IMPACT OF NEW POWER INVESTMENTS UP TO YEAR 2020 ON THE ENERGY SYSTEM OF BOSNIA AND HERZEGOVINA

by

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This paper investigates current and planned investments in new power plants in Bosnia and Herzegovina and impact of these investments on the energy sector, CO_2 emission, and internationally committed targets for electricity from renewable sources up to year 2020. Bosnia and Herzegovina possesses strong renewable energy potential, in particular hydro and biomass. However, the majority of energy production is conducted in outdated power plants and based on fossil fuels, resulting in environment pollution. The new major investments – Stanari Thermal plant (300 MW) and Block 7 (450 MW) at the Thermal Plant Tuzla are again focused on fossil fuels. The power sector is also highly dependent on the hydrology as 54% of current capacities are based on large hydro power. In order to investigate how the energy system of Bosnia and Herzegovina will be affected by these investments and hydrology, the EnergyPLAN model was used. Based on the foreseen demand for the year 2020, several power plants construction and hydrology scenarios have been modelled to cover a range of possibilities that may occur. This includes export orientation of Stanari plant, impact of wet, dry and average year, delayed construction of Tuzla Block 7, constrained construction of hydro power plants, and retirement of thermal units. It can be concluded that energy system can be significantly affected by delayed investments but in order to comply with renewables targets Bosnia and Herzegovina will need to explore the power production from other renewable energy sources as well.

Key words: *thermal plants, renewable energy, energy system, energy planning, EnergyPLAN model, CO_2 emission*

Introduction

Energy sector of Bosnia and Herzegovina (B&H) is considered as the sector with the strongest long term development potential based on the proven resources of hydropower and coal and strong potentials of other renewables. The present supply of electricity is above the current demand and in 2013 net export was 3,695 GWh [1]. The majority of electricity comes from thermal plants. From the total 15.7 TWh in 2013, 55.6% has been produced in thermal plants and remaining 44.4% in hydro plants. Good hydrological conditions have enabled hydro production to be 83.1% higher than in 2012 resulting in total 28.4% more electricity produced than

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in the year 2012. But hydrology is not always so favourable. The production from hydro sources was just 31.3% of the total in 2011 and represented only 55% of the hydro electricity produced in 2010. Additional illustration of impact of hydrology is a fact that lower hydro production rate resulted that B&H had negative balance for two months in 2009, 4 months in 2010 and 7 months in 2011.

Power transformation leads to high losses due to largely outdated or aging equipment and technologies and B&H is an energy intensive country. According to the IEA [2] energy intensity of B&H is estimated at 0.54 toe of primary energy per thousand USD (2005) of gross domestic product (GDP) meaning that B&H needs almost five times more energy than the average in EU (0.11) to produce the same living. Reliance on fossil fuels means increased CO_2 emissions. In 2011 the result was 22.81 Mt of CO_2. The highest share in this emission comes from the energy sector, accounting for 92% of the total [3]. Carbon intensity of 1.76 kg CO_2/GDP is seven times higher than the average in EU (0.24). B&H has no specific targets for energy from renewable energy sources (RES) but as a member of Energy Community [4] the target for the share of renewable energy in Gross Final Energy Consumption (GFEC) in 2020 is set to 40%. The basis for calculation was year 2009 when reference RES share was 34%. These targets have been transferred into local Action plans for use of RES. The Federation B&H plans to increase the share of RES in GFEC from 36% (in 2009) to 41% up to 2020 [5]. Action plan of RS is based on the increase from 42% (in 2009) to 48% [6].

Energy system of B&H is not planned by a specific level state energy policy or strategy. Energy Sector Study of B&H [3] gives projections of the sector development under different scenarios until 2025. Strategic Plan of Federation B&H up to year 2020 [7] and Energy Strategy of Republika Srpska up to year 2030 [8] envision significant changes in the power system in terms of commissioning new generation capacities and closure of some of the existing thermal facilities.

