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REVIEW OF THE PRODUCTION OF ELECTRICITY FROM PHOTOVOLTAICS IN THE REPUBLIC OF MACEDONIA

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Abstract: Global trends in the energy sector are focused towards extensive inclusion of renewable sources in the energy production. Solar energy has proven to be a valuable candidate, especially for direct conversion into electricity. Its wider use has, so far, among other, been constrained by the technological limitations, resulting in higher production costs compared to those from conventional non-renewable sources, primarily coal. In that sense, the efforts of the scientific community have for long been directed towards development of both efficient and inexpensive solutions. However, the major boost in the electricity production from photovoltaics (PV) came from the legislative measures, primarily the introduction of feed-in tariffs. Following the global trends, a significant increase in PV inclusion in the electricity production was made in the Republic of Macedonia. In the article we give a brief review of the achieved progress.

Keywords: solar energy, photovoltaic power plants, electricity production.

1. INTRODUCTION

The last two decades were marked both by an increased energy demand and an emphasized awareness of possible consequences that may arise from the extensive use of non-renewable fuels. It is nowadays a common knowledge that high emissions of greenhouse gases (especially water vapor and carbon dioxide), as a result of exploitation of fossil fuels in the energy production, adversely affect the global climate and may cause long-term consequences for the environment. Another major concern is that the extensive harvesting of non-renewable fuels will soon make their exploration extremely expensive and may eventually lead to the exhaustion of natural reserves. This would result in severe energy crises and a rapid increase in energy prices.

These facts affected the leading global factors in the fields of energy, economy and legislation, to call upon a global increase in the production of energy from renewable sources. Hydro, solar, wind energy and energy from bio-mass are considered natural candidates to replace fossil fuels in the near future. However, this is not an easy task. In [1], Smil defines five factors that will adversely affect a transition from fossil fuels to renewable sources. Some of these factors may be partially overcome with the expected advances in the technology; others are uncontrollable. Nevertheless, the global trends are directed towards a steady growth in the production of energy from renewable sources and reduction of energy production from fossil fuels (therefore reduction in the emission of greenhouse gases), in combination with the introduction of measures for rational and efficient energy spending. These are the three goals that the EU agenda 20-20-20 is based upon [2].

Solar radiation is by far the most powerful source of energy today. The global flux exceeds the total fossil energy demands in the year 2000 by 1000 times [1, p.23]. There are two important factors that have so far prevented significant replacement of the energy from fossil fuels with the energy from solar cells, especially concerning the production of electricity: technological limitations, primarily the efficiency factor of photovoltaics, and the cost of solar technologies. The first is being constantly addressed by the scientific community. According to the National Renewable Energy Laboratory, modern multi-junction cells have already passed the 30% efficiency line, with the most sophisticated three-junction cells (with concentrator, 948x) reaching efficiency of 44% [3]. Recently, Fraunhoffer Institute for Solar Energy, Soitec and CEA Leti have issued a joint press-release announcing that they produced a

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four-junction cell (with concentrator, 298x) that has an efficiency of 44.7% [4]. Certain analyses suggest that by implementing recent discoveries in non-imaging optics in the production of concentrators, the 50% efficiency line will soon be crossed [5].

The improvements in the technology resulted in the reduction of prices of conventional photovoltaics. The price of electricity produced from commercially most used photovoltaics (single-crystallized and multi-crystallized silicon cells, CdTe etc., with conversion efficiency of 5-18%) have dropped from 3.5 €/Wp in 2008 to 1 €/Wp in 2012 [6, p.204, Table 2]. Further price reduction is expected.

The most productive step forward in promotion of solar cell electricity, as well as electricity production from other renewable sources, was made by global introduction of feed-in tariffs. The main goal of this mechanism was to guarantee the return of the initial investment, made by the purchase of the technology, within a reasonable timeframe. Although implementation practices vary from country to country, the general mechanism addresses three major issues: producers receive guaranties that they will be able to access the power grid and that the total electricity production will be purchased; feed-in tariffs are different for different renewable sources, following the specific production costs; long term (usually 15-25 years) contracts [7,40].

