The potential of massive PV installation in Serbia

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Abstract

Paris climate agreement, adopted in December 2015, recognizes the need to revise voluntary submitted Intended National Determined Contribution (INDC) in order to limit global warming to 2°C.

With the objective to propose the improvement of Serbian INDC we investigate the technical potential of massive installation of residential solar PV roof top systems and utility scale solar PV power plants. Our research shows that solar may substitute around 81% of all electricity produced from coal and hydro. Thus, solar should be considered as a significant source of energy in future Serbian energy mix.

Keywords: *Serbia, low carbon economy, long term transition, solar, photovoltaic, technical potential, financial aspects*

1. Introduction

More than 180 states submitted their INDCs so far. However, estimated aggregate greenhouse gas emission levels in 2025 and 2030 resulting from existing INDCs do not fall within least-cost 2˚C scenarios but rather lead to a projected level of 55 gigatonnes in 2030. In order to hold the increase in the global average temperature to below 2˚C above pre-industrial levels States shall reduce emissions to 40 gigatonnes (UNFCCC, 2015).

Although adopted at the time of the 21st session of the Conference of the Parties (COP-21) the latest Serbian energy strategy (Republic of Serbia, 2015) suggests the continuation of usage of fossil fuels with focus on dirty lignite coal. No matter that the availability of some types of renewable energy resources (like solar) is much greater than in the Central Europe, the strategy underestimates the share of renewables in the future energy mix. Serbia and Serbian citizens already pays for their ignorance of renewables technologies. With only 6.2 $ per kilogram of oil equivalent (The World Bank, 2016a) and the high dependence on fossil fuels Serbian economy is one of the most energy and emissions intensive in the world. The increase of annual public health costs due the toxic emissions from burning lignite is estimated to 4 billion EUR (HEAL, 2016).

This paper presents new approach in the estimation of potential of solar energy in Serbia. The scope of our research includes the estimation of technical potential of massive installation of residential solar photovoltaic (PV) roof top systems and utility scale solar PV power plants. Solar thermal is out of scope. It will be addressed in the continuation of the research.

2. Solar energy potential – existing estimations for Serbia

Official data about the potential of various energy sources has been published in the national energy strategy that was adopted by the Parliament and the Government (Republic of Serbia, 2015). According to the authors of the strategy, total technically usable potential of solar power in Serbia is estimated to 0.24 million tons of oil equivalent (2.79 TWh per year). This figure includes electric and thermal potentials – 0.53 TWh and 2.26 TWh, respectively. The most important assumption in this official document that influenced entire estimation of potential of renewables was the consideration that the existing electric grid cannot handle more energy from intermittent sources than that presented in the strategy.

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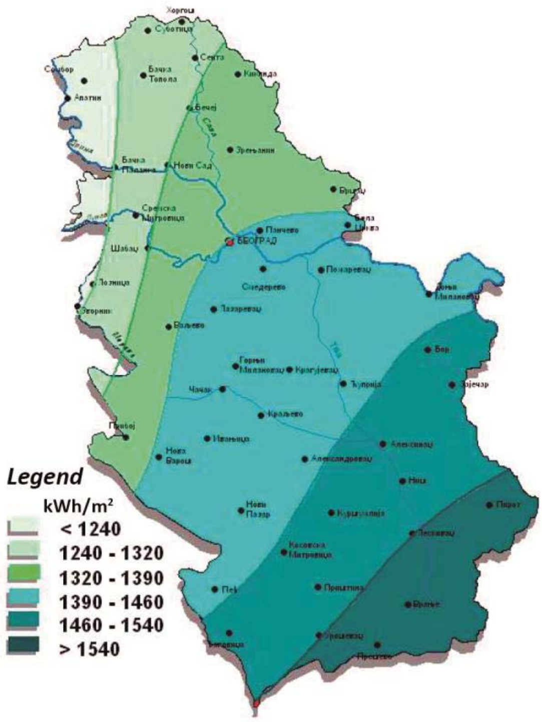

Fig. 1 Annual energy of global radiation on a horizontal surface (kWh/m^2). Source: (IMSI, 2004)

Fig. 1 shows that in Serbia, Sun energy has the tendency of increasing with decreasing latitude. The southern parts gain energy up to 1550 kWh/m^2 per year. However, solar energy is an intermittent source, which means that values vary on daily and seasonal levels. During the hot July days, square meter of horizontal surface receives an average of 5.9 to 6.6 kWh per day, but during January the radiation is reduced to only 1.1 to 1.7 kWh.