Several papers have been focused on energy system planning in the Western Balkans. In article [9] Serbia has been taken as a case study for planning an energy system dominated with lignite thermal plants. Wind energy integration in energy system based on conventional plants is analysed in the case of Croatia [10], Serbia [11], and Macedonia [12]. Renewable energy solutions for Western Balkans have been proposed [13]. Role of renewables for climate changes mitigation in B&H is given [14]. Impact of hydrology on the energy system of Croatia can be found [10] and on the Macedonian power sector [15].

As B&H is exporter of electricity the purpose of the paper is to answer question whether there is a need to invest in new facilities in order to satisfy expected demand up to year 2020. This will be done for three different hydrology cases – *wet*, *average* and *dry* year. Other goals are to investigate how the B&H energy system would be affected by delays or lack of investments into new electricity generating facilities, or if some of them are producing only for export, and the effect of planned investments on the RES targets and CO_2 emission.

Methodology

An overview of a number of energy tools and models used for energy planning and analysis of various policy measures or investments is given [16]. Considering aim of the paper, the EnergyPLAN [15] model has been chosen. This computer model, an hour-simulation model, is mainly designed for energy systems analysis on the level of a country or a region. It is well suited to perform analysis of intermittent renewables or different water inputs of hydropower plants. General inputs in the model are demands, renewable energy sources, energy plants capacities, costs and a number of optional different regulation strategies including import or export and excess electricity production. Outputs are energy balances and annual productions, fuel consumption, import/export of electricity, and total costs including income from the exchange of electricity. Schematic diagram of the EnergyPLAN model is presented in fig. 1. The model can be used for technical analysis, for market exchange analysis, and feasibility studies. In the case of the market exchange analysis, each plant optimises according to businesses-economic profits, including any taxes and CO_2 emissions costs. Technical analysis is used for large and complex energy systems where different technical regulation strategies can be applied. The technical regulation minimises the import/export of electricity, trying to see how system can be self-sustainable and seeking to identify the least fuel-consuming solution. The model has been used for the technical and economic implications of integrating fluctuating renewable energy using energy storage in Ireland [18] and for analysis of energy systems with a high share of combined heat and power (CHP) and wind power in Denmark [19], also for the design of way for 100% renewable energy systems of Croatia [20], Denmark [21], Portugal [22], and Australia [23].

As the paper tries to answer the question of meeting national demand, in this paper a technical optimization analysis has been selected with regulation strategy that tries to balance both heat and electricity demands. This implies a closed energy system. In that case EnergyPLAN works in such way that the total demand for heat and electricity is provided within the system by a country own production. Calculation of RES share in the GFEC has been done outside of the EnergyPLAN model as model calculates only the RES share in the total primary energy supply.

