Evaluation of Power Supply Options for Kosovo

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Executive Summary

Objective of the Study

The objective of the Power Supply Options Study (the Study) was to assess various electricity supply scenarios to meet Kosovo's forecast electricity demand at lowest economic cost and to help the World Bank decide whether to support the 450-megawatt[1] (MW) new coal power project pursued by the Government of Kosovo. The analyses of supply scenarios were conducted consistent with the requirements of the Criteria for Screening the Coal Projects under the Strategic Framework for Development and Climate Change (March 2010), the Economic Analysis of Investment Project Financing Guidance Note (April 9, 2013), the Discounting Costs and Benefits in Economic Analysis of World Bank Projects (May 9, 2016), and the Guidance Note on Shadow Cost of Carbon in Economic Analyses (Nov. 12, 2017).

The Study forecast Kosovo's electricity demand assuming significant improvements in energy efficiency (EE) and an ambitious scale-up of renewable energy (RE) from 73 MW to around 430 MW of small hydropower, wind, biomass, biogas, and solar energy. The study also evaluated new thermal power plants using different fuels with installed net capacities of 300 and 450 MW, and considered the use of electricity imports. The Study analyzed the option of reconstructing two units in the existing obsolete Kosovo A lignite plant (and decommissioning the remaining three units), as well as scaling up renewable power generation combined with a battery energy storage system (BESS).

Overview of the analytical approach

The analyses of system-wide power supply scenarios, which consider all projects to meet the domestic demand, were conducted using an optimization model. By minimizing the capital, fuel, and non-fuel variable costs of various packages of generation options and imports, the model determines the least-cost electricity supply scenario for meeting the forecast hourly domestic electricity demand. The analyses assumed that forecast hourly domestic electricity demand should be always met. The estimated electricity generation from each scenario was derived using the principle of merit order dispatch, i.e., from the lowest variable cost to the highest. The dispatch simulation was conducted on hourly bases for all base case and sensitivity scenarios for the evaluation period of 2017-2052.

Given the energy security considerations of the Government, the Study limited the volume of gross annual imports at 17 percent of total demand, which is consistent with the maximum observed historical gross annual imports (2014).[2] The hourly imports were capped at 70 percent, which is also consistent with observed historical values (2015-2016). The analyses also considered the minimum generation constraints for Kosovo A and Kosovo B power plants (see Table 1) and their respective ramp-up and ramp-down

[1] All MW in this report refer to electric load unless mentioned otherwise.
[2] Inclusive of imports as part of the electricity exchange with Albania.

limitations. This is important given that old lignite-fired coal plants cannot be quickly shut down and restarted or quickly increase and decrease generation.

The analyses did not consider exports as part of the total electricity demand because the primary objective was to optimize the capacity requirements for meeting the *domestic* electricity demand. Moreover, consideration of exports would require a more detailed regional study on supply and demand.

The Study evaluated the economic costs of various supply scenarios considering: (i) the forecast electricity demand; (ii) capital costs of potential new generation projects and projects under construction; (iii) capital costs of new investments in transmission, distribution, district heating (DH), mining, and energy efficiency (EE); (iv) fuel costs of existing and new projects; (v) non-fuel operating and maintenance costs existing and new generation; (vi) electricity import costs; (vii) the local environmental costs (air pollution); and (viii) the social cost of carbon, which is a global externality. All supply scenarios were analyzed and ranked in terms of the present value of supply costs, inclusive and exclusive of the local and global environmental costs.