Radičević et al. (2009) claims that solar PV will represent only negligent share of energy mix in near future due to high costs of technology. Other academic and expert researchers like (IMSI, 2004) limited their exercises to the estimation of annual insolation without clear scenarios how to proceed with the installation of solar systems in Serbia.

The major obstacles of presented approaches can be summarized as:

- Existing electrical grid is considered as incapable to accept large amounts of variable power produced by renewable sources; and
- The renewables are presented and considered as very expensive.

Our opinion is that the establishment of estimations of renewables technical potential on these assumptions is entirely wrong since it is clear that the transition to renewable energy system cannot and will not happen overnight. Many publicly available researches, global policies and scenarios identify 2050 as a target year to develop sustainable and clean energy system worldwide in order to prevent catastrophic consequences of climate change. Until that time, countries should work on the improvement of electric grids and the implementation of smart grids, as well as, energy storages, in order to accommodate energy produced by intermittent sources and manage demand.

In the meantime, further researches and the economy of scale will lead to the reduction of technology costs well below current levels making renewables more efficient, more environment friendly and cheaper than today. In addition to the fact that the reduction of prices of solar PV panels is already underway it is worth to compare true costs of production of conventional energy with those produced by solar. The high air pollution and carbon costs of burning fossil fuels make conventional energy much more expensive than solar or wind.

Fortunately, other more optimistic renewables potential estimations have appeared recently. A professor from the Stanford University Mark Z. Jacobson and his team work on 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All Sector Energy Roadmaps for 139 Countries of the World. They estimate total potential capacity for solar energy in Serbia to 15.441 GW (Jacobson et al., 2016). Only 45% of this potential capacity will be enough to support country's transition to cleaner energy system entirely run on wind, water, and sunlight (WWS).

The group of independent think-tanks from South Eastern Europe has developed the SEE 2050 Carbon Calculator – regional renewable energy model and tool for the creation of individual energy transition scenarios. According to this group, the solar PV technology may provide around 24.45 TWh annually in Serbia (SEE Change Net, 2016), almost 10 times more than official estimations.

3. Massive installation of solar PV systems and power plants in Serbia

"Solar energy is the most abundant of all energy resources. Indeed, the rate at which solar energy is intercepted by the Earth is about 10,000 times greater than the rate at which humankind consumes energy. Solar technologies can deliver heat, cooling, natural lighting, electricity, and fuels. Solar technologies offer opportunities for positive social impacts, and their environmental burden is small." (Arvizu et al, 2011)

Having in mind small environmental footprint of solar, plummeting costs of solar PV technology and great natural solar resources that Serbia has (average annual insolation is around 40% higher than in Germany) our research team has developed the alternative scenario of development of Serbian energy system. The alternative scenario includes massive installation of solar PV roof-top systems and utility scale solar PV power plants.

Massive installation of solar PV roof-top systems

Solar PV technology allows residents, and public and private entities to join transition to low-carbon economy. By applying solar PV panels each of these categories can contribute to the mitigation of climate change on individual level. In addition to being energy consumers, owners of PV systems become energy producers making new class of actors in energy markets – "prosumers". Massive installation of solar power plants owned by citizens and legal entities will enable the decentralization and democratization of energy production. Such diversification of energy sources will improve energy security on individual and national level, reduce the power of monopoly of traditional state-owned fossil fuel companies, as well as, to reduce dependence on fossil fuel imports.

The researched scenario includes the installation of 6 kWp solar systems on the residential house and building roofs in Serbia. The roof area under solar panels is estimated to 40 m^2. It is assumed that commercial, utility and administration buildings with larger roofs could house larger systems – up to 15 kWp (around 100 m^2 of panels). Solar thermal collectors were out of scope of this part of the research and will be addressed in later stages.

The estimation was performed using the on-line *PVWatts* calculator (NREL, 2016). In order to validate *PVWatts* results, its estimations were compared to the output of another on-line calculator – *PV*SOL Online Calculation* (Valentin Software, 2016). No significant deviation in final results between these two on-line tools has been identified.

