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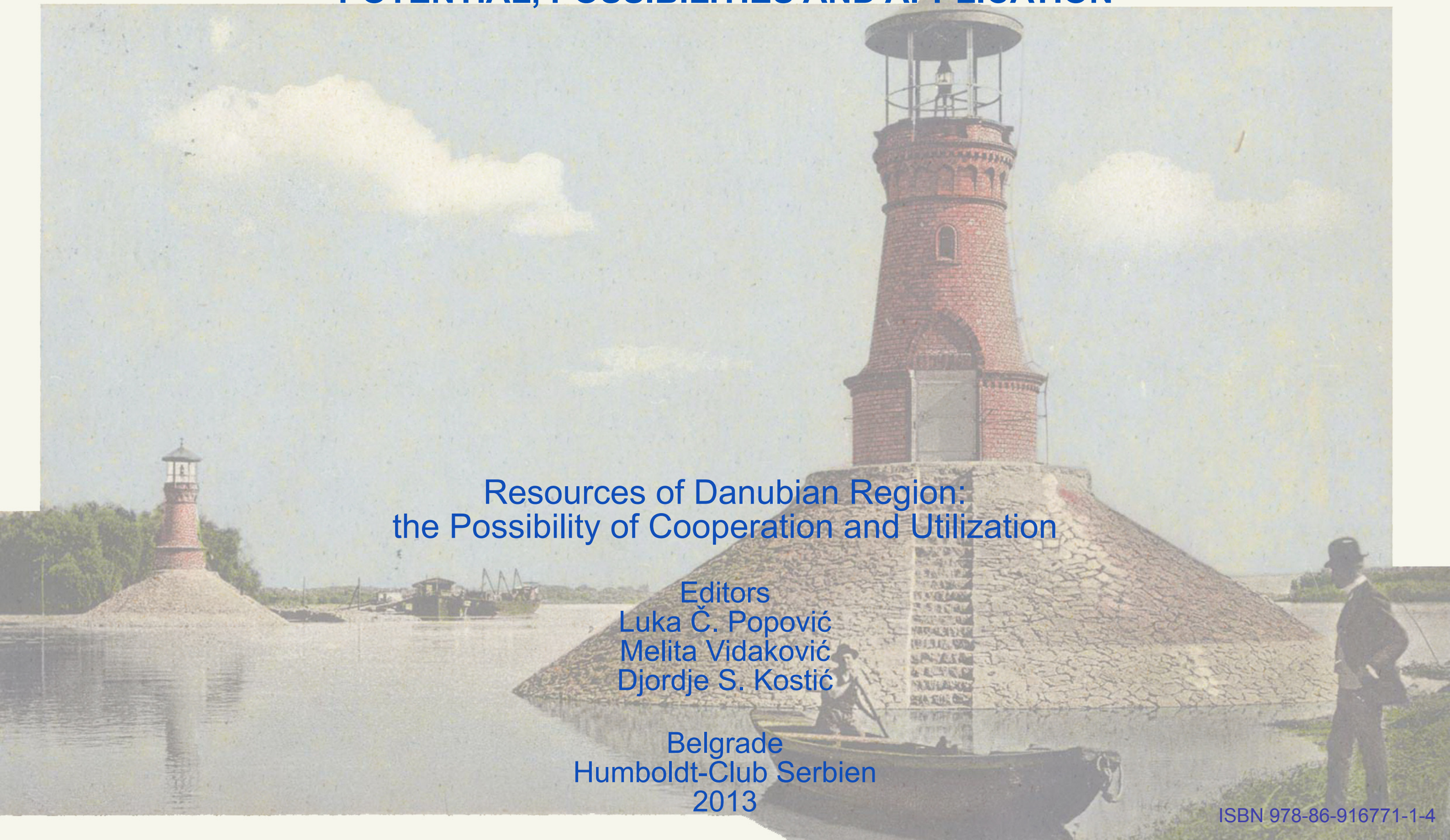
SOLAR ENERGY:
POTENTIAL, POSSIBILITIES AND APPLICATION



Resources of Danubian Region:
the Possibility of Cooperation and Utilization

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Abstract. The aim of this paper is to review some key issues and prospects related to solar photovoltaic power engineering. Solar potential, solar market and the government driven policy for renewable energy sources are analysed. European status as the world's leader in PV installed capacity is shown. Also, current and possible future development of PV engineering in the Republic of Serbia is addressed. The preliminary design of roof-mounted photovoltaic system on the School of Electrical Engineering at the University of Belgrade, created using self-developed solar power assessment software is presented.
Key words: Solar power; photovoltaic; markets and trends; government incentives; software

1. Introduction

When strategy to boost the development of the Danube Region was proposed by the European Commission, few years back, environmental protection and sustainable utilization of natural resources was one of the main pillars EU strategy was based on.

Environmental pollution and global warming are the first to be mentioned among the problems that should be addressed during this century. The current trend of energy production and consumption in the world is not doing any good in addressing these problems and presents the main cause of the greenhouse effect, acid rain and other negative global and local impacts on health and the environment.

