POTENTIAL UTILIZATION OF RENEWABLE ENERGY RESOURCES FOR ELECTRICITY GENERATION IN BOSNIA AND HERZEGOVINA

by

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Along with the current processes of restructuring of Energy power system of Bosnia and Herzegovina, liberalisation of the electricity market, and modernisation of the existing power plants, Bosnia and Herzegovina must turn to the utilisation of renewable resources in reasonable dynamics as well. Respecting this policy, the initial evaluation of the potential of renewable energy resources in Bosnia and Herzegovina is performed. The methodology of evaluation of wind energy utilisation is presented in this paper, as well as some other aspects of utilisation of the renewable energy resources in Bosnia and Herzegovina. Implementation of selected projects should improve sustainability of energy power production in Bosnia and Herzegovina, by reducing the total emission of carbon dioxide originated from energy power system of Bosnia and Herzegovina.

Key words: *energy pomer sistem, power plants, renewable resources, sustainability, emission of carbon dioxide*

Introduction

Bosnia and Herzegovina (B&H) has a large hydro potential, which is not sufficiently exploited. Coal reserves are large, and present the main energy source for electricity production.

B&H is temporary in a process of integration to the European association, and it is supposed to meet European standards for energy production in a limited period of time. A part of these standards relate to the energy power system, concerning restructuring of the electric power system, liberalisation of electricity market, and reduction the environment impacts.

Taking into account the mentioned above, the utilisation of renewable resources in B&H is a new challenge.

Generation and consumption of electricity in Bosnia and Herzegovina

For past several decades, it was noticed that the electricity consumption in B&H is changing. The gross consumption of electricity in B&H was growing in the period

from 1965 to 1985 year, with an average growing rate of 8.9%. However, after 1986, the economy grow was slowed down, and consequently electricity consumption was reduced in that period. In the period from 1990 to 1991 the economy was declining, and during the war in former Yugoslavia from 1991 to 1995, completely stopped. In 1991, the electricity generation reached 15,000 GWh. The installed capacity was 4,000 MW_e, and maximal load 2000 MW_e. During the war in B&H from 1992 to 1995, only 10% of the installed capacity was in operation. Most power plant installations were damaged, or completely ruined. Most of regions were without electricity for several years. Minimal electricity generation in micro-island systems was not enough for regular supply to the consumers. After the war, as the result of intensive efforts on refurbishment of entire electric power system, electricity supply has been normalised. In year 2000, the electricity generation was tripled related to the pre-war state, and reached 63% of electricity generation in 1990. Assessments of electricity consumption in domain of the Public Enterprise JP Elektroprivreda BiH (PE JPE) – the largest electricity producer in B&H, have shown that the growing of electricity consumption in the next period (till year 2020) should continue, fig.1.

Today, the combined capacity of all power plants is 3,940 MW, of which 1.983 MW is in hydropower plants (not including the small hydropower plants) and 1,957 MW is in thermal power plants. Oppositely, from the total installed capacity belonging to PE JPE (1,839 MW, or 47% of total capacity in B&H), only 482 MW is in hydropower plants, and 1,357 MW is in thermal power plants. An additional 11 MW is available to from small hydropower plants [1].

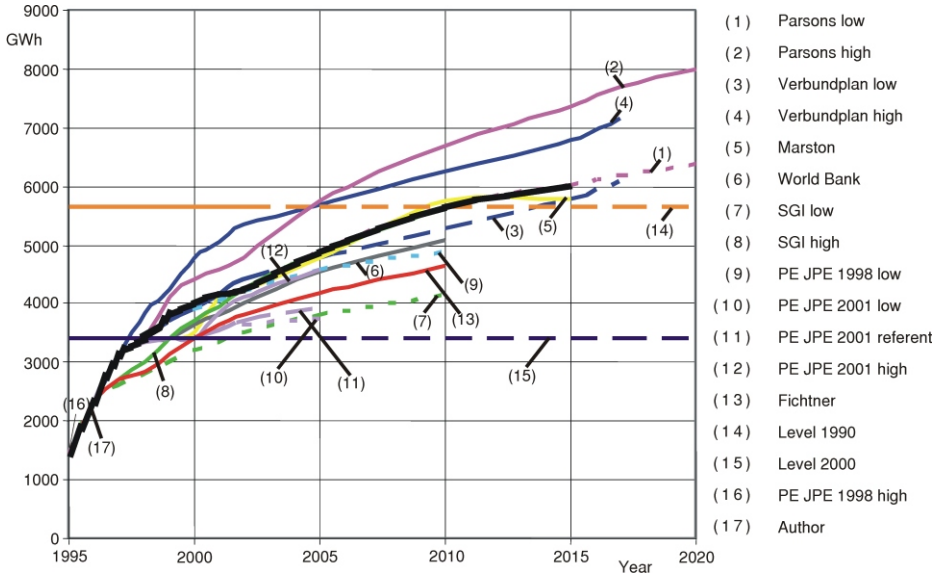

Figure 1. Estimation of electricity consumption in domain of PE JPE – the largest electricity producer in Bosnia and Herzegovina