The economic costs of supply scenarios were computed for the period 2017–2052. The final year of the evaluation period was chosen to be 2052 given that 30-year useful economic lives of potential new fossil-fuel power plants, to be commissioned in 2023, would end in 2052. This is also a requirement of the Guidance Note on Social Cost of Carbon,[3] which says that economic analyses of new fossil-fuel generation project should be conducted inclusive and exclusive of the social cost of carbon and cover the period of the economic life of the project. The following key steps were followed in evaluating the economic costs of supply scenarios:

- Forecast of electricity demand and simulation of electricity dispatch was conducted for the period 2017–2030. For the purposes of computation of economic costs from 2031 to 2052, the total annual electricity generation in 2031-2052 was assumed to be constant.
- The incremental capital investment, O&M, and local environmental costs (both domestic and cross-border) and the social cost of carbon were evaluated for 2017–2052.
- Replacement costs for power plants were included in the computation of total economic costs of supply in the cases where the useful lives of those plants ended before 2052.
- Terminal values of power plants were non-material beyond 2052 due to discounting effects, and thus were not included in the analyses.

Key assumptions

The key assumptions underlying the Study are presented below:

[3] Guidance Note on Social Value of Carbon in Project Appraisal (July 14, 2014)

- Real gross domestic product (GDP) growth is based on the forecasts by the International Monetary Fund (IMF).[4]
- The base case social opportunity cost of capital (economic discount rate) was estimated at 6.4 percent and was used to compute the present values of supply scenarios and levelized costs of electricity (LCOEs) for individual projects. The social opportunity cost of capital was assumed to equal the projected real GDP growth rate per capita, 3.2 percent,[5] multiplied by marginal utility of consumption of two. The Study tested the robustness of least-cost scenario using lower and higher social opportunity costs of capital equal to 4.4 and 10.4 percent.
- The estimated annual average increase in the price of electricity[6] was assumed to equal the rate of required increase of the current average tariff to reach by 2030 the calculated long-run average incremental cost (LRAIC) of the least-cost supply scenario.
- Two units of Kosovo A (A3 or A4 and A5) were assumed to be available for electricity generation until planned decommissioning by 2023. This is consistent with the current operating regime of the plant whereby one of the three available units is kept on the stand-by as a reserve.
- In the Kosovo A Reconstruction Scenario, units A1 and A2 were assumed to be reconstructed by the end of 2022 with total available capacity reaching 450 MW. Units A3, A4, and A5 were assumed to be retired by the end of 2022.
- Total available capacity of Kosovo B was assumed to increase from 520 MW prior to rehabilitation to 592 MW after the rehabilitation. The rehabilitation was assumed to be carried out in 2023-2024 by taking offline one unit at a time.
- Available capacity from Kosovo B for electricity generation was adjusted considering the increase in supply of District Heating (DH).
- Minimum capacities for both Kosovo A and Kosovo B units were conservatively assumed to remain unchanged after reconstruction and rehabilitation respectively.
- The capital costs of rehabilitation of Kosovo B and reconstruction of Kosovo A are based on the European Union's 2017 Feasibility Study for Kosovo B and the

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[4] World Economic Outlook, IMF, April 2018.

[5] Forecast long-term average growth rate of real GDP (4 percent) minus forecast growth rate of population (0.8 percent).

[6] It is important to differentiate between the term *price* as used here from the term *tariff*. The LRAIC indicated the price that would need to be charged to recover the *economic cost of new investments required* in the system, over the period to 2030. The tariff is, in contrast, a regulated price decided on by the Energy Regulatory Office and may reflect the cost of investments in the system in a different manner.

Bilfinger Study for Reconstruction of Kosovo A from 2015,[7] as well as further due diligence on coal power plant reconstruction projects in Europe.[8]

- The non-fuel variable operating costs and fixed costs of existing and potential new power plants are based on the above technical studies and benchmarks in international publications from the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), and other sources.
- The heat rates of the thermal power plants are based on IEA publications, *Handbook of Gas Turbine World 2015–2016*, and other sources. The heat rates were adjusted based on the capacity factors of power plants, which were derived from the dispatch simulation. The heat rate for potential 450 MW ultra-supercritical (USC) was based on the data provided by General Electric.