Aside from the aforementioned problem of the environmental pollution, the dynamics of fossil fuel exploitation will lead to the exhaustion of their reserves in the near future. This presents an additional and even bigger incentive for increasing the share of renewable energy sources within global energy consumption. Humankind needs to establish ecological balance and implement fast transition from the non-renewable to renewable sources of energy.

As a solution to meet the growing demand for energy and reduction of environmental pollution, many governments were forced to promote, through corresponding subsidies, the construction of power plants that use renewable energy sources. This policy has led to the popularization and increasing share of renewable energy sources within overall electrical energy generation.

The aim of this paper is to review some key issues and prospects related to solar photovoltaic (PV) power engineering in countries of the Danube region. Speaking of these issues, three main groups of parameters are to be analysed: solar potential, solar market and the Government driven policy for renewable energy sources. Even though the first two of the above issues have an important role in the development of solar sector, Government policy is what makes solar energy prosperity of one country.

This leads to some countries with great solar potential to have poorly developed solar energy sector comparing to more developed countries with much less potential.

2. Photovoltaic markets, trends and incentives

Solar energy has experienced large growth in recent years due to both technological improvements resulting in cost reductions and government policies supportive of renewable energy development and utilization. While the cost of solar energy has declined rapidly in the recent past, it still remains much higher than the cost of conventional energy technologies. Forecasted prices of photovoltaic system are shown in Fig. 1 [1]. Analyzing Fig. 1 it can be concluded that the average price for a 3 kW household PV system will go from around 6,000 € in 2012 to below 4,500 € before the end of this decade.

Like other renewable energy technologies, solar energy benefits from fiscal and regulatory incentives, including tax credits and exemptions, feed-in-tariff, preferential interest rates, renewable portfolio standards and voluntary green power programs in many countries [2]. Despite the huge technical potential, the development and large scale deployment of solar energy technologies still has to overcome a number of technical, financial, regulatory and institutional barriers. The continuation of policy supports might be necessary for several decades to maintain and enhance the growth of solar energy in both developed and developing countries.

A large number of policy instruments have been implemented to support solar PV. The key instruments highlighted here include feed-in-tariffs, investment tax credits, subsidies and renewable energy portfolio

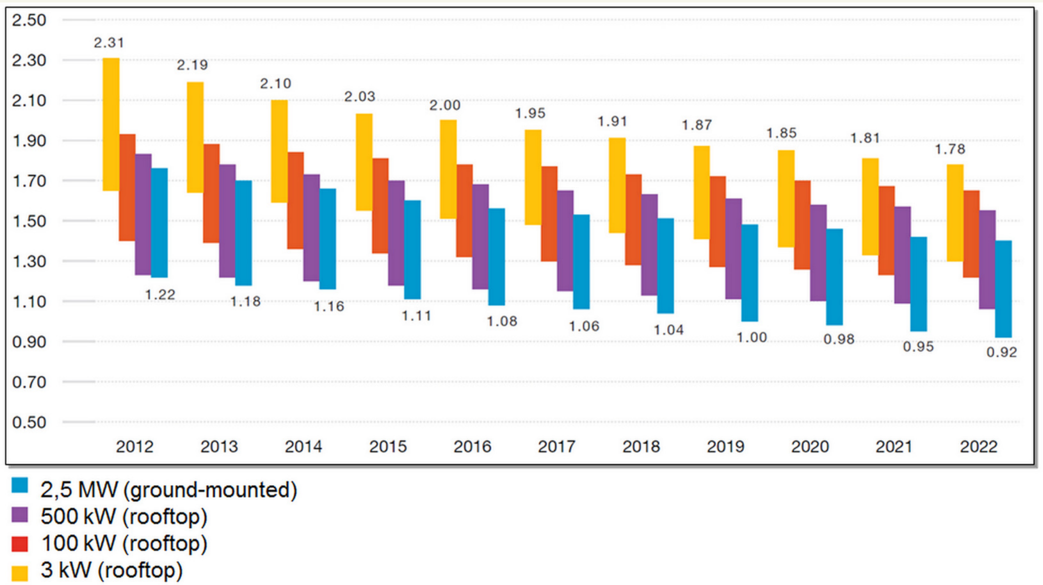


Fig. 1. Forecasted PV system prices (€/W) [1]

standards, with stress on feed-in-tariffs as the most commonly accepted policy instrument in Europe. More details about government incentives can be found in [2].

Feed-in-tariff

Feed-in-tariff (FIT) refers to a payment tariff to new and renewable energy technologies which are relatively expensive or may not be competitive with conventional technologies for electrical energy generation. The tariff is based on the cost of electrical energy produced plus a reasonable profit for the producer. It aims to send a signal to potential investors to make long-term investments on new and innovative technologies and thus ultimately help reduce the costs of those technologies. FIT has played a major role in boosting solar energy in countries like Germany and Italy, which are currently leading the world in solar energy market growth. FITs cover all types of solar energy technologies. The tariffs, however, differ across countries or geographical locations, type and size of technology. For example, German feed-in payments are technology-specific, such that each renewable energy technology type receives a payment based on its generation cost, plus a reasonable profit. The FIT is further subdivided by project size, with larger projects receiving a lower feed-in tariff rate in order to account for economies of scale, and by project type, with freestanding systems receiving a low FIT.