The effect of this measure, accompanied by the technology development and reduction of PV prices, had a boosting effect on the production of electricity from solar units worldwide. According to the report prepared by the European Photovoltaic Industry Association (EPIA) [8], the installed capacity of PV units has risen from 1.4 GW in the year 2000, to 102.156 GW in 2012 [8, p.13, Fig.2]. According to the same report, this number is expected to increase to 288.22 GW by 2017 in the business-as-usual (non-policy stimulated) and up to 422.8 GW in the policy driven scenario [8, p.35, Fig.22]. Similar predictions may be found in the IEA Medium-Term Renewable Energy Market Report 2013 [9, p10, Tab.1] - 268 GW by 2017.

In this paper we provide a review of electricity production from photovoltaic units in the Republic of Macedonia. We analyze the trends in the sector, especially in the last three years, in the context of measures taken to stimulate energy production from renewable sources.

The paper is organized as follows: in the next chapter we give a review of the structure of the electricity power system in the Republic of Macedonia; then based on the data from relevant institutions in the country, we present the actual situation with the production of electricity from photovoltaic power plants. Finally, we summarize the strategic directions of the Republic of Macedonia with regards to the issue, according to the Strategy for utilization of the Renewable Energy Sources in the Republic of Macedonia by 2020 [10].

2. STRUCTURE OF THE ELECTRICITY POWER SYSTEM IN THE REPUBLIC OF MACEDONIA

In this section, we give a brief overview of the structure of the electricity power system in the Republic of Macedonia, with an emphasis on the production. The presented information was collected from the website of the Energy Regulatory Commission of the Republic of Macedonia (ERC) [11] (especially the 2012 Annual Report [12]), Companies websites of AD ELEM [13], AD MEPSO [14], AD EVN [15] and from the Strategy for Energy Development in the Republic of Macedonia until 2030 [16]. For more information we refer the readers to consult these sources.

The electricity power system in the Republic of Macedonia is based on three major pillars:

- AD ELEM (Macedonian Power Plants) is the major producer of electricity in the country. According to the 2012 ERC Annual Report [12], AD ELEM produced 92.5% of electricity in the RM (5,370,050,371 kWh out of 5,806,626,016 kWh), thus meeting the total domestic needs (8,548,112,613 kWh) by 62.8%. The core production capacity of the company consists of two thermal power plants with installed capacity of 816 MW [17] running on lignite and eight hydro power plants with installed capacity of 538.4 MW (502 MW according to AD ELEM Annual report for 2011 [17] plus the installed capacity of HPP „Sv. Petka“, officially functional from August 1st, 2012 [18]). AD ELEM also operates one combined power plant (electricity, technological steam and hot heating water) "ELEM Energetika", with installed capacity (with regard to electricity production) of 30 MW [12] (generator capacity 75 MW [19]).
- AD MEPSO (Electricity Transmission System Operator of Macedonia) owns and operates a high-voltage transmission network in the Republic of Macedonia. It controls and regulates the electrical energy flow between the producers on one side and the distribution network (EVN) and the major consumers on the other side, as well as the export and the import of electric power in the country. AD MEPSO is fully state-owned [14].

• EVN Macedonia, a part of EVN Group, operates the distribution network in the Republic of Macedonia. EVN Macedonia also operates 11 small hydro power plants, with total installed capacity of 47MW [20].

Other participants in the electric power system of the Republic of Macedonia are:

• AD TEC Negotino is a state-owned company that operates the thermal power plant "TPP Negotino" with installed capacity of 210 MW [12,16]. TPP Negotino uses heavy oil as fuel and is not an active producer of electricity, i.e. is used only as a system back-up.

• AD TE-TO is a private company that operates a combined power plant which produces both heat and electricity. The power plant uses natural gas as fuel. The installed capacity of the electrical unit is 227 MW [12].

• AD KOGEL is a private company operating a combined power plant that produces both heat and electricity. The power plant uses natural gas as fuel. The installed capacity of the power facility is 30 MW [10,12].

• Small hydro power plants-owned mainly by private companies or established as a joint private-public initiative.

• Photovoltaic power plants owned by private companies.

3. CURRENT SITUATION WITH THE PHOTOVOLTAIC POWER PLANTS IN THE REPUBLIC OF MACEDONIA

The Republic of Macedonia has several comparative advantages in respect to most European and neighboring countries, concerning the possibilities for production of electricity from solar cells. Due to its geographical location, the number of sunny days per year is around 280. The annual operational number of working hours for photovoltaic power plants, used in strategic planning, is 1400 h [10]. According to several sources, the average annual solar insulation amounts to 1385 kWh/m^2. It peaks in the country's south-west with 1530 kWh/m^2, and dwells in the northern regions with 1250 kWh/m^2 [10, 21, 22]. Configuration of the terrain might be considered as an adverse factor: the Republic of Macedonia is predominantly mountainous, with mountains covering around two thirds of the territory [23].