Table 2: Heat Rates of Thermal Power Plants

Power plants	Heat rates (btu/kWh)[9]	Efficiency
Kosovo A pre-reconstruction	11,874	29%
Kosovo A post-reconstruction	9,190	37%
Kosovo B pre-rehabilitation	11,874	29%
Kosovo B post-rehabilitation	10,085	34%
New 300 MW subcritical coal power plant	9,190	37%
New 450 MW supercritical coal power plant	8,480	40%
New 450 MW ultra-supercritical (USC) or ultra-supercritical with biomass co-firing	8,667	42%
New 300 MW dual fuel plant[10]	6,963	49%
New 300 MW fuel oil plant[11]	6,824	50%

Source: World Bank team estimate.

- The installed capital costs for other projects were derived from observed project costs published by the IEA, International Renewable Energy Agency (IRENA), Bloomberg New Energy Finance, and other sources, including outputs from specialized consulting firms specializing in coal technology, such as VPC, RWE.
- The targets for scale-up of renewable energy—except for the RE Scale-Up with Storage Scenario and biogas—are based on the Government's decision on

7 "Feasibility Study for Environmental and Other Measures on Kosovo B Thermal Plant," European Union, 2017; "Proposal for Renewal of Kosovo A," Bilfinger, Feb. 2015.

8 Draws upon experience with reconstruction of coal power plants in Macedonia, Bosnia and Herzegovina, Serbia, and Poland.

9 Btu stands for British thermal unit.

10 Diesel (0.1% sulphur) and natural gas. All other specifications for diesel as per "Methodology and Specifications Guide: Europe and Africa Refined Oil Products," Platts, Jun. 2018.

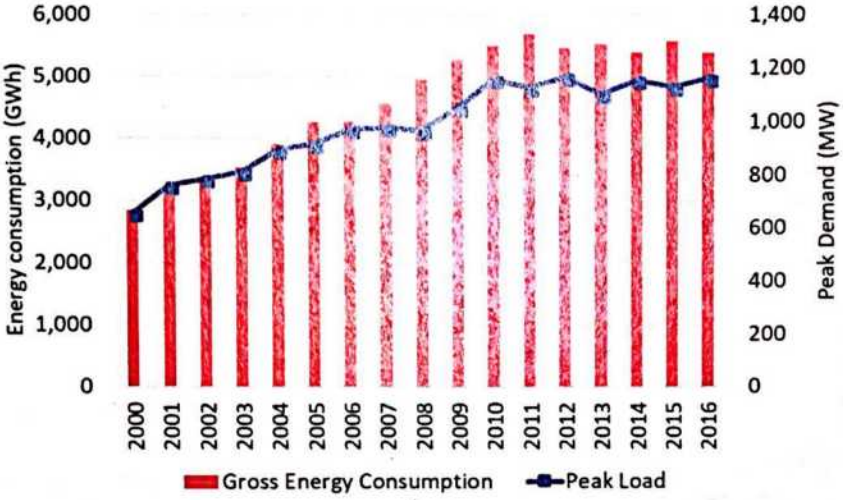
11 Heavey Fuel Oil (HFO), 1% sulphur. All other specifications as per All other specifications as per "Methodology and Specifications Guide: Europe and Africa Refined Oil Products," Platts, Jun. 2018.

renewable targets and commitments to the Energy Community Treaty. Renewable energy targets are further discussed in the section below on RE scale-up.