Germany's FIT assessment technique is currently based on a corridor mechanism. This mechanism sets a PV capacity installation growth corridor which is dependent on the PV capacity installed the year before, and results in a decrease or an increase of the FIT rates according respectively to the percentage that the corridor path was exceeded or unmet. As PV capacity installations were superior than planned by government in 2010, the FIT rates were decreased by 13% on January 1st, 2011, thereby accounting for the decrease in PV costs.

Investment tax credits

Different types of investment tax credits have been implemented in several countries around the world to support solar energy. In the United States, for example, the federal business energy investment tax credit is available for solar energy and fuel cells. For solar energy, the credit is equal to 30% of expenditures on equipment that uses solar energy to generate electricity, to heat or cool and on hybrid solar lighting systems. The 30% federal tax credits have provided significant leverage to solar energy development in the United Sates, where state governments have further supplemented federal tax incentives with their own programs. Despite their instrumental role in promoting solar energy, investment tax credits schemes are criticized for their impacts on government revenues.

Subsidies

Subsidies are the primary instrument to support solar energy development in almost every country around the world. A subsidy could be investment grants or capacity payments, output or production based payments or soft loans. In India, for example, the primary policy driver during the early years was capital subsidies funded either through donor and government funds. One remote village electrification program that aims to establish a single light solar PV system in non-electrified villages has 90% of the system cost covered by the government subsidy.

Renewable energy portfolio (RPS)

Many countries, particularly developed countries, have set penetration targets for renewable energy in total electricity supply mix. To meet the targets, electricity suppliers are required to have certain percentage of their electricity supply coming from renewable energy sources. These standards are commonly known as renewable energy portfolio standards (RPS) or Tradable Green Certificate (TGC) schemes in Europe. The standards create a trading regime where utilities with no or low renewable electricity share in their overall supply portfolio buy from those with high renewable electricity share.

3. PV in Europe: today and tomorrow

Over the last decade, PV technology has shown the potential to become a major source of power generation for the world – with robust and continuous growth even during times of financial and economic crisis. In 2011, more than 69 GW are installed globally and could produce 85 TWh of electricity every year. This energy volume is sufficient to cover the annual power supply needs of over 20 million households. In terms of global cumulative installed capacity, Europe still leads the way with more than 51 GW installed as of 2011 [3, 4]. This represents about 75% of the world's total PV cumulative capacity. The USA and Japan, once PV pioneers, are years behind Europe in terms of PV penetration. Figs. 2 and 3 show cumulative and annual installed PV capacity in the world.

Europe's market development is the result of a few countries that have taken the lead year after year, with Germany showing a constant commitment from policymakers to support the development of PV.

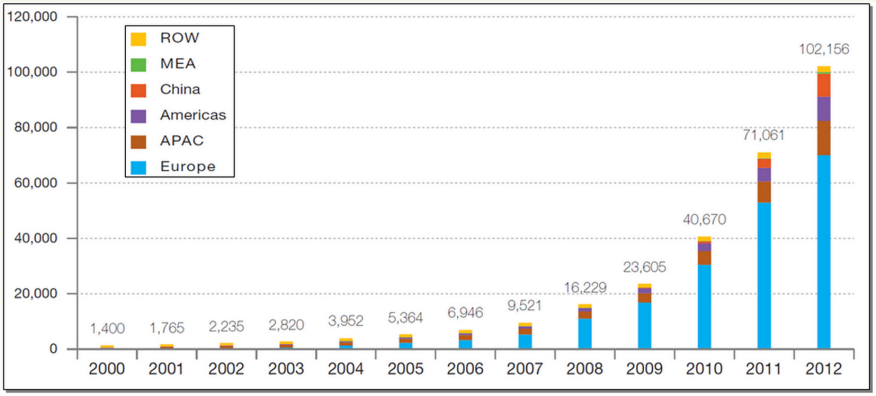


Fig. 2. Global cumulative installations of PV capacity (MW) [3]

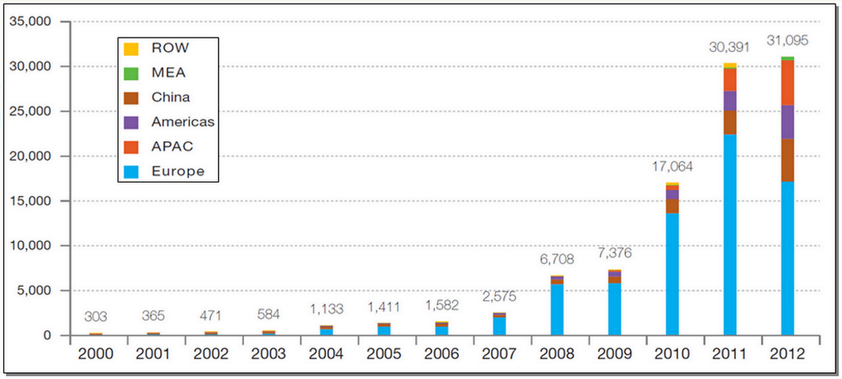


Fig. 3. Global annual installations of PV capacity (MW) [3]

After the Spanish boom in 2008, Germany was the only leading market in 2009. In 2011, the combined boom of Italy's connections and Germany's installations led again to huge growth (Figs. 4 and 5).

