

PROSPECTIVE THERMAL POWER GENERATION IN THE WESTERN BALKAN COUNTRIES

by

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The aim of this paper is to analyse the expansion of the thermal generation in the long-term for the Western Balkan region. This paper concentrates on the estimation of long-term energy data for the (Western) Balkan countries. The process was implemented by the use of the PRIMES model in order to perform simulations for the future growth of electricity supply and demand in the region. Two scenarios were applied. The first (Baseline) scenario was based on the current energy path of each country and on the absence of any specific energy policy like tax emissions or renewable subsidies. The second (Reference) scenario was practically a series of "environmental" sub-scenarios, based on specific energy subsidy policy applied to the electricity generated by renewable sources. Results were given for the period between 2015 and 2050 in 5-year steps and conclusions were made for the whole region. As such, the results can feed up trials of energy planning referring to the future energy condition.

Key words: *thermal generation, Western Balkan, PRIMES model, electricity supply, energy policy*

Introduction

General description

The Western Balkans countries are geographically situated in the region of the South-eastern Europe, an area which has always functioned and still functions as a crossroad of cultures between the European and Asian continents. The Western Balkan countries are Albania, Bosnia & Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia (FYROM), Montenegro, Serbia, and UNMIK/Kosovo**. These countries are strategically located between hydrocarbon-rich regions including Russia, the Caspian basin and the Middle East, and the energy-consuming regions of the Central and the Eastern Europe, [1]. As a result, the Western Balkan region has the potential to act as a strategically dominant factor in the transit of hydrocarbon resources, and in the diversification of oil and gas supply, both for the considered region and Europe [1]. The main characteristic of these countries is that with the exception of Albania, until the early 90's they were a single state, that of the former Yugoslavia. This means that these countries in many sectors, including those of energy and economy, show similarities, common struc-

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** This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and the ICJ Opinion on the Kosovo declaration of independence

tures, close relationships and interdependencies as they had shared the same infrastructure and financial operation before.

Because of the conflicts and the political instability during the decade of 1990 these countries suffered significant damage to their infrastructure. This is the main reason why they face serious problems and follow a different development in contrast to other European countries. Since then each country followed a separate course, at different political and economic pace.

In terms of regional energy policy and infrastructure development, the Western Balkan countries have all signed the Treaty establishing the Energy Community and agreed to follow the European Commission's Directives, where the main target is the creation of a regional energy market compatible with the internal energy market of the European Union (EU). The objectives of the Energy Community Treaty concern the creation of a stable regulatory and market framework, to attract investment in power generation and networks, to provide secure and sustainable energy supply, to increase the energy efficiency, to improve environmental issues and mitigate the climate change in relation with energy supply in the region, and to create an integrated energy market allowing for cross-border energy trade and integration with the EU market [2].

General hypotheses

In this paper, insight and development prospects are provided for thermal power generation in the Western Balkans in the long term. As will be mentioned in the *Economic and energy conditions in the Western Balkans*, thermal power capacities consist the core of the regional power system mainly because of the endogenous carbon resources [1, 3]. Assumptions can be derived answering on the question whether thermal facilities will continue to dominate and the levels of their participation in the regional energy mix. The main issue concerning these countries is the dilemma between “black and green” energy. Evidently, the implementation of renewable (RES) subsidy policies is directly connected to issues regarding modern policies according to the EU targets [4].

The actual European energy policy can be summarised by a trilemma of three objectives: security of supply, climate change and energy affordability. The main challenge for the Western Balkan countries is whether they will be able to achieve these three objectives simultaneously. The countries of the Western Balkans are at a critical status and the transition of energy trajectories is a strategic challenge as one of the greatest tests they have to tackle against [5]. This challenge results from the consequences of the climate change and the constant effort of lessening their dependence on energy imports and controlling their price system. Moreover, the aim of achieving a high level of energy security requires an increased standard of energy efficiency that improves the availability of energy flows.

Economic and energy conditions in the Western Balkans

The markets in the Western Balkans vary in size (tab. 1, [6]), wealth and development. Serbia is geographically the largest and most populous country, and Croatia is the second most populous in the series, but has the highest GDP compared to the others in the past decade, and the highest GDP per capita in the Western Balkan region. From these facts, it is assumed that Croatia is economically the most developed country so far in the region, and since June 2013 is member of the European Union. During the last 10 years significant economic growth in the Western Balkans has taken place. However, although the global financial crisis of 2008 had an impact on this evolution, it is expected that they will overcome these difficulties. The Western

Balkans' energy supply mix is heavily dependent on coal and oil. In short, a shift to cleaner fuels is evident and unavoidable. Also, low natural gas penetration on Western Balkans brings future growth opportunities.