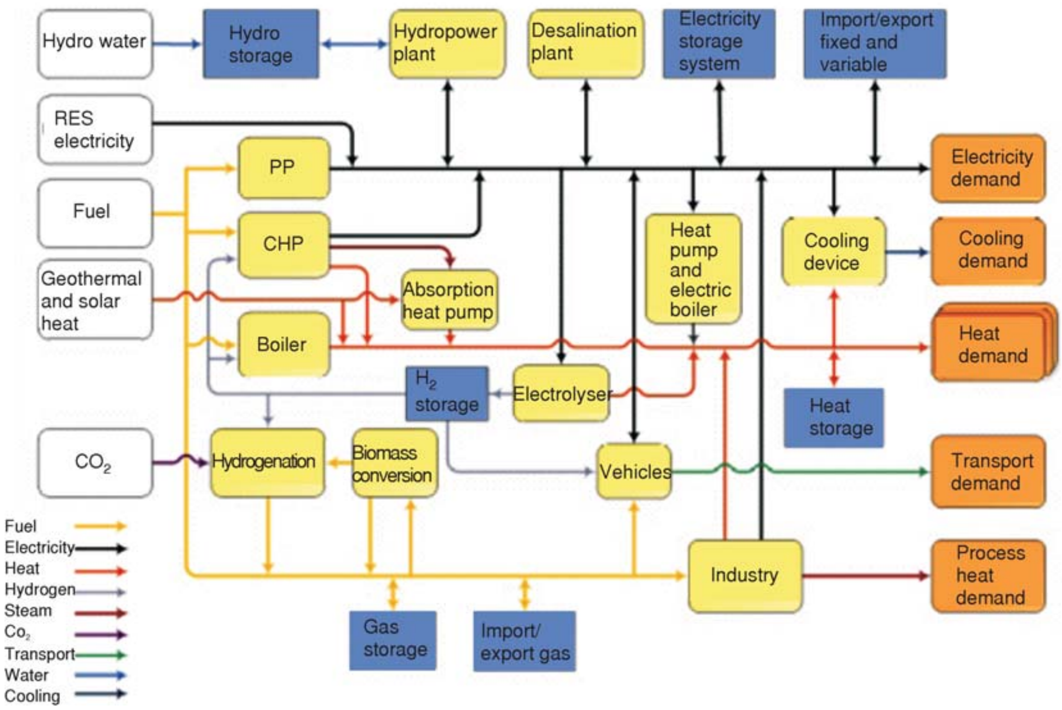

Figure 1. Components of the energy system in the EnergyPLAN model, version 11.1 [17]
(for color image see journal web site)

Energy system of B&H

Reference energy system

As a first step the energy system of B&H for year 2011 has been reconstructed in the model. Year 2011 was taken as a reference year since it was the last year for which statistical energy balance data were available [2]. The production capacities of installed hydro and thermal plants have been obtained from the system operator [3]. Hourly load data of B&H electricity power system have been obtained from ENTSO [24] electronic data database. Hourly production data of storage and run of river hydro plants have been created on the basis of data from [24-26]. Wind power production was calculated using wind speed measurement on the potential wind plant site Poklecani [27], near Mostar during 2009 and 2010. Photovoltaic (PV) production was calculated using outputs of PV plant built by Ivex energy from Usora for the year 2013 [28]. Temperature and insulation data were provided by entity hydro-meteorological institutions [29-31]. Based on them a load curve for hourly district heating demand has been calculated by using degree-day and temperature. Heat production from thermal plants (cogeneration plant) has been combined with district heating demand and represented with one hourly demand curve.

Currently there are 15 larger hydro plants (HP) and 4 thermal power plants (TP). Only one plant, Mostarsko blato (60 MW), has been put in operations during last 30 years (in 2010). The combined capacity is 3,825.6 MW, of which 2,060.6 MW is in HP and 1,765 MW is in TP. On the distribution network is also connected 87.43 MW of small renewable plants of which 85.9 MW, are small HP.

Few restrictions are set in the model. The technical minimum of thermal plants is initially set at 1065 MW [1]. Another condition is that at least 30% of the produced electricity (at any hour) comes from power units able to produce ancillary services such as thermal plants of hydro plants. Reference case calculated by EnergyPLAN model has been compared to publically available data and the conclusion is that it fits well and represents the situation in 2011.

Supply and demand

To define dependency of hydro plants from hydrology the production data from year 2003 to year 2013 have been analysed. As it was expected the production significantly varies across this period. Years 2009, 2010, and 2011 have been selected as indicative and representative (fig. 2). Year 2011 is considered as a "dry year", year 2010 as a "wet year" and year 2009 is between them and it is considered as "average year". In these years the highest hydro production from hydro resources was 7.9 TWh in 2010 and lowest was 4.3 TWh in 2011. Using these data adequate distributions have been created which enable analysis of impact of hydrology in future years.