The need to avoid irreversible climate change effects has led European Union (EU) countries to commit to reducing greenhouse gas emissions to 80-95% below 1990 levels by 2050. This implies an almost

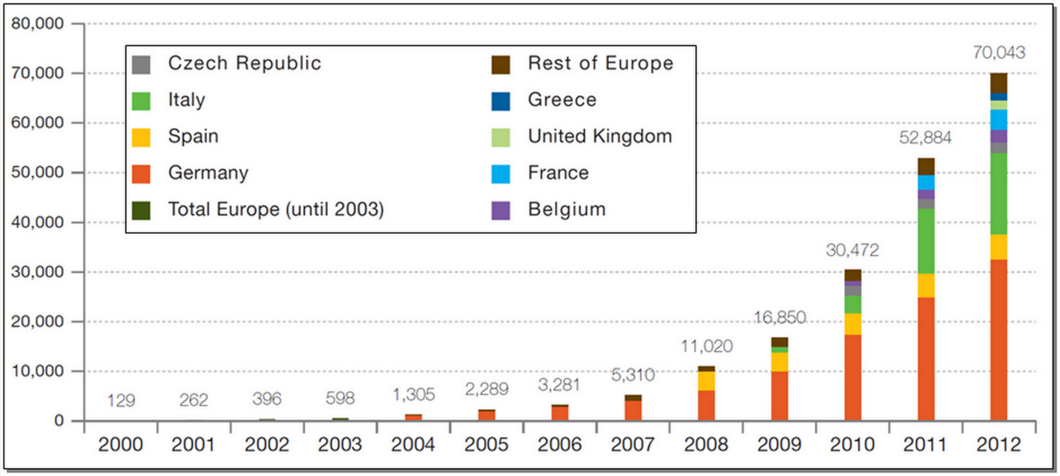
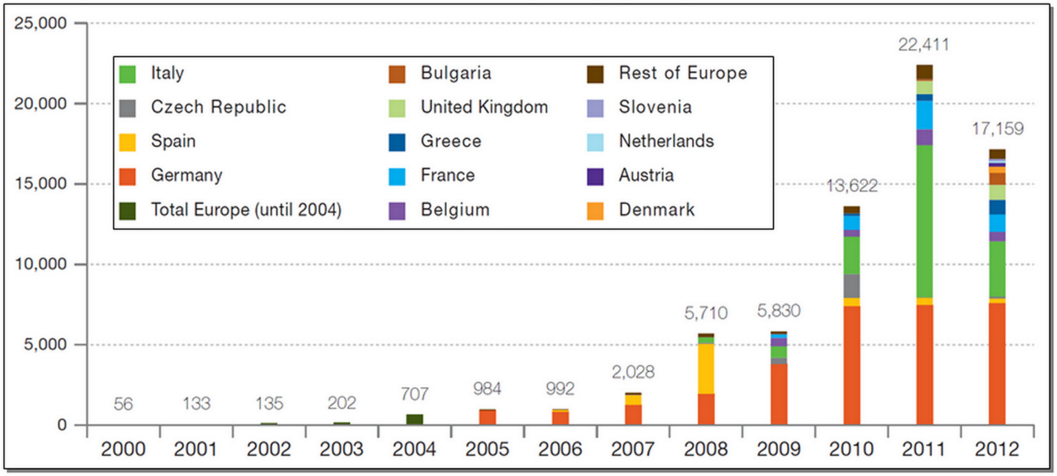


Fig. 4.
European cumulative installations of PV capacity (MW) [3]

Fig. 5.
European annual installations of PV capacity (MW) [3]



complete decarburization of Europe's energy sector by the middle of the century due to the difficulty of cutting emissions in other economic sectors. Achieving this goal will have important consequences for the continent's entire power system. The study prepared by the European Photovoltaic Industry Association (EPIA) aims to provide a holistic vision of how solar electricity will be integrated in the electricity system. It is based on new EPIA scenarios for the penetration of PV electricity in 2030 (Fig. 6).