- The constant plant-gate economic price of lignite was assumed to equal €9.4/ton, i.e., the average of the range presented in the Government's Mining Strategy.[12] The Bank team verified this economic price of lignite and it was estimated to include about €200 million of investments (the estimated requirement is €380–430 million) over 2017–2023. Those costs do not include reclamation and clean-up costs, for which no reliable estimates are available. The €380–430 million is based on the preliminary estimates from the Lignite Mining Development Plan, which is being finalized. The higher investment costs would impact long-run supply cost, and thus, the economic price of lignite. However, as sensitivity analysis with a higher lignite price shows, it would not change the least-cost scenario.
- The constant plant-gate economic prices for diesel, fuel oil, and natural gas were derived using the World Bank's Commodity Price Forecast (June 2018) with adjustments to take into account the relationships between liquid fuels and crude oil prices as well as transportation costs to Pristina.
- The plant-gate economic price of biomass (wood pellets) was derived using the published[13] Free on Board (FOB) Portugal prices for wood pellets and ground-based transportation costs from the region to Pristina. The wood pellets were assumed to be imported from the neighboring countries because various biomass studies for Kosovo estimated that local biomass would be sufficient to fire not more than 11 MW (some of which is under construction)[14] of biomass-based power generation capacity without impacting the use for other critical sectors such as animal farming (animal feed) or contributing to deforestation.
- Local environmental costs for Kosovo A and Kosovo B were estimated based on the damage costs of air pollution generated by reference fossil-fuel plants in the Former Yugoslav Republic (FYR) of Macedonia and Greece, which were adjusted to reflect the difference in GDP per capita between EU-15 and Southeastern European (SEE) countries. The original damage factors from nitrogen oxide (NO_x), sulfur dioxide (SO_2), particulate matter with diameter less than 2.5 micrometers ($PM_{2.5}$), cadmium, nitrogen, and other emissions for EU-15 were estimated using the well-known ExternE method.[15] The environmental costs of new plants were derived taking into account the results of EcoSense model.[16]

[12] Mining Strategy of the Republic of Kosovo for 2012 – 2025, Ministry of Economic Development, Pristina, 2012.
[13] Weekly Biomass Markets News and Analyses, Argus Biomass Markets, 31 Jan. 2018.
[14] Gjakova Combined Power and Heat Project with 8 MW thermal and 1.5 MW electric capacity.
[15] "External Costs of Power Production in South Eastern Europe," Antonis Papaemmanouil, Goran Anderson, Jan. 2008.
[16] Based on the estimates from EcoSense model and adjusted by inflation to convert into 2015 prices.

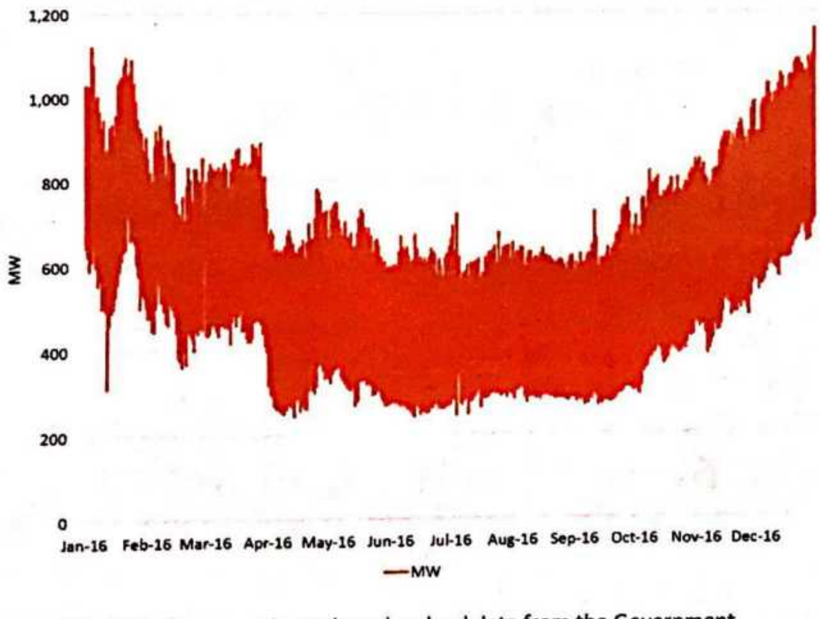
Figure 1: Historical Energy Consumption and Peak Demand in Kosovo



Source: Data were taken from Energy Regulatory Office annual reports (2004–16) and from the Energy Regulatory Office's "Statement of Security of Supply," July 2013.

The electricity demand in Kosovo has pronounced seasonal peaks. The electricity demand is highest in the winter period due to reliance on electric heating. Currently, the existing coal-fired and some hydropower plants supply the baseload energy, and the country relies on imports to meet peak demand.