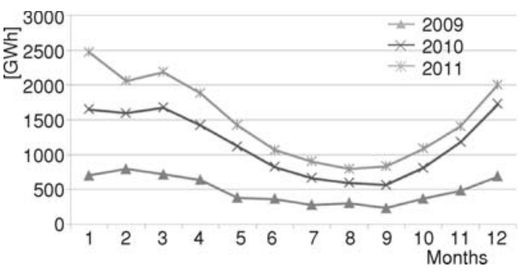

Figure 2. Total monthly electricity production from HP in B&H for years 2009-2011 [24-26]

The consumption has not been growing. But according to Energy Sector Study [3] for the reference scenario, the demand on the network was supposed to increase to 15.47 TWh in 2015 and 17.88 TWh in 2020. The strategy of RS [8], done after the global financial crisis, envisions lower demand and system operator [1] again much lower. If one compares those figures it can conclude that B&H is at least 5 years in delays to estimated economic development.

Initial calculations in this paper will be created for two demand scenarios. First one will be the one from Energy Sector study, but for year 2015 (as demand for year 2020 in order to account the crisis) resulting in total demand of 18.25 TWh. Second scenario will be based on the demand of 16.36 TWh [1]. Note that in order to calculate correct values of CO_2 emissions, 18% was added on top of the demand on the network to account for own use and losses as according to IEA [2] during last couples of years they account for 18-20% of the total electricity produced depending of the year.

Scenarios for the energy system 2020

Based on the data and hourly distribution curves scenarios for the year 2020 have been created by expanding the 2011 scenario and including some of the assumptions and energy balances made in the Energy Sector Study. The register of new capacities includes several thermal plants, 46 hydro power plants (2,221 MW) and 48 wind power plants (2,804 MW) [1]. These plans are ambitious but obviously unrealistic and dynamics highly questionable, as the level of technical documentation is low in most cases. The only plant that will cease its work by 2020 is TP Tuzla G3 (100 MW). Table 1 gives a list of significant plants which have some chances to be built in the coming period.

Table 1. New production capacities up to year 2020 [1]

Year/plant [MW]	2016	2017	2018	2019
HPS Dub and Ustipraca		17.1		
HP ulog		34.4		
Small HP Sutjeska		19.15		
HP Vranduk			19.6	
HP Dabar				159.9
TP Stanari	300			
TP Tuzla block 7				450
Gas plant Zenica		387.5		
Wind plant Trusina	51			

Note! In 2015 and 2020 – no new production capacities

As year 2020 presents relatively short time horizon, the following analysis will try to create some realistic scenarios which may happen depending on the various investment circumstances or environmental concerns. An overview of the installed capacities in the scenarios is given in tab. 2. The first, business as usual scenario (BAU) is the case under which no significant power plant will be completed by 2020 except TP Stanari. For this scenario three hydrology scenarios, dry, average and wet, have been created.

Scenario 2 is the same as BAU but TP Stanari is modelled as fixed export under constant hourly distribution taking into account planned production. For this case hydrology scenarios have been created as well. Scenario A includes all plants identified in tab. 1. Gas plant is modelled separately from other thermal plants as CHP plant which can provide heat only or electricity only if needed. Scenario B is same as scenario A but without CHP gas plant. The assumption is that price of gas or lack of supply can stop or postpone planned construction, or that investor can lose interest. Scenario C is thermal plants only scenario as plants HP Dabar and HP Ulog are not built. Scenario D includes additional decommissioning of old thermal blocks of Tuzla G4 (200 MW) and Kakanj G5 (110 MW). Scenario D1 is scenario D in the case of dry hydrology. Scenario D2 is the same but in addition TP Stanari works for exports only. Last scenario E is renewables only scenario. Under this scenario in addition to decommissioning of old blocks TP Tuzla 7 is not built.