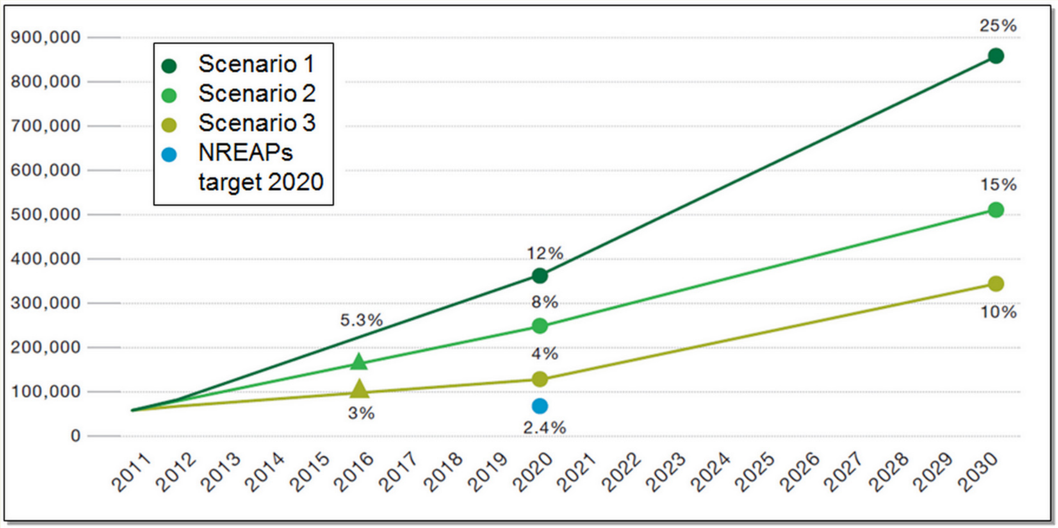


Fig. 6.
Projected penetration of PV in Europe until 2030 (MW) [1]

4. PV potential and possibilities in Serbia

The prosperity and perspectives of renewable energy in the Republic of Serbia is analyzed thoroughly [5-7]. The Government of the Republic of Serbia has established a firm political consensus on joining the EU and introduced European integration as its main political target. The European Energy Law will have great impact on Serbia and its renewable energy sector. Serbia, as a member of the Energy Community, has been committed to implement the relevant EU regulations concerning the energy sector step-by step. Law on Energy of the Republic of Serbia was issued on 24 July, 2004. Energy policy of the Republic of Serbia encompasses measures and activities that are being taken to realize long term aims in the area of energy and especially of:

1. Safe, qualitative and reliable supply of energy and energents.
2. Balanced development of energy activities so as to provide necessary quantity of energy to satisfy the needs of the energy consumers.
3. To provide conditions for the improvement of the energy efficiency and implementation of energy activities and energy consumption.
4. To provide for the conditions to stimulate the use of renewable sources of energy and combined production of the electrical and thermal energy.

5. To improve and protect the environment, etc.

Although on most of the territory of Serbia the number of sunny days is significantly higher than in many European countries (over 2000 h), high costs of solar irradiation modules and the accompanying equipment hinder more intensive use of this renewable energy source and it will depend primarily on the social incentives for the establishment and implementation of the national Renewable Energy Sources Program. According to the available data, use of solar energy is currently almost negligible. Production of solar energy, based on the sun potentials in Serbia, can be considered as attractive for potential investors, but it requires significant initial investments as well as purchasing foreign equipment, which makes it much less attractive compared to production of energy from other RES. Production of RES energy is one of the most successful ways for Serbia, as well as for other countries who signed it, to comply with the Kyoto protocol requests and achieve adequate stage of sustainable development.

Average solar irradiation on the territory of the Republic of Serbia ranges from 1.1 kWh/m2/day on the North to 1.7 kWh/m2/day on the South during January and from 5.9 kWh/m2/day to 6.6 kWh/m2/day during July. On annual basis average value of the global solar irradiation for the territory of the Republic of Serbia ranges from 1200 kWh/m2/year in the Northwest Serbia to 1550 kWh/m2/year in Southeast Serbia, while in the middle part it totals to around 1400 kWh/m2/year. Due to this fact Serbia exhibits favorable conditions for the use of solar energy and its conversion into the thermal and electrical energy. Fig. 7 shows solar potential in the Republic of Serbia. Comparing this potential to the one of Germany that hardly exceeds 1100 kWh/m2/year, it becomes really clear that Serbia is a country with great solar potential and poorly developed solar energy sector.