Table 1. Western Balkan countries – selected indicators for 2011 [6]

Country	Population (million)	GDP (billion 2005 USD)*	Energy production (Mtoe)	Net imports (Mtoe)	TPES (Mtoe)**	Carbon dioxide emissions (Mt of CO ₂)	TPES/pop (toe/capita)	TPES/GDP (toe/10 ³ 2005 USD)
Albania	3.22	11.05	1.49	0.71	2.17	3.87	0.68	0.20
Bosnia and Herzegovina	3.75	13.04	4.62	2.36	7.10	22.81	1.89	0.54
Croatia	4.41	46.27	3.79	4.68	8.44	18.77	1.91	0.18
FYR Macedonia	2.06	7.28	1.78	1.43	3.12	9.07	1.51	0.43
Montenegro	0.63	2.89	0.79	0.40	1.18	2.50	1.87	0.41
Serbia	7.26	28.42	11.17	4.87	16.19	49.78	2.23	0.57
UNMIK/Kosovo	1.79	5.06	1.80	0.70	2.53	8.48	1.41	0.50

* GDP: Gross Domestic Product

** TPES: Total Primary Energy Supply

Considering the structure of the primary energy supply in the Western Balkans, lignite occupies a considerable proportion (about 38%) of the total primary energy production in the region, especially in Bosnia, Kosovo, and Serbia, where it is the main fuel for the operation of thermal power generation plants (tab. 2). Oil comes next: its share is about 37%, followed by natural gas 13%, hydroelectric energy 7%, and renewable energy sources (mainly through wind farms) 5% [1, 3].

As far as the electricity generation is concerned, as illustrated in tab. 2, Serbia occupies the largest total electricity generation, where lignite dominates as its share reaches the 74% of the total electricity produced. In Bosnia & Herzegovina, which follows Serbia considering the total generated electricity, thermal power generation dominates as it consists the 67% of the total generation. In Croatia, the electricity generation is (approximately) equally distributed between fossil fuels and renewable energy sources. It should be noticed that among the Western Balkans Croatian power system is the only one where wind farms have been incorporated so far. According to the European Wind Energy Association (EWEA), at the end of 2013 302MW of wind farms were in operation in Croatia. In Serbia, the construction of the first wind farm has already begun (within 2013), and it is expected to be completed in 2015. The use of lignite and natural gas with lower shares, are the main sources of the electric energy production in FYROM. Considering the Albanian power system, the structure of the local electricity generation heavily relies on the operation of the hydro power plants, and in lower levels on oil products. Consequently, Albania could be considered as a leader in the utilisation and exploitation (proportionally) of renewable energy sources in the region. The penetration of the solid fuel power plants in the Albanian power system will be one of the most important challenges to be faced, assuming that the electricity demand will rise in the long term.

Table 2. Electricity generation structure and total consumption per country in 2012

Country	Albania [7]	Bosnia & Herzegovina [8]	Croatia [8]	Montenegro [8]	FYROM [8]	Serbia [8, 9]	UNMIK [8-10]
Total generation [GWh]	4722	12234	9878	2783	5813	34509	5448
Fossil [GWh]	–	8426	4695	1240	4452	24665	5383
– Lignite	–	8426	–	1240	4471	24275	5383
– Coal	–	–	2024	–	–	–	–
– Gas	–	–	2063	–	281	350	–
– Oil	–	–	158	–	–	–	–
– Mixed fuels	–	–	450	–	–	–	–
Renewables [GWh]	4722	3808	5183	1543	1061	9844	65
– Wind	–	–	327	–	–	–	–
– Solar	–	–	0	–	–	–	–
– Biomass	–	–	77	–	–	–	–
– Hydro	4722	3808	4779	1543	1061	9844	65
Imports [GWh]	2538	4481	13168	3595	4281	6003	572
Exports [GWh]	297	4525	5564	2473	1629	5359	371
Electricity consumption [GWh]	7617	12124	17278	3905	8465	39628	5350

The “Primes” energy system model

General description

The methodology approach was based on the PRIMES energy system model, which has been developed by the Energy-Economy-Environment Modelling Laboratory of National Technical University of Athens in the context of a series of research programs of the European Commission [11-13]. The PRIMES model is a partial equilibrium model [11], simulating the entire energy system, both in demand and supply. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply matches the quantity consumers wish to use. The equilibrium is static, but repeated in a time-forward path, under dynamic relationships. The model is organised in sub-models (fig. 1), each one representing the behaviour of a specific or representative agent, a demander and/or a supplier of energy. The agent's behaviour is modelled according to microeconomic foundation: the agent is represented to perform maximisation of benefit (profit, utility, *etc.*) from energy demand and/or supply (for industry also from use of non energy production factors), under constraints that refer to activity, comfort, equipment, technology, environment or fuel availability. Microeconomic foundation is a specific feature of the PRIMES model and applies to all sectors. Although the decision is assumed to be economic, many of the constraints and possibilities reflect engineering feasibility and restrictions. The model thus combines economics with engineering, in order to ensure consistency, [11-13].