In this Section we give a brief review of the electricity production from photovoltaic power plants in the Republic of Macedonia. Only the companies that were granted feed-in tariffs have been considered in the analysis. The information about the companies was collected from the Registry of producers of energy from renewable sources [24], and the documents on the Renewable Energy/Privileged Producers page [25] on the ERC website, as well as the documents published in the Official Gazette of the Republic of Macedonia [26]. For more information about the utilization of renewable energy sources in the Republic of Macedonia, we refer the readers to the "Strategy for utilization of Renewable Energy Sources in the Republic of Macedonia by 2020" [10], as well as the paper of Mijakovski and Mijakovski [21].

According to the data from the ERCs 2012 Annual report [12], a share of the production of electrical energy from photovoltaic power plants, in the period 2010-2012, in the total electricity production was 0.0225%. This is illustrated in Table 1.

Table 1. Share of electricity generated from photovoltaic power plants in the total production of electricity and in the electricity demand in the Republic of Macedonia in 2010, 2011 and 2012. Data obtained and adapted from 2012 Annual Report of ERC [12, p. 26, Tab. II.23].

	2012	2011	2010
Electricity requirements (in kWh) – losses included	8,548,112,613	9,036,647,009	8,327,351,071
Produced total (in kWh)	5,806,626,016	6,287,894,865	6,725,038,417
From photovoltaic units (in kWh)	3,088,640	1,120,656	26,193
Share of PV electricity in the electricity requirements (in %)	0.0361	0.0124	0.0003
Share of PV electricity in the production (in %)	0.0532	0.0178	0.0004

As illustrated in the Table, both the production and the share of electricity produced from photovoltaic units in the total electricity production, during the time period from 2010 to 2012, rose by more than 100 fold. This is a result of the changes that took place in the legislation regulating the energy sphere, first with the "Law on Energy" passed in 2006 [27], and then with the new "Law on Energy" passed in 2011[28].

The laws introduced feed-in tariffs for production of electricity from renewable sources and from highly efficient combined units. The value of feed-in tariff for electricity produced from photovoltaic sources was corrected several times in the period 2008-2012. With the last corrections, the privileged tariff feeds for production of electricity from photovoltaic power plants with installed capacity smaller than 50kW is set to 16 €c/kWh, and for those with installed capacity greater than 50kW – 12 €c/kWh [29]. The restriction on cumulative installed capacity on a national level that would be supported by feed-in tariffs is set to 4 MW for plants under 50kW and 14MW for plants over 50kW [30].

According to the "Registry of Producers of Energy from Renewable Sources" [24], and the documents on the "Renewable Energy/Privileged Producers" page [25] on the ERC web site, as well as the documents published in the Republic of Macedonia Official Gazette [26], twenty-six companies have so far obtained permits to sell electricity from photovoltaic power plants using feed-in tariffs, and are actively included in the electricity power grid of the Republic of Macedonia. The 26 companies operate a total of 30 photovoltaic power plants. The total installed power of these units sums up to 7.08 MW, with planned annual production of around 9,637 MWh per year. The geographical distribution of the plants is illustrated in Fig. 1.

