Fig. 6. Dependence between the service life (year) and the generated electricity (MWh)

5. CONCLUSION

Of all renewable energy sources in agriculture (solar energy, biomass, plants for processing harmless hazardous waste etc.), solar energy has the greatest potential because of the minimal infrastructure necessity. Problems for broader use of renewable energy sources are of economical nature, continuity in supply and informing farmers. Solar energy is the most effective renewable energy source that can be applied in agricultural production, both in terms of availability and the aspect of terrain configuration. In order to make the investment in solar plant profitable, the price of the equipment used should be considerably lower than the cost of other conventional fuels. This means that the solar plant should return the invested money in the shortest possible time, and the energy obtained until the end of service life of the device was free. However, due to the low electricity prices in the Republic of Serbia, which is a social category and does not conform to the prices in the European Union and generally in the world, the solar energy used only for irrigation of perennial plants is not yet payable. Validity would increase if after irrigation period it could be used for other purposes in agriculture. But after further harmonization of electricity prices in the coming period in the Republic of Serbia, with the prices in the European Union, the validity of the application of these installations in agricultural production (irrigation) is very certain.

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