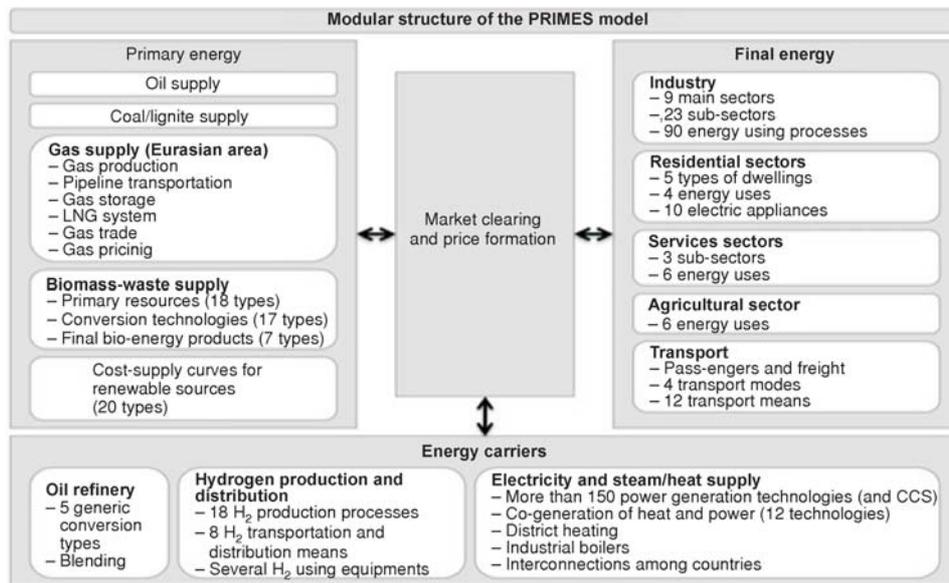


Figure 1. Modular structure of the PRIMES model [11]

The PRIMES model is more aggregated than engineering models and more disaggregated than econometric (or reduced form) models. It is a general-purpose model, conceived for energy outlooks, scenario construction and impact assessment of policies. It covers both medium and long-term horizons. It is modular and allows either for a unified model use or for partial use of modules to foster specific energy studies.

The model can support policy analysis in the following fields [12]:

- standard energy policy issues: security of supply, strategy, costs, *etc.*,
- environmental issues including climate change mitigation,
- pricing policy, taxation, standards on technologies,
- new technologies and renewable sources, and alternative fuels,
- energy efficiency in the demand-side,
- conversion decentralisation, electricity market liberalisation, and
- policy issues regarding electricity generation, gas distribution, and new energy forms.

The PRIMES model is organised, by the energy production sub-systems (oil products, natural gas, coal, electricity and heat production, biomass supply, and others) for supply and by the end-use sectors for demand (residential, commercial, transport, nine industrial sectors). Some demanders may be also suppliers, like the industrial co-generators of electricity and steam.

Typical inputs, outputs and special features of the PRIMES model

The basic necessary input and output data for PRIMES model are presented in tab. 3 [11-13].

As far as electricity generation by thermal capacities is concerned, the main fuels included in PRIMES model are coal, lignite, natural and derived gas, crude-oil, residual fuel oil,

Table 3. Basic input and output data in the PRIMES model

Inputs	Outputs
– GDP and economic activity per sector	– Detailed energy balances (EUROSTAT format)
– World energy supply outlook – world prices of fossil fuels	– Detailed balance for electricity and steam/heat
– Tax and subsidy policies	– Production of new fuels
– Interest rates, risk premiums, <i>etc.</i>	– Transport activity
– Environmental policies and constraints	– Association of energy use and activities
– Gas and electricity network infrastructure	– Investment, technologies and vintages in supply and demand sectors
– Technical and economic characteristics of future energy technologies	– Energy costs, prices and investment expenses per sector and overall
– Energy consumption habits and comfort parameters	– CO ₂ emissions from energy combustion and industrial processes
– Cost-supply curves of potential for primary energy, potential of sites for new plants, energy efficiency potential, renewables potential per source type, <i>etc.</i>	– Emissions of atmospheric pollutants Policy Assessment Indicators

diesel oil, liquefied petroleum gas, kerosene, gasoline, naphtha, coke, peat and other solid fuels other oil products, bio-fuels, thermal solar (active), geothermal, steam/heat (industrial and distributed heat) and electricity. Considering electricity generation by renewable energy sources, the relevant fuels are hydro lakes & run of river hydrogen, solar PV & thermal electricity, wind onshore, wind offshore, biomass and waste (5 types), tidal, and wave energy.