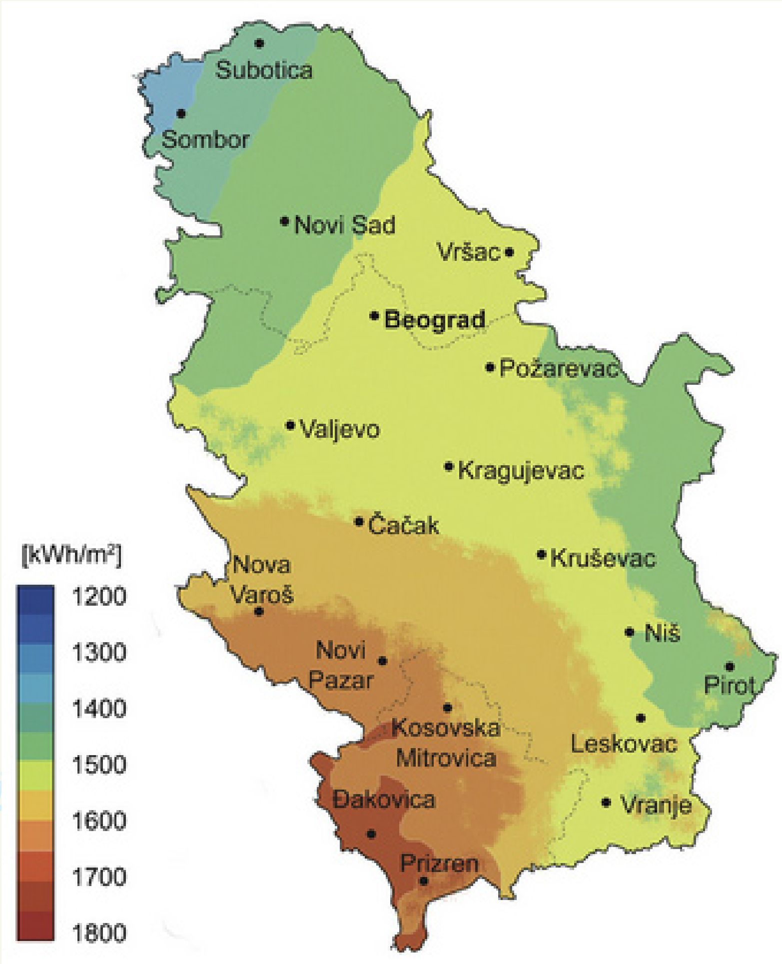


Fig. 7.
Solar potential in Serbia

5. PV practical application in Serbia

Designing photovoltaic systems entails a series of calculations, more or less complicated, which are implemented in order to form an energy efficient system at a given location. The energy efficiency of photovoltaic systems is influenced by numerous factors including irradiation (radiation power per unit area) at the panel surface, atmospheric conditions (temperature, precipitation, atmospheric contamination, etc.), orientation of the panel, etc. Based on measurements of horizontal irradiation and temperature, collected at the desired location, it is possible, with a group of equations, to estimate the electrical energy generated by a photovoltaic system at the same location during the same period. Without using a PC, the entire procedure of photovoltaic system design and evaluation of electrical energy generation, with respect to all the influential parameters based on actual measurements, would be long and arduous, almost impossible. Hence the idea for developing the software for photovoltaic system designs in actual exploitation conditions. An accurate evaluation of electrical energy generation is essential for further cost-benefit and other economic analysis. A more accurate estimate is obtained by taking into account as many influencing factors as possible, based on actual measurements taken over as long a period as possible (at least one year). This may lead to the need to process over 100,000 bits of measured data, which justifies the efforts made to develop software that allows quick and easy estimation of PV electrical energy generation.

Using MATLAB, software that estimates electrical energy generation of a grid-connected photovoltaic system was developed. The software uses actual measurement data of temperature and horizontal irradiation with an arbitrary time interval and arbitrary resolution of the data. The software is user-friendly and follows a logical sequence of calculations used for photovoltaic system design [8].

As an example of the software application, the preliminary design of roof-mounted photovoltaic system on the School of Electrical Engineering at the University of Belgrade is conducted. The basic idea is to create a demonstration photovoltaic grid-connected system on the roof of the Education Centre of Science. Additionally, two panels are planned to have a sun-tracking mechanism, hence enabling the development of the Renewable Energy Laboratory.

Based on the available measurement data of the ten-minute average horizontal irradiation during 2009 in Belgrade, the average daily horizontal irradiation is calculated. Diagram of the horizontal irradiation is shown in Fig. 8.

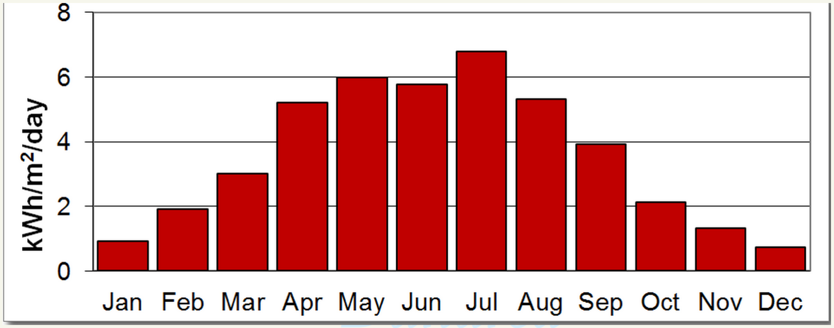


Fig. 8.
Horizontal irradiation in Belgrade in 2009.

Building of the School of Electrical Engineering in Belgrade is located at 44.8 ° north latitude and 20.47° east longitude. The building is oriented towards the south-west, at an angle of 30° to the south (Fig. 9).