Sustainability of energy system of Bosnia and Herzegovina

Thermal power plants take the mean load in the electricity generation in B&H. In year 2000, the electricity generation in thermal power plants took 73% of overall electricity generation. All thermal plants in B&H are conventional pulverised coal-based power stations, which burn low-valuable domestic coals, resulting in a limited efficiency from one side and strong environment impact from the other side. More technical data on coal-based power plants are given in tab.1.

Table 1. Characteristics of thermal power plants in Bosnia and Herzegovina

Plant	Put in operation	Coal	Heat rate in 2003 [kJ/kWh]	Capacity factor	Installed capacity [MW]	Technical minimum [MW]	Available capacity	
							for energy [MW]	for steam [MW]
Tuzla A1	1964	LB	14,855	0.8	32	18	0	0
Tuzla A2	1964	LB	16,072	0.8	32	19	0	0
Tuzla A3	1966	LB	13,986	0.9	100	82	85	43
Tuzla A4	1971	LB	11,629	0.9	200	145	182	50
Tuzla A5	1974	LB	12,752	0.9	200	145	180	5
Tuzla A6	1978	B	11,391	0.9	215	145	188	5
TUZLA F		B	11,934		779	554	635	103
Kakanj A1	1956	B	15,450	0.8	32	18	0	
Kakanj A2	1956	B	15,450	0.8	32	18	0	
Kakanj A3	1960	B	15,450	0.8	32	18	0	
Kakanj A4	1960	B	16,700	0.8	32	18	0	
Kakanj A5	1969	B	13,507	0.8	110	55	100	6
Kakanj A6	1977	B	13,581	0.8	110	55	90	6
Kakanj A7	1988	B	11,803	0.9	230	103	208	5
KAKANJ F			12,545		578	285	398	17
GACKO RS	1983	L	11,466	0.9	300	180	265	
UGLJEVIK RS	1985	B	11,553	0.9	300	180	268	
Total B&H					1,957	1,199	1,566	120
Total PE JPE			12,158		1,357	839	1,033	120

B – brown coal; L – lignite; LB – lignite and brown coal; F – Federation of B&H; RS – Republic Srpska

Although most of the units have been modernized in last recent years, the environment issue is still outstanding; the plants are still not equipped either with sulphur extraction or nitrogen oxide capturing facilities (fig. 2).

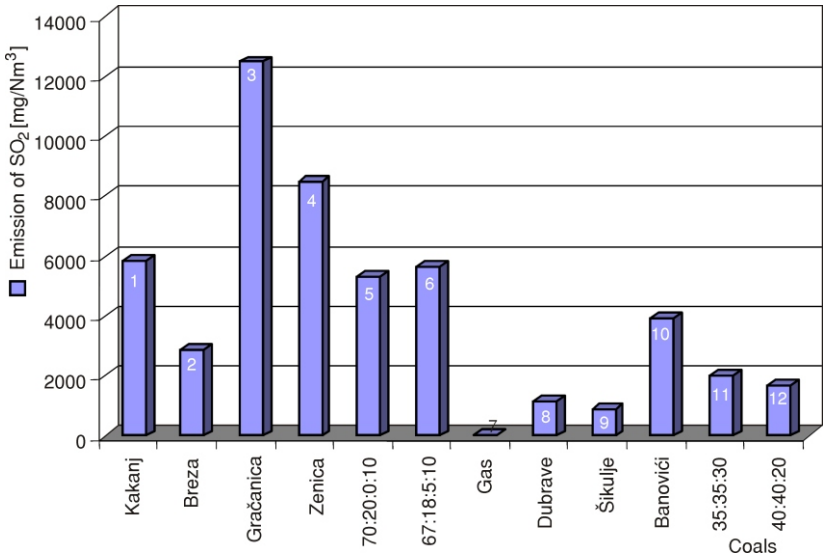

Figure 2. Emissions of SO_2 for combustion of domestic coals [4]
By columns 5 and 6 are given emissions for blends of previous 4 coals for given share, by columns 11 and 12 are given emissions for blends of previous 3 coals for given share

Beside high emissions of sulphur dioxide and nitrogen oxide from these plants, total emission of carbon dioxide is considerable as well, tab. 2, [2].