The model represents activities for the residential sector, services and agriculture, the industrial sector and transportation. The residential sector distinguishes five categories of dwelling, which are defined according to space heating. Each type of dwelling is further subdivided in 4 typical energy uses. As far as services and agriculture are concerned, the model distinguishes between the commercial sector (subdivided in three sub-sectors) and the agricultural sector. The model calculates energy services (useful energy) for each sub-sector, which are further subdivided in energy uses defined according to the pattern of technology. The industry is divided into 9 sectors, namely iron and steel, non-ferrous, chemicals, non-metallic minerals, paper and pulp, food drink tobacco, engineering, textiles, other industries. For each sector different sub-sectors are defined (in total about 23 sub-sectors, including recycling of materials). For each sub-sector a number of different energy uses are represented (in total about 100 types of energy process technologies are included). The transport sector distinguishes passenger transport and goods transport as separate sectors. They are further subdivided in sub-sectors according to the transport mean (road, air, *etc.*)

The main data sources [11-13] for the PRIMES model are:

- EUROSTAT
 - energy balance sheets,
 - energy prices (complemented by other sources),
 - macroeconomic and sectoral activity data, and
 - population data and projection
- International Energy Agency (IEA)
- Technology databases developed under European Commission programs
- Various surveys (*e. g.* combined heat and power) and databases on power plants,

- Specifically commissioned studies and others.

For the integration of this thesis, many necessary data were collected from the reports of the relevant Electric Power Industries and Energy Regulatory Authorities of these countries (References), in order to integrate the scenarios and evaluate the results. Considering the regional coverage and the timeframe of the PRIMES Model, it should be mentioned that PRIMES is operational for all EU27 member-states and also for the Western Balkans countries (Albania, Croatia, Bosnia-Herzegovina, FYR of Macedonia and Serbia) including UNMIK and Montenegro), the European Free Trade Association (EFTA) countries (Switzerland, Norway) and Turkey.

Moreover, it is a long-term model that integrates projections for the period between 1990 and 2050, running by period of 5 years. For years 1990, 1995, 2000, and 2005 the model results are calibrated to Eurostat statistics. For year 2010 the model results are semi-calibrated by taking into account the latest statistics and short-term expectations.

The Baseline scenario

Basic assumptions

The Baseline scenario was formed according to the PRIMES model in order to simulate the equilibrium solution for the electricity supply and demand of the power system in the Western Balkan for the period between 2015 and 2050. In this way, supply corresponds properly to the growth of the demand. Main targets are the minimisation of the total costs and the reduction of pollutant emissions (mainly of carbon dioxide – CO₂). This scenario simulates each power system, which means that the procedure is a projection and not a prediction. Via the results an insight to the future development of energy balance is provided, where an extensive analysis of the electricity generation structure and of the installed capacity is included. Moreover, data concerning the emissions of CO₂, the investment for the construction of new power capacities and the refurbishment of the existing ones, fuel consumption for electricity and steam generation, and others are calculated. The main orientation of the Baseline scenario is the current condition of the West Balkan countries in the fields of energy and economy. Neither specific energy nor environmental policy were applied, including strategies like carbon values, subsidy policies regarding the support of the renewables energy sources, the emissions trading system, energy efficiency schemes and others.

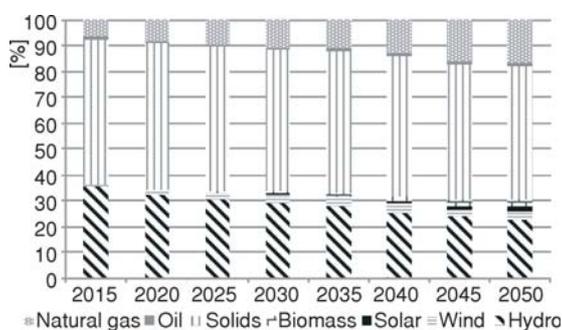


Figure 2. Electricity generation structure in the Western Balkans

Baseline scenario results

As far as thermal energy generation is concerned, the projection shows that the power sector in the Western Balkans will continue to rely on the thermal power capacities until 2050, as it is illustrated in tab. 4 [3].