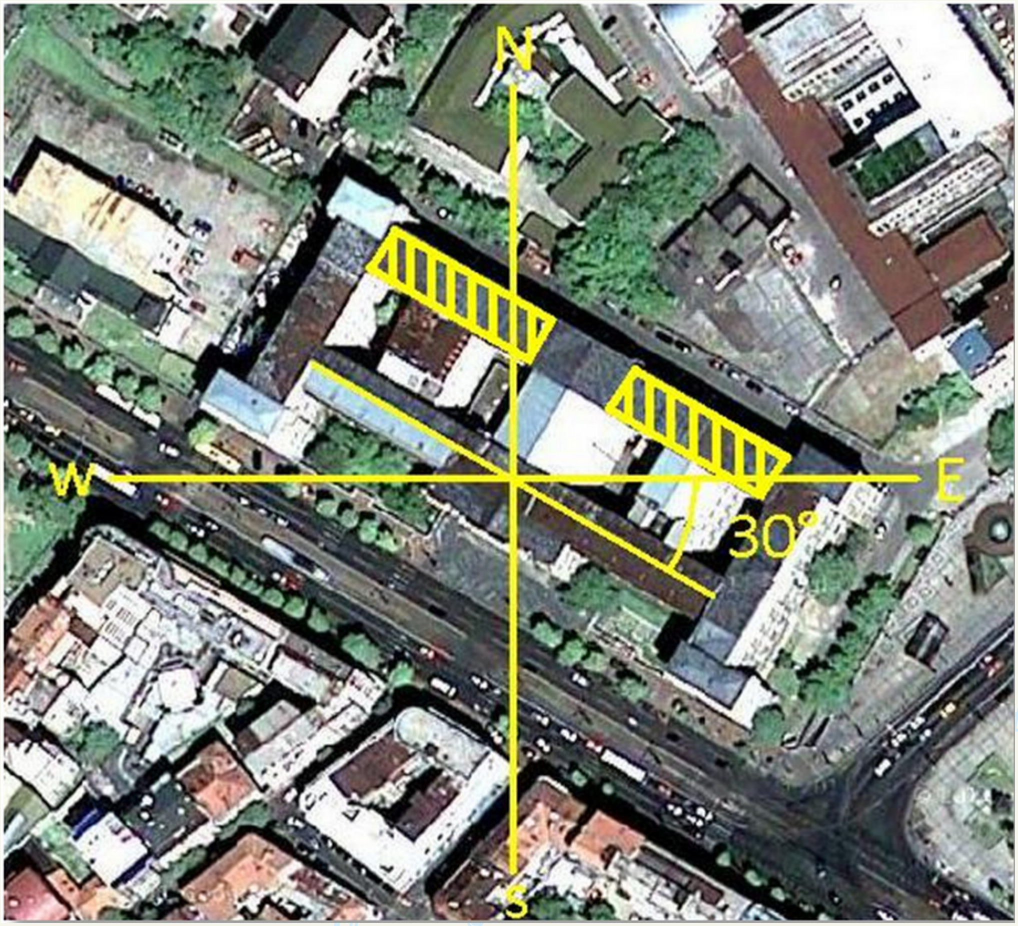


Fig. 9.
The bulding orientation.

The roof deck has a slope of 7° and, as shown in Fig. 9, is oriented at an angle of 30° to the south-west. Because of this orientation of the roof, two cases were analyzed: panels positioned on the surface of the roof and panels placed on additional structures in order to achieve maximum efficiency. In both cases, the panels have the are azimuth angle of 30°, to follow the roof surface. Diagrams of electrical energy production for both cases, estimated using the developd software, are shown in Fig. 10. It is calculated that the annual production in the case of the optimal tilt angle is increased by 6% compared to the production of panels under the tilt angle of 7°.