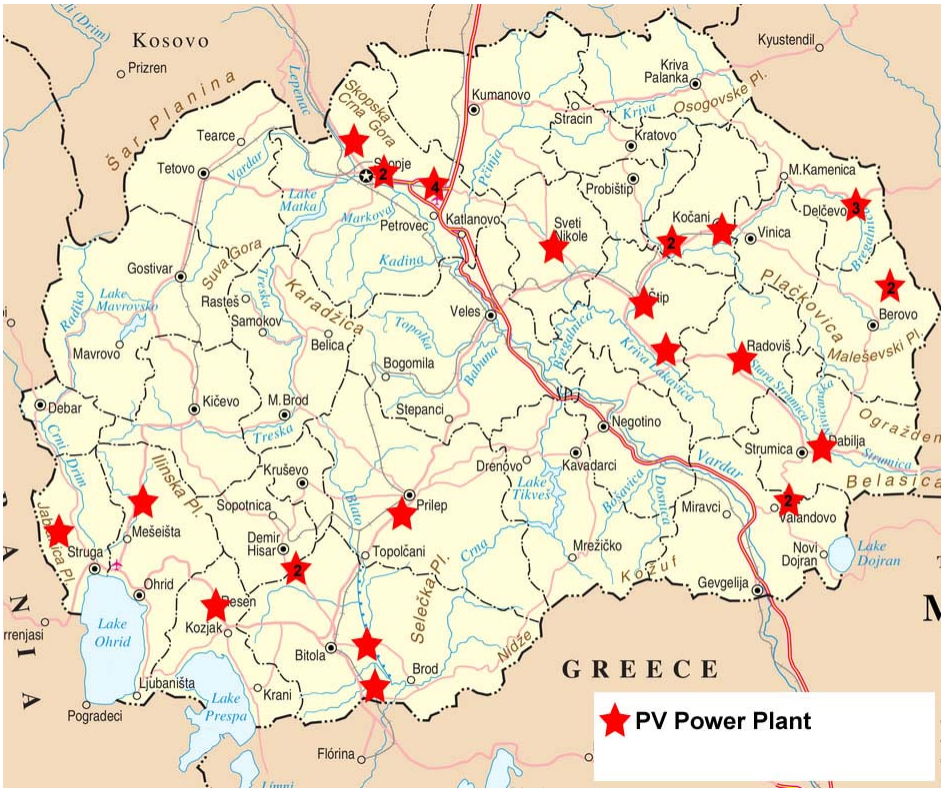

Figure 1. Geographical location of photovoltaic power plants in the Republic of Macedonia. (Derivative work. Map based on [31])

It can be seen in the figure that most of the PV power plants are located either in the east-south east part of the country, on a triangle between Sveti Nikole, Delcevo and Valandovo, or in the south-western- parts, on the line stretching from Bitola on the east to Vevcani on the west. This setting is in full compliance with the findings of a comprehensive JRC study on the potential of the solar energy in Europe and Africa [32,33], with regards to the Republic of Macedonia [34,35]. Most plants are small, with installed capacity in the range 45-55KW, with only five approaching the installed capacity of

1 MW. The detailed analysis of the units in respect to installed power and planned yearly production is presented in Tables 2 and 3:

Table 2. Number of photovoltaic power plants using feed-in tariffs, in respect to installed capacity

Installed capacity (in KW)	<15	40−55	200−500	500−900	>900
Number of power plants	2	18	5	2	3

Table 3. Number of photovoltaic power plants using privileged tariff feeds according to the planned annual production

Planned Annual Pro-	<50	50−100	100−500	500−1000	>1000
Number of power plants	2	16	5	3	4

According to the available data on the origin of the installed equipment at each site (from the issued electricity production licenses [36]), and the information about the equipment from the respective manufacturer's sites, most power plants use multi-crystalline and mono-crystalline silicon solar modules, with the conversion efficiency of 14-15.5%. Two of them use power tracking equipment, which increases the planned production of electricity by 54%, compared to the averaged production of the remaining same-size plants.

4. PROSPECT OF PHOTOVOLTAICS UTILIZATION IN THE REPUBLIC OF MACEDONIA

With the "Strategy for utilization of Renewable Energy Sources in the Republic of Macedonia by 2020" [10], the installed capacity of the photovoltaic systems is expected to reach between 10 and 30 MW by the year 2020. The strategy suggests a number of stimulation efforts that may be additionally undertaken by the legislators in order to support the high-end of the goal. However, as pointed out, the extent of the progress will be in close correlation with the prices of both the energy and the photovoltaic technology in the forthcoming period [10].

Country's economy and political future should be considered as serious factors in any forecast. With GDP per capita of US $4,568 (according to the World Bank [37]), Macedonia, together with the neighboring countries (Serbia, Bulgaria, Albania and Kosovo), is in the lower third of the European ranking. The lack of start-up capital is a serious issue that affects the level of investments in new facilities. Currently, special credit lines for support of renewable energy projects are provided by foreign funds (EBRD, ICL) in cooperation with the Macedonian Bank for Development Promotion and several domestic commercial banks [38,39]. Full membership in the EU, which is the country's strategic goal, will further allow access to both grants and low-interest credits from the European financial institutions, which may be used for start-up. The measures taken by the government for attracting foreign investors, in the last few years, may also result in an increase of PV capacities especially in the industrial development zones.