Figure 2 depicts the structure of the electricity generation in the Western Balkans, as given by the PRIMES model per 5 year period steps, [3]. More specifically, electricity production by solid fuels (mainly from endogenous lignite) is expected to increase and its shares are pro-

jected to remain above 50%. The role of solid fuels in this area will remain very important, since the endogenous lignite reserves are significant and will have to be exploited at the most efficient way. In this case, such evolution would not be in accordance with the European Union legislation concerning the climate change mitigation and the its long term energy policy, or global agreements like the Kyoto Protocol. However, the viability of the regional power system is a matter of priority, as the energy sector is the backbone of the economy. Consequently, decisions concerning the operation and investment on coal-fired power plants will be an important part of the formulation of the action energy plan of these states in the future.

Table 4. Baseline scenario results for the Western Balkan countries

	2015	2020	2025	2030	2035	2040	2045	2050
Total electricity generation [GWh]	92234	104742	112799	120864	132550	151005	168591	184007
Thermal generation [GWh]	57193	67448	73677	78733	86871	101334	115144	124788
– Solid fuels [GWh]	50419	58194	62086	64897	70941	80842	86917	92261
– Natural gas [GWh]	1010	787	726	602	1498	1585	2123	2200
– Oil [GWh]	5764	8466	10864	13234	14432	18907	26104	30326
Renewables [GWh]	35041	37294	39123	42131	45679	49671	53446	59219
Installed capacity [MW]	23944	26258	27784	30342	33059	38006	42891	47959
– Thermal capacities [MW]	12849	14437	15185	16453	18588	22141	25615	28283
– Renewable capacities [MW]	11095	11822	12599	13889	14470	15865	17276	19676
CO ₂ emissions [Mtons of CO ₂]	75.32	83.95	88.72	89.37	90.85	95.18	101.80	106.91

Natural gas power shows significant deployment in the long term, because of the low power generation costs (especially if considering the operation of the natural gas-fired combined cycle power plants (NGCC) and their modest environmental impact), reaching 16.5% from the total electricity production by 2050. Moreover, as far as not only Western Balkans are concerned, but also the whole region of the South-Eastern Europe, it should be highlighted that South Stream natural gas pipeline is emerging as an important factor in the Western Balkan's energy supply and security, bringing closer Serbia, Croatia, Bosnia & Herzegovina, and Slovenia. At the same way, Trans Adriatic Pipeline (TAP) will supply and interconnect Turkey, Greece and Albania. The Baseline Scenario projections indicate that, according to tab. 4, electricity generation from crude oil and its derivatives will slightly increase in the long term, reaching an intermediate reduction in the period between 2015 and 2030. It is indicated that their shares will be limited at 1.2% in 2050.

Intermittent renewables emerge under the Baseline conditions, attaining 6% of the total electricity generation by 2050. Furthermore, as far as renewable energy sources are concerned, it should be included that hydro power plants will continue to constitute a fundamental part of the regional power system, especially for covering the baseload demand. The projections show that the shares of hydro power will show intermediate fluctuations between 24% and 37% between 2015-2050.

Under the Baseline scenario assumptions, it is estimated that, in the Western Balkan region many power plants will be decommissioned or refurbished (fig. 3, [3]), but there exist significant possibilities for further investment in new power capacities. The construction of new in-

intermittent renewable power facilities and modernized lignite power plants will strengthen the achievement of perspective and long term planning, especially in terms of environmental sustainability and energy equity. Figures 3 and 4 show the proportional distribution of generation capacities investments for the Western Balkan region per type of purpose and type of technology, respectively [3].

The projection shows new investment in lignite power plants and shows also as optimal investment more than 10 GW of new natural gas power plants (fig. 4). In this way, the gasification process is in accordance with the regional energy policy towards the diversification of the energy mix and the security of energy supply. The solid fuel (lignite) power plants require further refurbishment and modernisation. According to the results, considerable investments are projected.

Reference sub-scenarios

Basic assumptions

The countries of the European Union and definitely the Western Balkans will face challenges concerning uncertainties in the energy sector, especially in terms of the affordability, equitability and security of the energy supply, and the mitigation of carbon dioxide emissions. These challenges require a general framework to establish policies and actions, combined with structural and technological changes in order to foster the exploration and investment in new power generation technologies, and to implement strategic plans concerning environmental issues, which would have an impact on energy options leading to a climate resilient economy [4]. In order to address those challenges and to achieve the aim of competitive and sustainable energy development, the considered countries are summoned to develop a strategy for increasingly efficient use of energy and support of financial development in the coming decades.