Figure 2: Shape of Hourly Electricity Demand, 2016

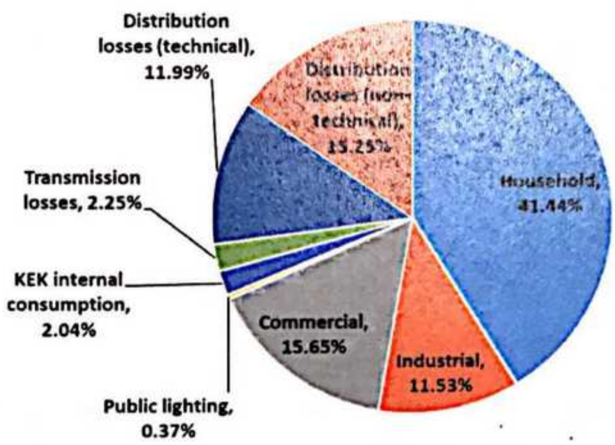


Source: World Bank team estimate based on load data from the Government.

Residential consumers account for the largest share of electricity demand. Most metered electricity demand in Kosovo is residential (38 percent of gross consumption in

2016), followed by industrial demand. Technical and non-technical losses in the network remain high, representing approximately 30 percent of gross electricity consumption in 2016, although they declined from 43 percent in 2008.[17]

Figure 3: Composition of Gross Electricity Consumption, 2016



Source: Energy Regulatory Office Annual Report 2016.

Electricity demand forecast

Under the Study's base case, in 2017–2030, electricity demand[18] is projected to grow at 1.66 percent per year. The electricity demand forecast is based on the projected GDP growth rate in real terms, the estimated increase in the electricity price that would be required to cover the economic costs of meeting the forecast growth in electricity demand as new supply capacity is brought online, and demand reduction due to EE improvement. Growth of real GDP would increase electricity demand, while electricity tariff increases would reduce the demand.

Table 5: Summary of Electricity Demand Growth Rates

Electricity Demand Scenario	Annual Growth Rate of Real GDP	Annual Change in Electricity Price	Forecast Average Annual Growth of Electricity Demand	Actual Gross Electricity Demand in 2016	Gross Electricity Demand in 2025 Under Current Forecast	Gross Electricity Demand in 2025 Under 2011 Forecast
Low Case	3%	3.13%	0.73%	5,383	5,710	7,413
Base Case	4%	3.13%	1.60%	5,383	6,156	9,452
High Case	6%	3.13%	3.31%	5,383	7,385	No forecast

Source: World Bank team estimate.

17 "Statement of Security of Supply for Kosovo," Energy Regulator Office, Pristina, 2015.

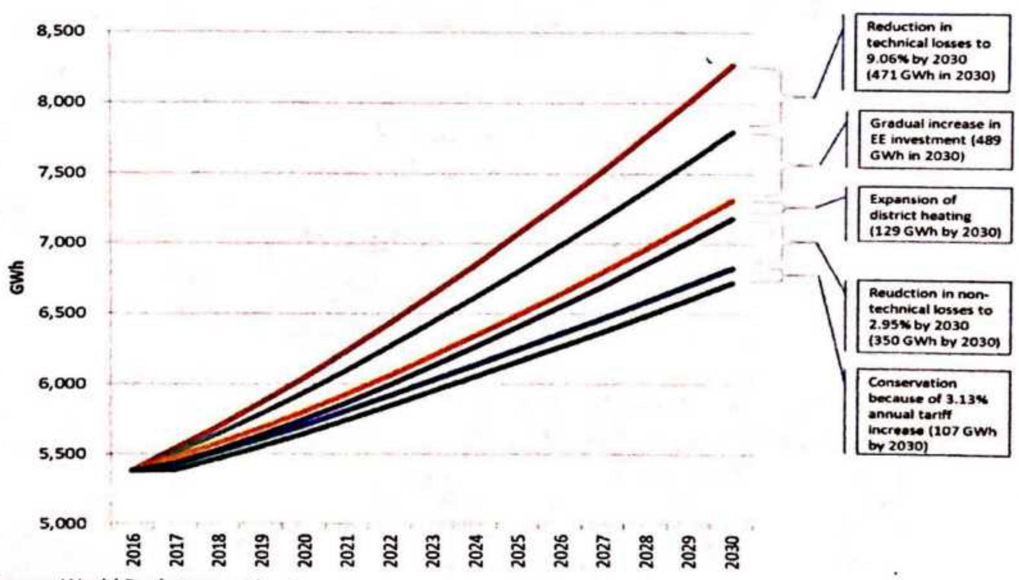
18 Gross electricity demand, which is the total annual energy requirement inclusive of technical losses and non-technical losses. The peak demand is assumed to grow by an average annual rate of 1 percent under the base-case.