5. CONCLUSION

In conclusion, the Republic of Macedonia has undertaken serious steps to promote production of electricity from photovoltaic power plants. Initial results are already visible (Table 1). The future of the technology exploitation in the country will however depend on global trends. The development of low-cost/highly efficient photovoltaic power plants would promote higher participation of photovoltaic generated electricity, as will globally.

6. REFERENCES

[1] V. Smil, *21st Century energy: Some sobering thoughts*, OECD Observer, no. 258/259, Dec. 2006, 22−23.

[2] European Commission. *EUROPE 2020: A strategy for smart, sustainable and inclusive growth*. European Commission: Communication from the commission, COM (2010) 2020, 1−32. [Online] Retrieved from:http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf. [Nov. 15th, 2013].

[3] National Renewable Energy Laboratory. „Best Research-Cell efficiency", Internet: http://www.nrel.gov/ncpv/images/efficiency_chart.jpg. [Nov 15th, 2013].

[4] Fraunhoffer Institute for Solar Energy, Soitec and CEA Leti. *World Record Solar Cell with 44.7% Efficiency.* (Press Release, no. 22/13). Freiburg, Germany. Sep. 23rd, 2013. p.1-6. Retrieved from: http://www.ise.fraunhofer.de/en/press-and-media/pdfs-zu-presseinfos-englisch/2013/press-

release-world-record-solar-cell-with-44-7-efficiency.pdf . [Nov. 15th, 2013].

[5] A. Luque, *Will we exceed 50% efficiency in photovoltaics?*, J. Appl. Phys., Vol. 110−3 (2011) 031301/1-19.

[6] T. Pavlovic, D. Milosavljevic, I. Radonjic, L.Pantic, A. Radivojevic, M. Pavlovic, *Possibility of electricity generation using PV solar plants in Serbia*, Renewable and Sustainable Energy Reviews, Vol. 20 (2013) 201−208.

[7] T. D. Couture, K. Cory, C. Kreycik, E. Williams, *A Policymaker's Guide to Feed-in Tariff Policy Design*. National Renewable Energy Laboratory. NREL/TP-6A2-44849. Jul. 2010, p.1−25. [Online] Retrieved from: http://www.nrel.gov/docs/fy10osti/44849.pdf [Nov. 15th, 2013].

[8] European Photovoltaic Industry Association, *Global Market Outlook for Photovoltaics 2013-2017*, European Photovoltaic Industry Association. May 2013. pp. 1−58. [Online]. Retrieved from: http://www.epia.org/fileadmin/user_upload/Publications/GMO_2013_-_Final_PDF.pdf [Nov 15th, 2013].

[9] International Energy Agency (IEA), *IEA Medium-Term Renewable Energy Market Report 2013 - Market Trends and Projections to 2018: Executive Summary*", International Energy Agency (IEA), 2013, p. 1−11. [On line] Retrieved from: http://www.iea.org/Textbase/npsum/MTrenew2013SUM.pdf. [Nov 13th, 2013].

[10] Government of the Republic of Macedonia, Ministry of Economy, *Strategy for utilization of the Renewable Energy Sources in the Republic of Macedonia by 2020*, 2010. Available at: http://uncsd2012.org/content/documents/677Strategy_for_utilization_RES_Macedonia.pdf

[11] Energy Regulatory Commission of the Republic of Macedonia. Commission website. Internet: http://erc.org.mk/default_en.aspx. 2013. [Nov. 7-12, 2013]

[12] Energy Regulatory Commission of the Republic of Macedonia, "Годишен извештај 2012 (2012 Annual Report)", Energy Regulatory Commission of the Republic of Macedonia, March 2013, p.1−130. [Online] Retrieved from:

http://erc.org.mk/odluki/Godisen%20izvestaj%20za%20rabota%20na%20Regulatornata%20komisija%20za%20energetika%20na%20RM%20za%202012%20godina.pdf. [Nov. 7-15, 2013]. (In Macedonian)

[13] AD ELEM. Company web site. Internet: http://elem.com.mk/index.php?lang=en. 2013. [Nov. 07th, 2013].

[14] AD MEPSO. Company web site. Internet: http://www.mepso.com.mk/en-us/Default.aspx. 2013. [Nov. 07th, 2013].

[15] AD EVN. Company website. Internet: http://www.evn.mk/default.aspx?lang=en-US. 2013. [Nov. 07th, 2013].