Considering that energy demand is projected to increase since recession will probably relent, this strategy aims to prevent shortages and strengthen the industrial development. For this reason, this part analyses the effects of applying a subsidy policy to support the electricity generation from renewable energy sources. This is a general safety standard of supply including a long-term energy strategy where the aim is to analyse the growing contribution of renewable energy sources, with intermittent operation.

In the Western Balkans the feed-in tariff system has been established as it is shown in tab. 5, in order to accelerate investment in renewable energy sources [14-18].

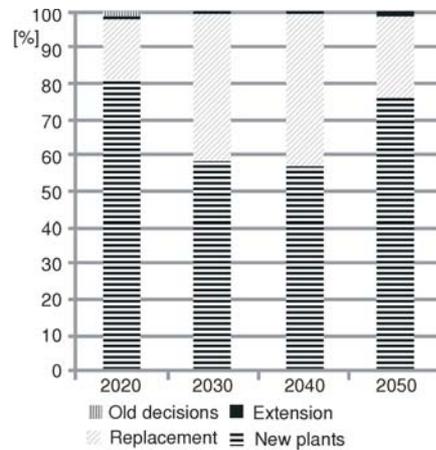


Figure 3. Shares of investments for the Western Balkan countries per type of purpose

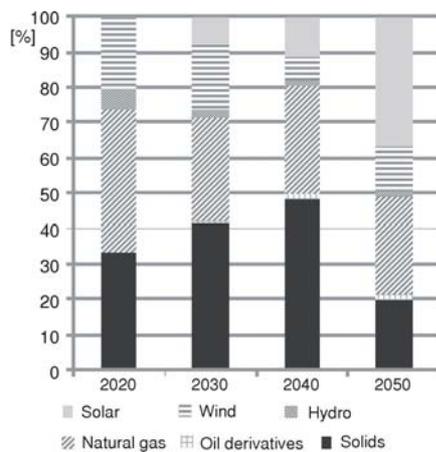


Figure 4. Shares of investments for the Western Balkan countries per type of technology

Table 5. Feed-in tariffs (€/MWh) in the Western Balkans [14]

Type of RES	Bosnia & Herzegovina [15]	Croatia [14, 16]	FYROM [17]	Montenegro [14]	Serbia [18]
Wind	84.5	95.0	89	96	92
Solar PV	120.7	145.8	120	150	162.5
Hydro	67.8	79.5	50	50.4	73.8
Biomass	115.6	118.8	150	137	82.2

As far as the exchange rates are concerned, the used ones in this paper in order to calculate the feed-in tariffs according to the data sources, it was considered that the exchange rates (between euro and the national currency) were for Bosnia & Herzegovina and Croatia 1.956 [19] and 7.545 [20].

The inclusion of the subsidy price strengthens the contribution of renewable fuels (mainly those of solar and wind energy) to the power system, the potential of which has not been extensively exploited yet by those countries (tab. 2). The reference scenarios [3] are actually simulations starting from the Baseline scenario to which various subsidy prices for electricity generation from renewables are included. The variable subsidy (renewable value) acts on the model as marginal revenue for power companies according to generation from renewables and equals to the marginal value of applying so that part of generation must come from renewable sources. The simulating sub-scenarios were six in total and the applied values were 15 €/MWh, 30 €/MWh, 40 €/MWh, 50 €/MWh, 60 €/MWh and 80 €/MWh (same values for generated electricity from all types of renewable energy sources) respectively. These values multiplied by the generated electricity from renewable energy sources shall be deducted from the total cost of electricity and will also be taken into account for the final pricing of electricity to consumers. In this way, the extra cost is compensated but enterprises are urged to generate from renewable sources.

The implementation of variable supporting policies (subsidy value) for renewables in the specific region is projected to have medium effects on the structure of the regional power energy system. The electricity generation by solid fuels and natural gas will continue to dominate. As the subsidy value rises, the shares of lignite decrease, but they are expected to remain considerable (more than 50%). The development of renewables in the Reference scenario includes a moderate rise of the shares of wind and solar electricity if compared with the baseline levels. Moreover, as far as natural gas is concerned, the policies for renewable still imply significant investment in the construction of new natural gas power plants, especially on combined cycle (NGCC). At this rate, the gasification and the modernisation of the power system of the region are estimated to be accelerated.

The aim of current international negotiations is the establishment of new global limits on greenhouse gas emissions for the period after 2012, and these may set new requirements on the countries in the Western Balkans, [3]. The subsidies for renewables are expected to strengthen the generation mainly by wind and solar energy and, as a result, the total emissions of CO₂ will be lower compared with those of the Baseline levels. However, these differences are estimated to be limited and the total emissions will rise in the long-term because of the strong participation of the coal power plants.