Under the base case, the forecast assumes that the real GDP growth gradually will reach 4 percent per year by 2022 and remain at that level until 2030, consistent with the most recent IMF forecast.[19] The electricity price is assumed to increase by 3.13 percent per year to reach the LRAIC of supply by 2030. The low- and high-case electricity demand forecasts are based on 1 percent lower GDP growth per year from 2017 to 2030 and 2 percent higher GDP growth per year from 2017 to 2030, respectively.

The electricity demand forecast in this Study is significantly lower than in the 2011 report because (a) the impacts of EE and gradual transition to district heating on demand are incorporated, which were not taken into account in the 2011 demand forecast; and (b) the long-run real GDP growth rate of 4 percent under the base case is lower than the 2011 forecast of 4.5 percent.

***EE improvements would reduce electricity demand*.** Under all demand growth scenarios, the Study assumed that electricity losses would be reduced, investments would be made in improving EE in public and residential buildings, and more electricity consumers would switch from electric to district heating. About 1,550 gigawatt-hours (GWh) of electricity consumption were estimated to be saved from loss reduction, EE improvement measures, and the switch to district heating during the 2017–2030 forecast period. In all the subsequent years, the electricity demand was assumed constant for the purposes of economic evaluation of supply options.

Figure 4: Demand Forecast Assuming Reduction of Losses, EE Measures, Expansion of DH, and Tariff Increase



Source: World Bank team estimate.

[19] World Economic Outlook, April 2017, IMF.

Technical losses (inclusive of transmission and distribution) were assumed to decline from 14.24 percent of gross electricity demand in 2016 to 9.06 percent in 2030. This is consistent with the observed technical loss reduction, which could be achieved considering the experience in various countries in Europe and Central Asia Region, including, but not limited to Croatia, Georgia and Armenia. Non-technical distribution losses were assumed to decline from 15.25 percent to 2.95 percent of gross electricity demand by 2030. Additionally, sensitivity analysis was conducted to test the changes in costs in the case in which non-technical losses are eliminated and fall to 0 percent by 2025.

The potential for EE improvements is based on the Government's second National Energy Efficiency Action Plan (NEEAP) and other studies assessing the technical potential for electricity savings in buildings. The cost of EE improvement measures was assumed to cost €12.1 million over a period of 2017-2030 years. Finally, the Study assumed that Kosovo B would supply heating to Pristina, displacing electric heating, thereby reducing electricity demand. The costs associated with the expansion of DH networks in Pristina was assumed at €87.5 million over a period of 2018-2022.[20] Sensitivity scenarios tested the impact of demand growth resulting from lower or higher annual GDP growth.

Existing electricity supply capacity

Electricity supply reliability and adequacy remain a major challenge for the power sector. Frequent load shedding severely affects electricity consumers. It is driven by unplanned outages (about 95 percent of the outages) and insufficient available reserves to substitute the supply from existing generating units in case they fail. In 2016, annual electricity demand would have been about 21 GWh higher in the absence of load shedding.