Having in mind that the roof orientation and tilt are uncertain categories, the estimated potential of a PV system is an average result calculated by variation of the following performance parameters:

- PV panel type (Standard, Premium);
- tilt (30° and 45°); and
- azimuth (East, South and West).

The assumed location of a solar PV system in this exercise is Belgrade, capital of the Republic of Serbia.

The exercise showed that azimuth has the greatest impact on the amount of generated electricity. The best results are obtained if solar panels are oriented to South (azimuth 180°).

Average annual amount of electricity generated by small-scale solar PV system with the capacity of 6 kWp mounted on the roof of the object in Belgrade is estimated to 6,269 kWh. The amount of generated electricity varies during the year picking in July (Fig. 2) – 823.45 kWh, i.e. 2.5 times greater than average monthly electricity consumption of household in Serbia.

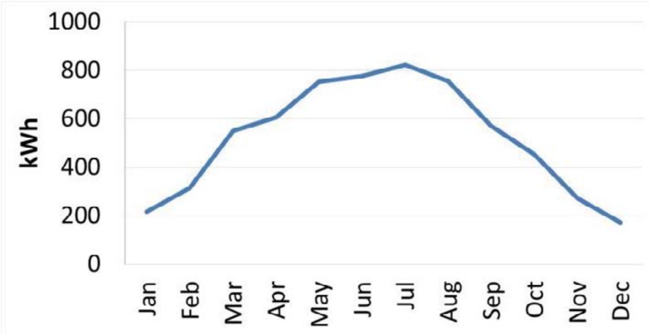

Fig. 2 Variation of production of 6kWp solar PV system located in Belgrade

The amount of electricity generated by 15 kWp solar PV system mounted on public and commercial buildings is obtained by the extrapolation of modeled small-scale solar PV system electricity production and amounts 15,671 kWh.

The total number of family houses in Serbia that can be used as locations for 6 kWp solar PV systems is estimated to 2,186,000 (Jovanović-Popović et al, 2013). The number of buildings that can house larger systems (15 kWp) is estimated to 42,389 (Statistical Office of the Republic of Serbia, 2016).

Tab. 1 Massive installation of small scale PV systems in Serbia: Estimated capacity and annual generation

Type of object	Number of objects	Capacity of installed system (kW)	Annual produ-ction of single system (kWh)	Total installed capacity (GW)	Annual generation of electricity (TWh)
Family houses	2,186,000	6	6,269	13.116	13.704
Residential buildings	9,556	15	15,671	0.143	0.150
Other buildings (commercial, admin.)	32,833	15	15,671	0.492	0.515
			Total	**13.751**	**14.369**

The amount of electricity generated by these 2.2 million solar systems mounted on rooftops is estimated to 14.369 TWh per annum (Tab. 1). The installation of these 13.751 GW of solar PV panels could cost somewhere between 30.252 and 71.505 billion USD. The costs are calculated according to the lowest and highest price of the installation of residential solar PV systems in the world published in (IRENA, 2015).

Massive installation of utility-scale PV power plants

In addition to the roof-top PV solar systems the research included the estimation of the installation of utility-scale PV power plants.

There are currently only a few major photovoltaic plants installed on the ground In Serbia. The most famous are “Solaris 1” (1 MW) and “Solaris 2” (675 kW) near Kladovo (Eastern Serbia), “Matarov” (2 MW) in Merdare (Southern Serbia) and solar power plant of capacity of 1 MW in Tancoš near Beočin (Vojvodina). According to the data provided by Serbian Ministry of Mining and Energy (MME), 17 solar PV power plants have status of privileged or temporarily privileged producers of electricity with total installed capacity of 6 MW (MME Serbia, 2016). These producers have right to receive feed-in tariffs.

Although, solar energy is considered as a clean, free and practically limitless energy source, systems for the exploitation of solar energy, such as photovoltaic plants, have certain restrictions, which depend on the type and size of projects. These restrictions primarily relate to the occupation of land which is limited and precious natural resource in today’s conditions.

In order to develop resource efficient scenario the research includes only the usage of degraded land as a location of potential big PV power plants. Degraded land is an area where the natural conditions are altered by human activity, and envisaged for rehabilitation after the exploitation. In accordance with the aim of the gradual replacement of conventional energy sources with renewable energy sources, the sites of the surface exploitation of the energy minerals (coal, lignite, bituminous rocks, oil and gas) are selected as potential locations of solar power plant. These sites are defined and presented as a shape files. The assumption to use sites of the surface exploitation of the energy minerals as potential solar power plant locations is in line with the obligation of the Electric Power Industry of Serbia (EPS) to initiate the closure of coal power plants that do not meet requirements of the European Large Combustion Plants Directive after 2023.