Reference sub-scenarios results

Applying the Renewable support policy in the Western Balkans has an impact on the regional power generation system, as illustrated in figs. 5-8. In the charts above the structure of electricity generation of the whole region is graphically illustrated-indicatively for the sub-scenarios of 40 €/MWh and 80 €/MWh. The developments in the Reference scenarios imply higher penetration of the renewables with increased electricity generation and further power capacities investment.

The reference sub-scenarios [3], especially for lower subsidy values (below 60 €/MWh) show small changes compared to projections of the Baseline Scenario. In these sub-scenarios it is

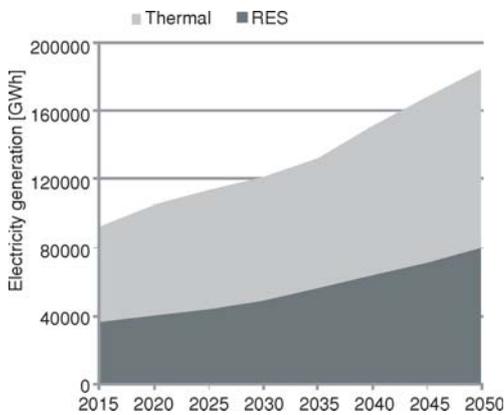


Figure 5. Electricity generation for Western Balkan – 40 €/MWh sub-scenario

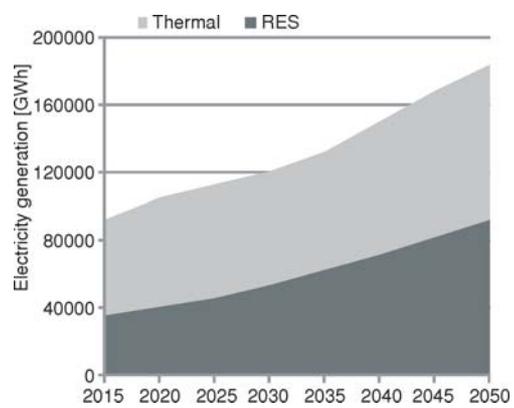


Figure 6. Electricity generation for Western Balkans – 80 €/MWh sub-scenario

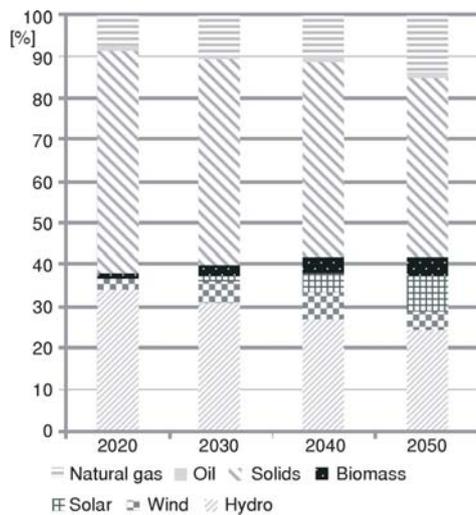


Figure 7. Electricity generation structure for Western Balkans – 40 €/MWh sub-scenario

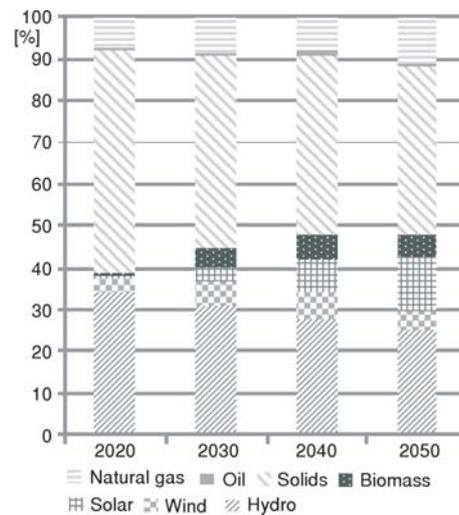


Figure 8. Electricity generation structure for Western Balkans – 80 €/MWh sub-scenario

projected that, thermal capacities will continue to dominate and consist the core of the regional power system. Power generation from solid fuels (lignite) and natural gas is further increasing in the Reference scenarios, but not at the same rate as in the Baseline. According to the projections, power generation from solids is expected to rise in the long term (figs. 5 and 6), but their shares are estimated to be lower than the relevant from the Baseline scenario (figs. 7 and 8). Their values are estimated to be around 40% in the great majority of the sub-scenarios.

The adoption of strong RES shows to be effective in supporting further penetration of the renewables in the regional power system. However, as it was mentioned in Baseline Scenario, coal-fired power plants will still remain the most substantial part of the electricity generation system, and very essential for covering the baseload and medium-load demand and adapting to the intermittent electricity generation of some renewables.