[16] Government of the Republic of Macedonia, Ministry of Economy, *Strategy for Energy Development in the Republic of Macedonia until 2030*, 2010. [Online] Retrieved from: http://www.ea.gov.mk/projects/unece/docs/legislation/Macedonian_Energy_Strategy_until_2030_adopted.pdf [Nov. 07th, 2013].

[17] AD ELEM, *ELEM Annual Report for 2011*, Online multimedia presentation. Internet: http://www.elem.com.mk/2011/start.html. [Nov. 07th, 2013].

[18] AD ELEM, *HPP Sveta Petka*, Internet: http://www.elem.com.mk/index.php?option=com_content&view=article&id=120\&Itemid=149&lang=en [Nov. 7th, 2013].

[19] AD ELEM, *Energetika*, Internet: http://www.elem.com.mk/index.php?option=com_content&view=article&id=137:energetika&catid=36&Itemid=95&lang=en. 2013. [Nov. 11th, 2013].

[20] EVN Macedonia, *Generation*, Internet: http://www.evn.mk/Za-nas/Proizvodstvo.aspx. 2013. [Nov. 07th, 2013].

[21] V. Mijakovski and N. Mijakovski, *Review of current position and perspectives of renewable energy in the Republic of Macedonia with focus on electricity production*, Renewable and Sustainable Energy Reviews, Vol. 15−9 (2011) 5068– 5080.

[22] Energy Agency of the Republic of Macedonia, *2009−2013 Energy Agency of the Republic of Macedonia*, March, 2013, 1−36. [Online] Retrieved from: http://www.ea.gov.mk/images/stories/E_Izdanija/Agencija_2009_2013.pdf 2013. [Nov. 13th, 2013].

[23] Macedonian Forests, *Geographical features of Republic of Macedonia*, Internet: http://mkdsumi.com.mk/zasumite.php?page=3&s=3 . [Nov. 13th, 2013].

[24] Energy Regulatory Commission of the Republic of Macedonia, "Обновливи извори/Регистер на повластени производители (Renewable sources/Registry of privileged producers)." Internet: http://erc.org.mk/pages.aspx?id=57. 2013. [Nov. 7th-14th, 2013]. (In Macedonian)

[25] Energy Regulatory Commission of the Republic of Macedonia. "Обновливи извори/Повластени производители (Renewable sources/Privileged producers)." Internet: http://erc.org.mk/pages.aspx?id=56. 2013. [Nov. 7th-14th, 2013]. (In Macedonian).

[26] Energy Regulatory Commission of the Republic of Macedonia, *Одлука за користење на*

повластена тарифа на електрична енергија произведена од обновливи извори на енергија (Decision on usage of feed-in tariffs for electric energy produced from renewable sources), Official Gazette of the Republic of Macedonia, Multiple issues: no. 112/2009, Sep.09, 2009, pp. 44; no. 129/2010, Sep. 28, 2010, pp.51−52; no. 31/2011, Mar. 14, 2011, pp.19; no. 62/2011, May 5, 2011, pp.81; no. 75/2011, Jun. 03, 2011, pp. 25; no. 93/2011, Jul. 11, 2011, pp. 52−53; no. 51/2012, Apr. 19, 2012, pp.10; no. 125/2012, Oct. 8, 2012, pp. 4−5; no.144/2012, Nov. 15, 2012, pp.39; no. 152/2012, Dec. 3, 2012, pp152; no.168/2012, Dec. 27, 2012, pp. 16−17; no. 28/2013, Feb. 25, 2013, pp.53; no. 38/2013, Mar. 11, 2013, pp. 31−32; no. 51/2013, Apr. 5, 2013, pp. 30−31; no. 78/2013, May 29, 2013, pp.8; no.90/2013, Jun 27, 2013, pp.61−62; no. 100/2013, Jul. 15, 2013, pp. 81; no. 108/2013, Jul. 31, 2013, pp.7; no. 147/2013, Oct. 28, 2013, pp. 53−54. (In Macedonian).

[27] Assembly of the Republic of Macedonia, *Закон за енергетика (Law on energy)*, Official gazette of the Republic of Macedonia, Multiple issues: no. 63/2006, May 23, 2006, pp. 1−33; no. 36/2007, Mar. 23, 2007, pp. 1−2; no. 106/2008, Aug. 27, 2008, pp. 2−8, (in Macedonian).