In addition, the study includes areas for the exploitation of metallic and industrial raw materials, dumps of tailings and ashes, landfills, sites of conventional coal power plants, thermal power plants, brick plants etc.

For the purposes of this research, 2447 locations were identified and assessed. The total area covers 238.75 km^2 or 0.27% of the territory of Serbia.

The data on the overall installed capacity and annual production of energy have been obtained by the online software *Energy Capacity Assessment Tool* (First Solar, 2015) that uses GIS shape files as a source data about the form and size of power plant.

The total installed capacity of photovoltaic power plants on degraded land amounted to 15,531.93 MWdc for photovoltaic power plants that are built from cadmium-telluride solar cells, or to 16,178.12 MWdc power plant based on multi-crystalline solar cells. The results show, that the installation of photovoltaic power plants at all 2447 degraded locations under consideration would lead to the generation of 18.02 TWh electricity per year. This is around 33 times higher than the technically usable potential published in national energy strategy.

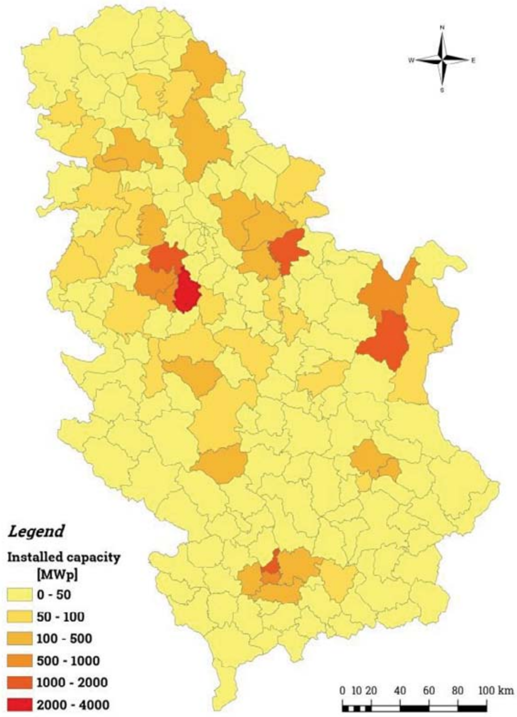

Fig. 3 Estimated total installed PV capacity per municipalities in Serbia

Fig. 3 presents the estimated capacity of installed solar PV power plants per municipality. The largest percentage of the production of solar energy (38%) would be accomplished by installing photovoltaic panels on existing mines of energy producing materials like open coal pits located in the following municipalities Obrenovac, Lazarevac and Kostolac (the darkest color on the map).

The Republic of Serbia has submitted the National Emission Reduction Plan (NERP) to the Secretariat of the Energy Community (Energy Community, 2016). Although the document is not publicly available there are indications that Serbia selected opt-out option for several operational coal power plants. This is expected to lead to the significant reduction of electricity generation capacity, by some 10% in year 2023, according to our assumptions. We recommend that Serbia prepare its energy system for this shock and make use of available renewables technology to cover the gap that will emerge after the closure of outdated coal power plants.

The state-owned energy company EPS produced 37.433 TWh of electricity in 2013 (EPS, 2014). The implementation of utility-scale photovoltaic plants in the territory of the Republic of Serbia as presented in this article can substitute around 48% of the current production of the EPS.

Construction costs of photovoltaic systems at these locations are projected to 25 to 70 billion USD according to the lowest and highest installation costs in the world published in (IRENA, 2015).

Since the Spatial Plan of the Republic of Serbia 2010-2020 (RASP, 2010) envisions the establishment of a system of regional waste management centers, the surface of existing landfills, could be significant resource for the construction of a photovoltaic power plants, too.

4. Summary

Our research provides new outlook of solar prospective in Serbia. Unlike national energy strategy our scenario involves massive installation of solar PV systems and power plants that results in significantly greater estimations than official figures.