Table 2. Installed capacities in the scenarios

Scenarios	Thermal [MW]	Large hydro [MW]	Run of river [MW]	Wind [MW	PV [MW]	CHP gas	Biomass [MW]	Stanari export	Dry hydro	Thermal minimum
BAU	1965	2060.6	100		1					1165
Scen 2	1965	2060.6	100		1			Yes		1165
Scen A	2415	2254.5	160	51	5	387.5	25			1350
Scen B	2415	2254.5	160	51	5		25			1350
Scen C	2415	2060.6	160	51	5		25			1350
Scen D	2105	2254.5	160	51	5	387.5	25			1165
Scen D1	2105	2254.5	160	51	5	387.5	25		Yes	1165
Scen D2	2105	2254.5	160	51	5	387.5	25	Yes	Yes	1165
Scen F	1655	2254.5	160	51	5	387.5	25			980

Results and discussion

Need for construction of new plants

The results presented in tab. 3 prove that B&H needs to start construction of new power production facilities as soon as possible. B&H can satisfy future consumption demand in critical years only if thermal plants work extensive hours. Also, thermal plants need to work at peak capacity so often that in the case of dry hydrology average is close to maximum of rated capacity. Even in the case of more pessimistic, minimal increase of demand all thermal plants need to work only for domestic market to satisfy that demand. In the case that TP Stanari, as a merchant plant, exports electricity abroad, the capacity factor, defined as average power/rated power, increases significantly. In the case of dry year the TP work constantly across the year. The capacity factor goes up to almost 80% for demand of 16.3 TWh or even above 88% in the case of demand of 18.25 TWh. This is practically impossible in particular for an old energy sys-

Table 3. Thermal plants production in year 2020

TP Production	Demand 18.25 TWh						Demand 16.36 TWh					
	BAU			Scenario 1 (Stanari export)			BAU			Scenario 1 (Stanari export)		
	Dry	Avg	Wet	Dry	Avg	Wt	Dry	Avg	Wet	Dry	Avg	Wet
Average [MW]	1545	1402	1305	1733	1586	1425	1370	1270	1218	1571	1393	1292
Maximum [MW]	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965	1965
Minimum [MW]	1165	1165	1165	1165	1165	1165	1165	1165	1165	1165	1165	1165
Total [TWh]	13.57	12.32	11.46	15.22	13.93	12.51	12.03	11.16	10.7	13.8	12.23	11.35
Import [TWh]	0.11	0.04	0.02	0.39	0.06	0.02	0.01	0	0	0.18	0.01	0.01
Export [TWh]	0.08	0.44	1.21	0.01	0.08	0.46	0.33	1.14	2.33	0.27	0.35	1.17
Capaciti factor [%]	0.79	0.71	0.66	0.88	0.81	0.73	0.70	0.65	0.62	0.80	0.71	0.66
Negative balans [months]	2	2	2	9	6	1	2	1	0	4	0	0

tem as it is the one of B&H. And even if these capacities are used extensively the number of months with negative energy balance in worst case goes up to 9. Export potential exists only in the case of lower demand during wet or average hydrology.

Selection of plants

Table 3 shows that if no other significant production capacity is added to the system the capacity factor is 0.63. From fig. 3 it is visible that capacity factor stays equal in the first three scenarios A, B, and C. Minimal increase occurs in the case of decommissioning of old plants (Scen. D) suggesting that in the case of building new thermal plants, old thermal blocks can be decommissioned without any significant impact on the energy system of B&H.

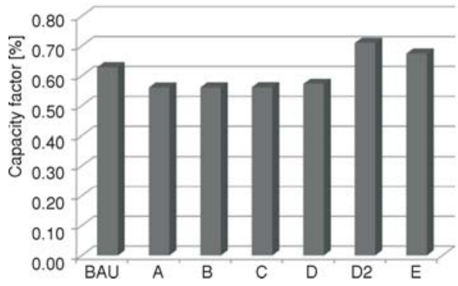

Figure 3. Capacity factor of TP for different scenarios, year 2020 (demand 16.3 TWh/year)

The situation is slightly worsened during the dry season but even in the case that Stanari exports entire production the renewed energy system will be capable to satisfy local demand. In the case of Scenario E, which represents only construction of renewables plants in addition to Stanari plant, capacity factor understandably increases to 0.67 to compensate for lost capacity. In the case of dry hydrology this would be higher and indicates that this minimal renewables installation is not sufficient suggesting that the construction of a new power capacity as in TP Tuzla, Block 7 is necessary if B&H wants to ensure local electricity supply. As there are less thermal plants in the system renewables become more dominant and consequently RES share increases (fig. 4.).