As far as the gasification of the Western Balkan region is concerned, it is assumed that that the expansion of the gas power sector will not be significantly affected, if compared to the relevant level of the Baseline scenario. The shares of natural gas are projected to fluctuate between 10% and 15% in all the sub-scenario cases. Under the assumptions of the 80 €/MWh electricity generation is projected to be almost equally distributed between thermal and renewable facilities.

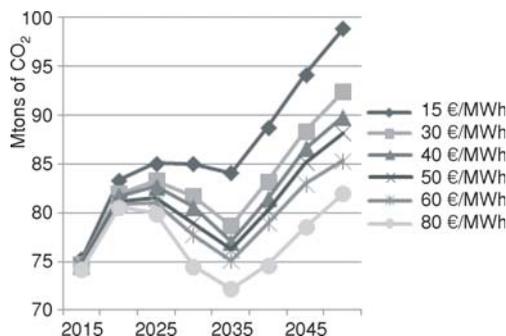


Figure 9. CO₂ emissions in the Reference sub-scenarios in the Western Balkans

and secondarily from biomass and geothermal energy. Consequently, the CO₂ emissions will slightly or drastically (depending on the subsidy value levels) during this period. Wider expansion of solid fuel power plants after refurbishment, further investment and construction of new thermal capacities is the reason for the estimated rise of the CO₂ emissions for the periods 2015-2025 and 2035-2050. Moderate changes (in contrast to the Baseline scenario results) are projected to occur in the power generation structure in the medium values Reference scenarios (15 and 30 €/MWh). In the scenario of 80€/MWh, where almost half of the generated electricity is projected to rely on carbon free technologies in 2050, the carbon emissions values are projected to drop by 23.4% compared to the relevant values of the Baseline scenario.

Conclusions

For both the Baseline and Reference sub-scenarios assumptions the following conclusions are evident.

- Solid fuels will continue to constitute the most important primary energy source in the Western Balkans, mainly if considering the regional endogenous lignite reserves especially

A reduction in the CO₂ emission values (if compared to the relevant levels of the Baseline scenario) is expected according to the Reference scenarios' results [3]. CO₂ emissions are projected to fluctuate intermediately because of the increased participation of the renewable capacities in the electricity generation of the regional power system during the period between 2020 and 2035 (fig. 9). According to the Reference scenarios results, many thermal power plants will be decommissioned and an optimal choice investment in new intermittent wind and solar power plants is projected.

The additional renewables in power generation are primarily from hydro, wind and solar,

in Bosnia, Kosovo, and Serbia. However, under the projections of the Reference scenarios it is assumed that their long-term use and future participation in the regional power generation system will be highly sensitive on RES supporting policies, carbon prices or probably the development of the carbon capture, use and storage (CCUS) technology.

- Gasification trends remain valid and achievable in all the scenarios, if considering the value of natural gas in terms of energy efficiency and environmental concerns. The gasification of the regional power generation system in the upcoming years remains a dominant factor, but heavily relies on the growth of the natural gas prices, any policy constraints or renewable energy supporting schemes. Further investment in natural gas power generation technologies will be some of the priorities according to the regional energy policy framework, if taking into consideration the value of their operation in order to adapt on the intermittency of the renewable power capacities.
- Oil and its derivatives will continue to participate in the fuel mix but their role will decline in the power generation sector, remaining however important in other uses, like transportation.
- As far as thermal generation as a whole is concerned, evidently the Western Balkan region will continue to rely on “black” energy (fossil fuels). Especially if considering the economic viability, the industrial development and the energy equity in these countries, mainly in terms of energy supply and electricity prices regulation, unavoidably thermal energy sources will remain the catalyst in the energy sector. However, such evolution does not act as an obstacle or does not impede the support and the penetration of the RES, as shown in the Reference sub-scenarios.

Considering the challenges mentioned in the section *General hypotheses*, the Western Balkans need to pursue modernization of their existing capacities and energy efficiency policies, to move in the direction of strengthening investment projects in energy infrastructure in the areas of advanced coal-fired plants and renewable sources, to guarantee the supply of oil and natural gas through long term agreements and establishing regional gas grids, and plans for the CCUS. Other important factors should be taken into consideration, such as the changing features of energy demand in levels of energy infrastructure, the increase in electricity imports and the rise in the pricing of fuels in order to successfully address the problems of supplying and moving to a competitive low carbon economy. The diversification of energy sources and the environmental issues are accelerating the process that will transform the Western Balkans to a region for transportation, storage and power supply.

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