Tab. 2: Estimated potential for roof-top solar PV systems and utility-scale PV solar power plants in Serbia

Type of object	Number of objects/ locations	Capacity of installed system (kW)	Total installed capacity (GW)	Annual generation of electricity (TWh)
Family houses	2,186,000	6	13.116	13.704
Residential buildings	9,556	15	0.143	0.150
Other buildings (commercial, administrative)	32,833	15	0.492	0.515
Utility scale solar PV power plants	2,447	from 280 to 3,563,220	16.178	18.02
		Total	**29.929**	**32.389**

The summarized data are presented in Tab. 2 Estimated solar generated 32.389 TWh per annum can substitute around 81% of current total electric energy production in Serbia, i.e. the whole electricity produced by lignite power plants. Such huge estimated potential should make solar PV a critical element of the future country energy mix.

Initial capital installations costs have been estimated on the basis of average costs in countries across the world identified by (IRENA, 2015). The initial costs are presented in Tab. 3.

Tab. 3: Estimated total investment for the transition to solar PV-based electrical system in Serbia

Type of object	Total installed capacity (GW)	Installation costs (2014 USD/kW) (IRENA, 2015)	Initial capital installations costs (billion USD)	Estimated costs per year 2020-2050 (billion USD)
Family, residential, commercial small-scale solar PV systems (6 or 15 kW)	13.751	2,200 - 5,200	30.252-71.505	1.008-2.384
Utility scale solar PV power plants	16.178	1,570 – 4,340	25.399-70.212	0.847-2.340
Total	**29.929**		**55.651-141.717**	**1.855-4.724**

Total investment in the development of solar PV-based electrical system in Serbia by 2050 is estimated to 55 to 142 billion USD. This investment corresponds to 1.5 to 3.9 yearly gross domestic products (GDP) of Serbia (based on GDP value of 36.513 billion USD in 2015 (The World Bank, 2016b)).

Certainly these, at first glance, large figures may discourage decision makers to consider planned and persistent installation of renewable systems necessary for transition to low-carbon economy and the mitigation of climate change. Yet this total investment should not be considered as “pay at once costs” but rather as a long-term investment up to 2050. In this case the highest amount of investment is leveled to 4.724 billion USD per annum or 13% of current GDP. In order to get clearer picture about this investment it could be compared to the economic cost of deaths from outdoor and indoor air pollution that are estimated to 33.5% of Serbian GDP (WHO, 2015).

The absence of environmental costs of solar PV energy production should be major driver to initiate and the transition to clean energy. (HEAL, 2016) claims that outdated Serbian coal power plants are responsible for 4 billion EUR (around 4.44 billion USD) of increased public health costs associated with air pollution.

The research presented in this article busts three renewable energy related myths in Serbia:

- It proves that natural resources for the transition to the low-carbon economy exist in Serbia;
- It proves that such transition can be undertaken using existing technology for the energy production; and
- Financial resources for such transition already exist in Serbian society, too. However, they are used to cover consequences of electricity generation by old technology.

The need for the transition to renewable energy sources has never been questioned from ecological and social perspectives. Our research shows that there are economic reasons for such a transition. Cost effectiveness in economic terms is added to the existing ethical reasons for the transition to renewable energy.

It is clear that the transition cannot be executed all in once and that coal will stay around for a while. The aim of this research is to stimulate national discussion and to show that alternative, clean future is possible. Our recommendation to national decision makers is to investigate possibilities of renewable energy and gradually divert capital flow from fossil fuels to renewables, particularly solar. Such strategy will ensure clean, cheap, abundant and decentralized energy available to all, while it pays for itself by reducing public health costs.

We recommend the following policy measures that can support the transition to low carbon economy:

- Incorporation of true costs of burning fossil fuels into price of energy by the implementation of carbon fee and dividend; and
- Improvement of country's capacity to effectively and efficiently perform the transition by including climate change and renewables topics/trainings in school and university education.

The presented research is the first step in the broader investigation of potential of solar energy in Serbia. Future research will include the estimation of potential of solar thermal in residential and commercial use. The presented investment includes the installation costs only. Our intention is to address operation and maintenance costs of running the electric generation system comprised of more than 2.2 million production units, as well as, to estimate the electricity costs to end-users. Envisioned transition from centralised electricity production to decentralised production based on solar technology offers new jobs. We will end research activities on this topic with the analysis of impact of transition on job market and estimate the number of lost and produced jobs.

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