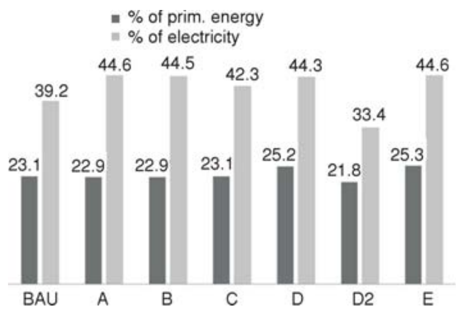

Figure 4. RES share as a percentage of primary energy and electricity, year 2020 (demand 16.3 TWh/year)

RES share of primary energy ranges from 22.9% in the case of scenario A to 25.3% in the case of scenario E. Share of renewables in the electricity is correlated to hydrology in addition to installed capacities and ranges from 33.4% in the case of scenario D2 to 44.6% in scenario E. Action plan for use of RES resources in the Federation B&H envisions 4% increase in RES share in electricity [5] and for example indicative goal for wind power plants is 230 MW. Similar situation is in Republika Srpska. Envisioned RES share increase in electricity is 12.1%. Obviously new investments do not increase share of RES in electricity.

Under previously mentioned assumptions, in some cases critical electricity excess production/export (CEEP) is observed (fig. 5), meaning that the technical regulation strategy used for the balancing energy system is not sufficient and CEEP can occur. CEEP is the mismatch between supply

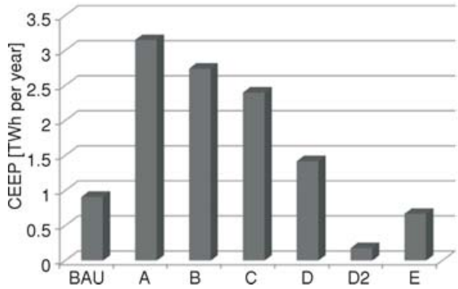

Figure 5. Critical electricity excess production for different scenarios

and demand, and shows the inability of the energy system to absorb the extra electricity. This is actually minimal export potential for certain scenarios and it is highest 3.15 TWh in the case A when all planned plants are built.

Figure 5 shows that in this case, under average hydrology conditions, there is certain over capacity of thermal plants in B&H. This proves that in that case old plants may be decommissioned, in particular considering their efficiency and impact on CO_2 emission which can be observed in fig. 6. This also underlines assumption that some of these new facilities are planned for export. Under these conditions B&H can satisfy its needs even if TP Stanari works for export only.

Data from figs. 4 and 5 suggest that impact of gas CHP plant Zenica on the energy system of B&H under this regulation strategy is minimal. The selected regulation strategy tries to balance heat and electricity demand, and takes into account current relatively low district heating demand in Zenica but also shows that this plant will not be engaged for so many hours as indicated in the planning document. Considering current high gas prices in Europe and low coal prices in the local market it is hard to believe that electricity produced in this plant will be competitive. If one of two planned thermal plants is not built or in the case of dry hydrology that plant should become more important, it is still questionable how many hours this plant will operate. Further analysis is needed to show if heating of Zenica alone without electricity production, or with limited electricity production can justify such an investment. The analysis should include other options as well such as use of waste heat from industry or use of TP Kakanj as a combined heat and power plant. It should not be surprise if the investors further postpone this investment under current conditions.