The total installed electricity generation capacity is about 1,560 MW. However, only 733-989 MW is operational. Most of the generation comes from two thermal power plants built in the 1960s and 1980s, Kosovo A and Kosovo B, with combined net operating capacity of about 660-915 MW. A few hydropower plants, a small wind power plant, and some solar PV with combined installed capacity of 73 MW account for the rest of generation.

Kosovo A, which is the largest and the oldest power plant, is unreliable and inefficient. Two of its units, A1 and A2, are out of operation and the remaining three units, A3-A5, were overhauled during the period 2006–2008, but remain unreliable and operate below their installed capacities. Kosovo Energy Corporation (KEK) typically operates only two units of Kosovo A while keeping the third unit as a reserve.

Kosovo B, although not as old as Kosovo A, continues to have mechanical and electrical problems that result in frequent forced outages of both of its units. Additionally, deterioration of critical plant components has reduced the total capacity to about 520 MW.

[20] "Kosovo: District Heating Sector Assessment," World Bank, June 2017.

Table 6: Existing Electricity Generation Capacity

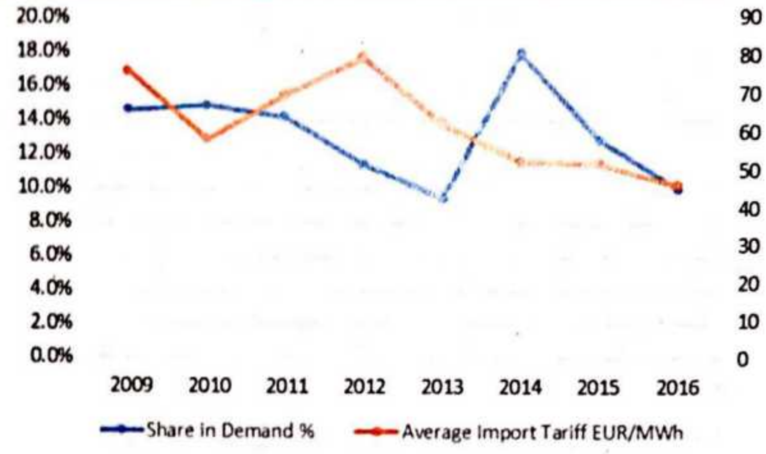
Plant name	Fuel	Installed capacity (MW)	Net available capacity (min/max) (MW)	Supply to the Network (GWh 2016)	Commissioned
Kosovo A	Lignite				
Unit A1		65	0		1962
Unit A2		125	0		1964
Unit A3		200	100–130		1970
Unit A4		200	100–130		1971
Unit A5		210	100–135		1975
Total, Kosovo A		**800**	**300-395**	**2,033**	
Kosovo B	Lignite				
Unit B1		339	180-260		1983
Unit B2		339	180-260		1984
Total, Kosovo B		**678**	**360-520**	**3,568**	
Ujmani	Hydro	35	32		
Unit 1		17.5			1983
Unit 2		17.5			1983
Lumbardhi	Hydro	8.08	8		2006
Dikanci	Hydro	4.02	3.34		2013
Brod II	Hydro	5.2	5.0		2015
Other hydro	Hydro	23.89	18.75		
Total, hydro		**77.14**	**71.31**	**235 (all RE)**	
Wind		**1.35**	**1.35**		
Solar		**0.6**	**0.6**		
Total		**1,557**	**733-989**	**5,835**	

Source: Based on ERO Annual Report, 2016.

Electricity imports and connectivity

Kosovo has historically been importing up to 17 percent of its total demand at tariffs that have been reducing since 2012. Gross imports of electricity have ranged between 9 and 17 percent of total annual consumption between 2009 and 2016. Those imports also include the electricity imported from Albania as part of the seasonal electricity exchange whereby Kosovo supplies electricity in summer/fall and receives in winter. The volumes of imports have fluctuated primarily due to availability of domestic lignite plants and winter weather conditions.