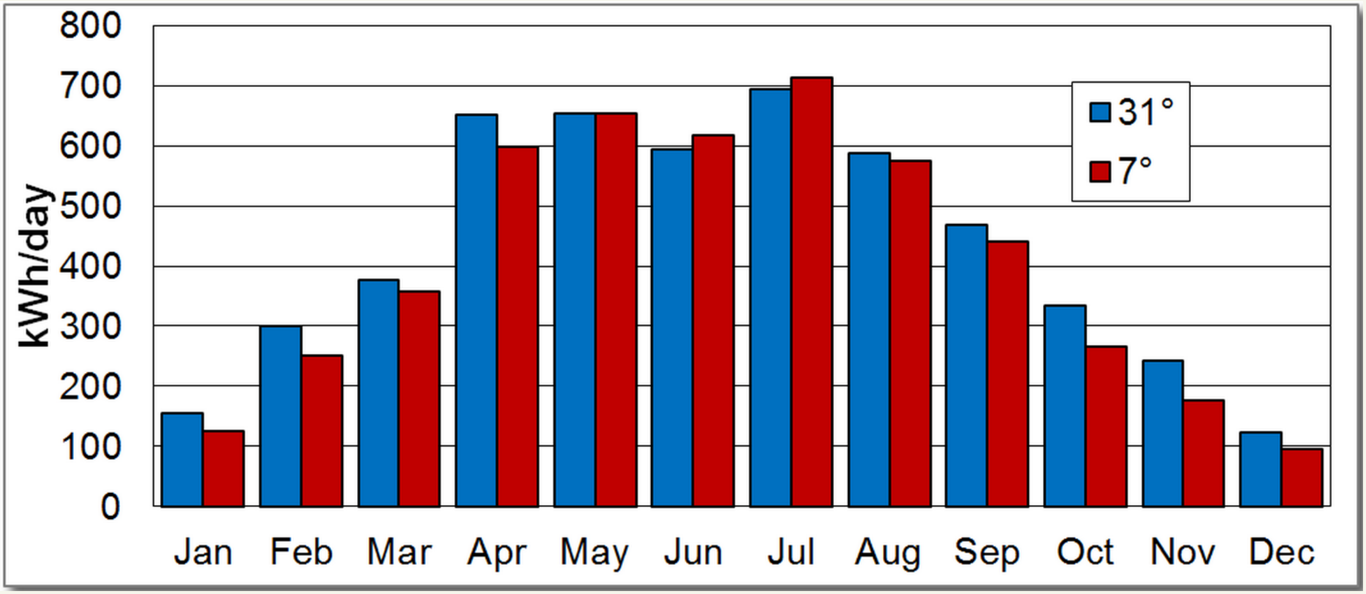


Fig. 10.
PV system production for the two cases.

Using the electricity bils, electrical energy consumption of the Technical Faculties during the year is assessed. Looking at the diagram in Fig. 11 it can be concluded that the designed photovoltaic system accounted for a small part of the Faculty consumption (about 20%). However, given the privileged price (FIT) of 0.20 €/kWh for electrical energy produced from photovoltaic systems, it can be seen (Fig. 12) that over 75% of the annual electrical energy cost is covered.

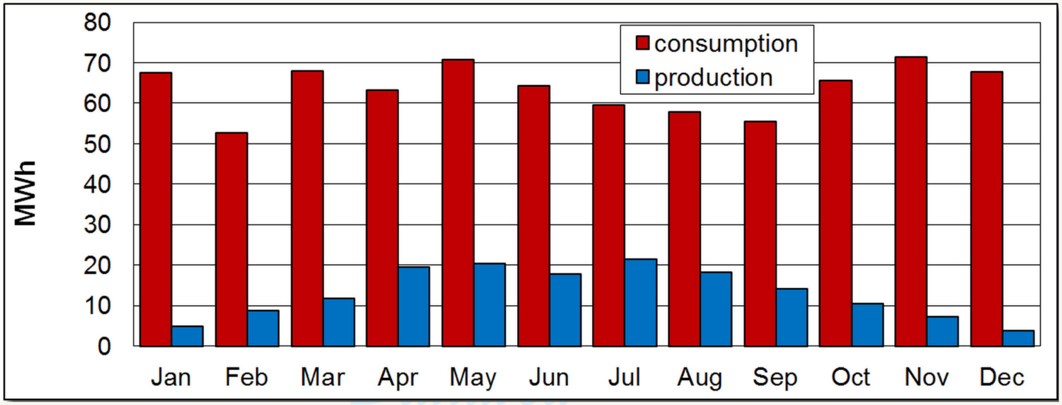


Fig. 11.
Electrical energy consumption coverage

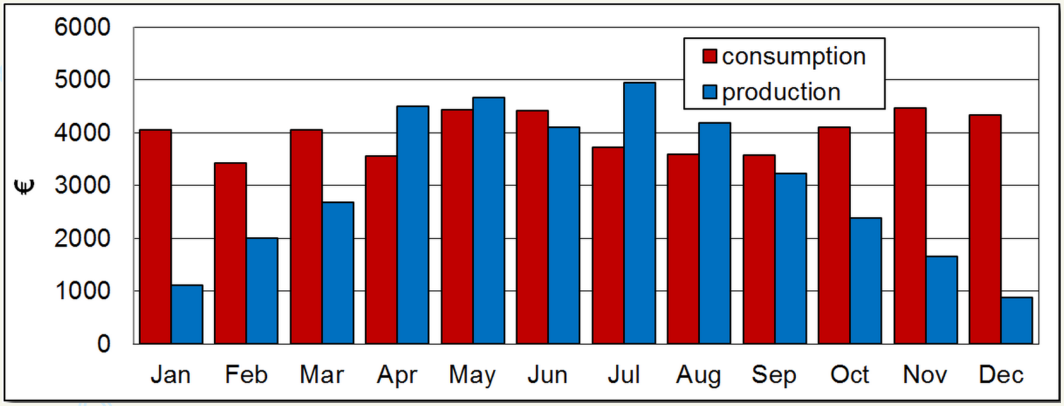


Fig. 12.
Electrical energy costs coverage

6. Conclusion

Government policy is what makes solar energy prosperity of one country. The incentives encourage potential investors to invest in innovative technologies and thus help reduce their costs. This is the reason the PV prices are constantly dropping in the past years. However, this policy lead to some countries, like Serbia, with great solar potential to have poorly developed solar energy sector comparing to more developed countries with much less potential. Economic development and strengthening of regional cooperation and partnership in the Danube region can lead to development and utilization of solar energy in Serbia.

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