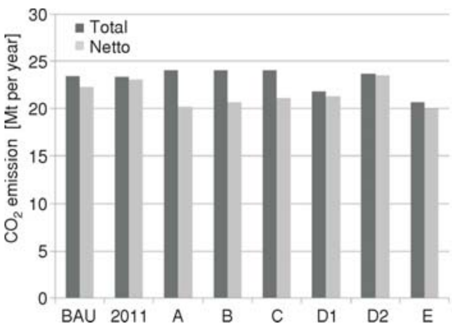

Figure 6. CO_2 emission in year 2020 under different scenarios and comparison with

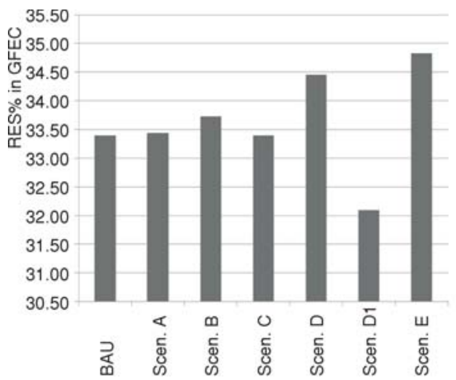

Figure 7. RES share in GFEC in B&H in year 2020 for different scenarios

Environmental evaluation

The CO_2 content in the fuels has been used in order to calculate associated emissions with each of the scenarios. As B&H is an energy intensive country the selection of future plants and their efficiency is of significant importance.

If dominant source of energy for power generation continues to be coal, this will lead to increased CO_2 emission as it is illustrated in fig. 6. The CO_2 emission reduction can be achieved in two cases. As it is expected in the case of decommissioning of old energy inefficient thermal blocks or in the case if Block 7 is not built at all. In that case, CO_2 emission decreases from 24.06 Mt/year in initial scenarios to most favourable 20.71 Mt/year in scenario E.

Figure 7 shows the impact of new and proposed investments on the RES share in GFEC. It is obvious that these new investments are not bringing B&H closer to set targets, and rather keep it almost on the same level as the starting point. The focus on thermal plants and investments in limited number of hydro plants means that B&H will not meet these targets. Only in the case of favourable hydrology (scenario D) or renewables only scenario (E) RES share in GFEC increases above 34%. B&H will have to do more if wants to change this situation and explore other renewables options. Significant unused hydro potential is available if environmental concerns can be overcome. 350 MW of wind power can be added to the power system without any problems [26]. And finally B&H biomass potential for both the provision of heat and electricity need to be further analysed.

Conclusions

In this paper an energy system of B&H for year 2020 has been designed. Several scenarios have been analysed. The analysis shows that despite current significant electricity export B&H needs to invest in new energy plants in particular if energy demand increases in the future. B&H can satisfy future consumption demand in critical years only if thermal plants work extensive hours. In the case of dry hydrology minimal investments in renewables installation, as currently envisioned, are not sufficient suggesting that the construction of a new power capacity as in TP Tuzla, Block 7 is necessary if B&H wants to ensure local electricity supply. It can be concluded that the security of energy is undermined by delays in investments and technological progress. But investment into thermal plants keeps the country on the level of 34-35% of RES share in GFEC. Also, if the country wants to decrease CO_2 emission and satisfy internationally binding emission requirements inefficient blocks of thermal plants need to be decommissioned as soon as possible. Environmentally most friendly solution for B&H, but still satisfying future needs, is to invest into renewables and only limited capacity of thermal plants which will replace old thermal blocks. If new thermal plants solutions do not satisfy EU directives in power after 2018 [32] B&H can face significant problems in its relations with the Energy Community and European Union. The analyses have also proved that planned investments are primarily export driven. Planned investments are not result of any strategic exercises, environmental obligations or priorities' setting. They are primarily driven by investors' whish or based on the coal potential. This is further emphasized by internal division where three public companies look at only their territories and not on the energy system as a whole. This may lead to expansion of environmentally not so friendly energy capacities in the future. This leads to conclusion that B&H needs to start immediately work on its new energy policy that needs to integrate use of strong potential for renewable energy and energy efficiency, and strengthen local capacities for energy production, taking into account the climate, geographic and technological conditions. That is the only way B&H can meet internationally accepted obligations and satisfy future demand. If energy potential is developed in a timely manner considering all factors it can have significant positive impacts on the economic balance of the country otherwise B&H can be stuck with fossil technologies for decades.

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