[28] Assembly of the Republic of Macedonia, *Закон за енергетика (Law on energy)*, *Official gazette of the Republic of Macedonia*, Multiple issues: no. 16/2011, Feb. 10, 2011, pp. 1−-63; no. 136/2011, Oct. 3, 2011, pp. 13−14; no. 79/2013, May 31, 2013 (In Macedonian).

[29] Government of RM, "Уредба за повластени тарифи за електрична енергија" (Act on privileged feed-in tariffs for electricity)," *Official gazette of the Republic of Macedonia*, no. 56/2013, Apr. 17, 2013, pp. 3-6 (in Macedonian).

[30] Government of RM, *Одлука за вкупната инсталирана моќност на повластените производители на електрична енергија произведена од секој одделен обновлив извор на енергија* (Decision on the total installed capacity by producers of electricity from renewable sources produced by each individual renewable source), Official gazette of the Republic of Macedonia, no. 56/2013, Apr. 17, 2013, pp. 6 (in Macedonian).

[31] United Nations. UN map number 3789, Rev. 5. Internet: http://www.un.org/Depts/Cartographic/map/profile/macedonia.pdf. [Nov 11th, 2013].

[32] M. Šúri, T. A. Huld, E. D. Dunlop, H. A. Ossenbrink, *Potential of solar electricity generation in the European Union member states and candidate countries*, Solar Energy, Vol. 81−10 (2007) 1295–1305.

[33] T. Huld, R. Müller, A. Gambardella, *A new solar radiation database for estimating PV performance in Europe and Africa*, Solar Energy, Vol. 86−6 (2012) 1803−1815.

[34] Joint Research Center – Institute of Energy and Transport, *Global irradiation and solar electricity potential – Horizontally mounted photovoltaic modules: FYR of MACEDONIA*, Internet: http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_cmsaf_hor/G_hor_MK.pdf. [November 07th, 2013].

[35] Joint Research Center – Institute of Energy and Transport, *Global irradiation and solar electricity potential – Optimally-inclined photovoltaic modules: FYR of MACEDONIA*, Internet: http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_cmsaf_opt/G_opt_MK.pdf. [Nov. 7th -14th, 2013].

[36] Energy Regulatory Commission of the Republic of Macedonia, *Issued Licenses/Renewable sources*, Internet: http://erc.org.mk/pages.aspx?id=76. [Nov. 7th -14th, 2013]. (In Macedonian.)

[37] World Bank, *GDP per capita (current US$)*, Internet: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD [Nov. 21, 2013]

[38] Macedonian Bank for Development Promotion, *Financing Sustainable Energy Sources Projects*, Internet: http://www.mbdp.com.mk/index.php/en/lending/energy [Nov. 26, 2013]

[39] Macedonian Bank for Development Promotion, *Annual Report 2012. Macedonian Bank for Development Promotion*, Apr. 2013. pp. 1−54. [Online]. Retrieved from: http://www.mbdp.com.mk/images/finansiski-izveshtai/godishni-izveshtai/eng-annual-reports/2012-annual-report.pdf [Nov. 26, 2013].

[40] M. Mendoca, *Feed-in Tariffs: Accelerating the Deployment of Renewable Energy*, Sterling, VA: Earthscan 2007.

ПРЕГЛЕД ПРОИЗВОДЊЕ ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ ИЗ ФОТОНАПОНСКИХ СИСТЕМА У РЕПУБЛИЦИ МАКЕДОНИЈИ

Сажетак: Глобални трендови у сектору енергетике усмјерени су ка великом укључењу обновљивих извора у производњи енергије. Доказано је да је соларна енергија вриједан кандидат, нарочито у погледу директне конверзије у електричну енергију. Међутим, до сад је њена шира употреба била условљена технолошким ограничењима која су за резултат имали веће производне трошкове у поређењу са традиционалним не-обновљивим изворима, превасходно угљем. У том погледу, напори научне заједнице су већ дуго усмјерени ка развоју ефикасних и економичних рјешења. Међутим, главни потицај у производњи електричне енергије из фотонапонских ћелија (PV) дошао је из законодавних мјера, у првом реду од увођења повлаштених тарифа. Слиједећи глобалне трендове, у Републици Македонији дошло је до значајног повећања производње електричне енергије. У раду дајемо кратак преглед постигнутог напретка.

Кључне ријечи: соларна енергија, фотонапонске енергане, производња електричне енергије.