Table 2. Emissions of carbon dioxide in domain of PE JPE in year 2003

Year 2003	TPP Tuzla	TPP Kakanj	HPP Neretva	Small HPP	Total
$P_{\text{el + therm}}$, [MWh]	2.712,847	1.569,997	1.359,000	66,000	5.707,844
m_{CO_2} [t]	3.519,303	2.000,590	54,360	0	5.574,253
e_{CO_2} [g/kWh]	1,297	1,274	40	0	977

The mentioned relates to the need for an extensive utilisation the available renewable energy resources in future development of energy power system of B&H. This should give a significant contribution to the sustainability improvement of the electricity generation, by reducing the total emission of carbon dioxide originated from energy power system of B&H.

Renewable energy resources under consideration

Renewable energy resources, which could be used for the electricity generation in B&H, are:

– small hydro power plants,
– wind energy,
– landfill waste gas energy, and
– geothermal energy, [1].

Small hydro power plants

At present, 13 small hydro power plants of maximal load capacity of 28.38 MW in B&H are in operation, [3, 5]. Furthermore, 293 potential micro locations for installing small hydro power plants are under evaluation. The potential capacity is 144.75 MW. Among this, four small hydro power plants near town Fojnica are in final phase of construction.

Wind energy

Wind energy potential

Preliminary selection of potential locations for installing wind power plants in B&H is performed. Temporary, 12 locations are marked as good-potential, mainly situated in southern part of the country. Total estimated installed capacity is 720-950 MW, implying annual production of 1,440-1,950 GWh. Global evaluation of quality of the regions B&H is relying on existing data. According to the data issued by Meteorological institutes in B&H, and preliminary measurements performed on these locations, the region of Southern B&H has the strongest potential for electricity production from wind. Thus, extended area of *Podveležje*, situated app. 30 km from Adriatic see, is very convenient for wind energy utilization.

Especially interesting investigation is being performed in mountain-prevailing Sarajevo region. The investigation should give the answer whether the wind-power utilisation is possible in mountain-prevailing regions with strong winters. Evaluation of selected micro locations within this macro location is done, and the used methodology is briefly presented here.

Methodology for evaluation

First, tables with data on frequency and velocities of wind for Sarajevo area are formed, based on inputs provided by measurements. Charts in figs. 3 and 4 generally show frequencies and velocities of wind in respective directions on mountain site Bjelašnica and in settlement Butmir [3, 5]. It can be seen that the average wind velocity in Butmir site is about 2 m/s, so this location is rejected in preliminary evaluation by the technological criteria *wind velocity*. In opposite to this, wind velocity on Bjelašnica site is

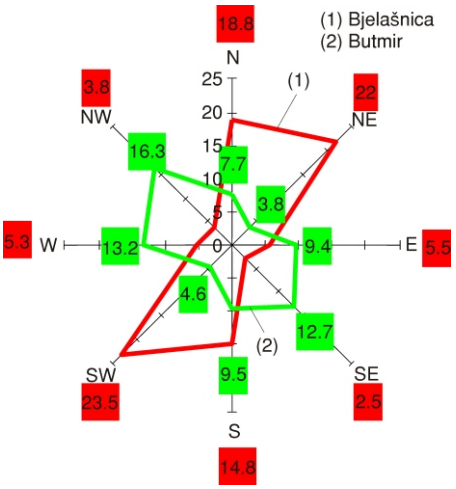

Figure 3. Wind frequencies in respective directions in regions of Bjelašnica and Butmir sites

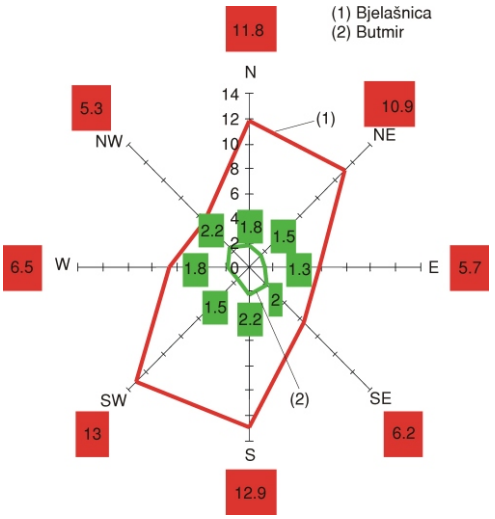

Figure 4. Wind velocities in respective directions in regions of Bjelašnica and Butmir sites

shown as very convenient, especially in directions NE–SW and N–S, so this region is considered in further evaluation.

By use of relation (1), the wind velocity at different altitudes can be estimated by calculation:

$$\frac{v}{v_0} \quad \frac{H}{H_0}^{\alpha} \tag{1}$$

where: v is the wind velocity for Bjelašnica site, v_0 – wind velocity for Butmir, H – altitude of top of Bjelašnica H_0 – altitude of settlement Butmir, and α – average value of 4 prevailing directions.

Results of this calculation for Bjelasnica site are given in fig. 5 [1].

On the base of presented data, using criteria *wind velocity*, *wind frequency*, *available surface*, and *nearest of the existing road*, four micro location are selected for further assessment:

– top of mountain Bjelašnica, altitude 2,067 m A. S., wind velocity 12 m/s, near the existing road and high voltage line of 10 kV,
– location "Lokve", altitude 1,300 m A. S., wind velocity 6,1-7 m/s, near the existing road, but far from high voltage line of 10 kV,
– location "Djurino Brdo" (above Malo Polje – Igman), altitude 1,510 m A. S., wind velocity 7,6-8,4 m/s, near the road and transformer station, and
– location "Lisičija Glava", 1,700 m A. S., wind velocity 9-10 m/s, near the road and high voltage line of 10 kV.

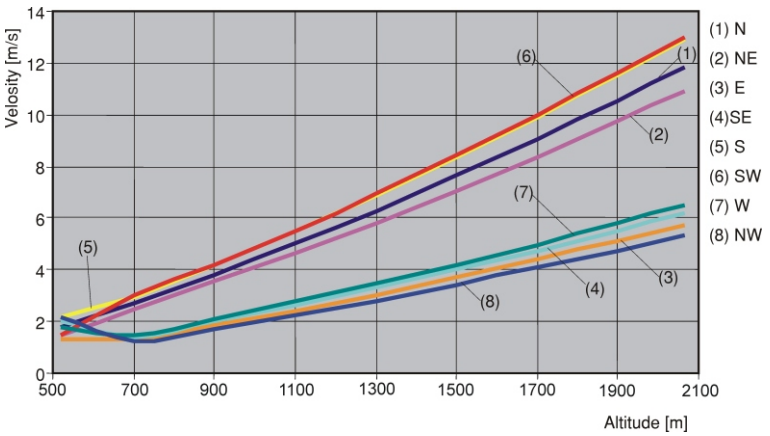

Figure 5. Estimated wind velocities for different altitudes

To make a valuable comparison between to each other, an annually production of 20 GWh is assumed for all four options, based on app. 10 MW of installed power and app. 2000 of working hour for each considered location.

Finally, by employing additional economic criteria *electro-transformer equipment and arrangement of high voltage line,* which directly affect the investments, two of these locations are evaluated as the most convenient, tab. 3.

Table 3. The most convenient locations for installing the wind turbines in Sarajevo area

Location characteristics	Top of Bjelašnica	Lisiičja Glava
Average velocity	12 m/s	10 m/s
Altitude	2,067 m A. S.	1,762 m A. S.
Maximal power coefficient	0.4	0.4
Rotor diameter	40 m	40 m
Power	451 kW	274 kW
Wind turbo-generator power	600 kW	450 kW

Using of waste gas from landfill waste deposit

Recent investigation on landfill waste deposit Buća Potok – Smiljevići nearby Sarajevo has shown that it is feasible to obtain about 2 MW_e, using waste gas from this source [1, 3]. As the first step of the Project, a small gas turbine power plant of 350 kW_e

was installed and entered into operation in year 2001. Its capacity of 0.350 MW gives an annual electricity production of 0.52 GWh. This power plant is connected to the local voltage network.

Geothermal energy

Beside already exploited geothermal water resources in location Ilidža – Sarajevo (water temperature is 58 ºC), the project of utilisation geothermal water from three boreholes (water temperature of 120 ºC) is being carried out, [1, 3, 5]. Warm water mass flow is 100 kg/s. Beside its use in agriculture, for district heating, tourism and mineral water treatment, this geothermal source is planned to be used for electricity generation as well.

Conclusions

Taking into account indisputable need for improvement the sustainability of energy power system of Bosnia and Herzegovina, as well as convenient conditions for the utilisation of renewable energy resources at some locations, a more extensive utilisation of renewable energy resources can be expected in the future. On the base of initial evaluation of possibility for utilisation of renewable energy resources in Bosnia and Herzegovina, renewables as small hydro power plants, wind energy, landfill gas energy and geothermal energy are indicated as good-potential sources for electricity generation. By implementation of the planned projects, specially concerning small hydropower and wind energy utilisation, global figure of carbon dioxide emission in Bosnia and Herzegovina can be improved. Evaluation of wind utilisation in Sarajevo area presented in this paper, indicates a possible methodology – *i. e*. a concept of assessment and selection optimal micro-locations within the same option of renewable energy sources. Input data based on measurements are key point in such evaluations. Further providing the reliable inputs and results measurements (on sites) is major task in the next period.

Following the renewables energy resources potential presented here, it can be concluded that utilisation of renewable energy resources should be significant contribution to sustainable development policy in Bosnia and Herzegovina.

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