Figure 5: Electricity Imports as a Share of Total Demand and Import Tariffs

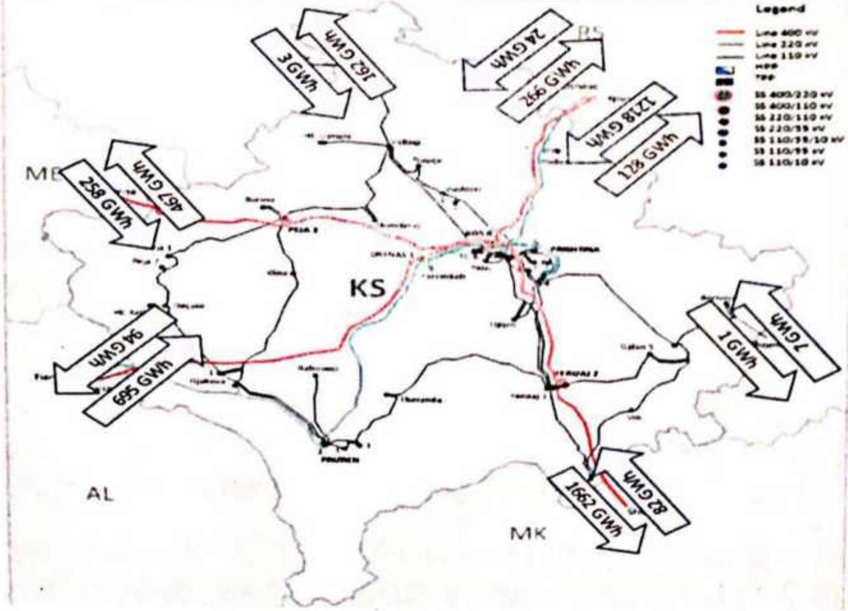


Source: Data from ERO annual reports.

Kosovo has a well interconnected and strong transmission network. There are four 400 kilovolt (kV) lines with Albania, Macedonia, Serbia and Montenegro; two 220 kV lines with Albania and Serbia, and two 110 kV lines with Serbia. Those lines have a combined throughput capacity of about 2,300 MW. All lines are utilized for imports, exports, and transit flows except for 400 kV line with Albania. The latter is not energized due to existing unresolved political issues between Serbia and Kosovo over the control of interconnection capacities. The transmission network of Kosovo also facilitates large electricity transits, especially towards Macedonia, Montenegro, and Albania. Specifically, in 2013-2016, electricity transit flows through Kosovo were between 1,903 – 2,281 GWh/year, which represents around 34-42 percent of total domestic demand during the same period. There are no physical or other bottlenecks for importing electricity required for meeting domestic demand.

There is the unresolved issue of Kosovo not being able to allocate its transmission capacity. This is due to the fact that Kosovo has not yet been recognized as a separate control block/area within European Networks of Transmission System Operators for Electricity (ENTSO-E). However, this has not been a constraint for importing electricity.

Figure 6: Interconnections of Kosovo Transmission Network



Source: ERO Annual Report, 2016

Electricity supply scenarios to meet forecast demand

Ten supply scenarios were analyzed to determine the lowest economic cost scenario for meeting forecast hourly electricity demand. The Study estimated the present values of the economic costs of these supply scenarios to identify the scenario that would minimize the economic cost of supply. The composition of electricity supply scenarios is discussed below.

All electricity supply scenarios assume improvement in EE as described in the demand forecast section. Investments in EE improvement in social and public buildings as well as increased penetration of district heating would reduce electricity demand.

All electricity supply scenarios assume significant scale-up of hydropower, wind power, and biomass/biogas according to the assumptions outlined below. The Energy Regulatory Office (ERO) established a feed-in tariff mechanism to promote investments in small RE projects.[21] The progress with construction and the final authorizations (i.e. ready to commence construction) issued by ERO suggest that recently there has been significant private investor interest in construction of small RE.

- <u>Biogas and biomass</u>. The Study assumed 11 MW[22] of biomass-based generation capacity to be constructed by 2020. This is consistent with the target in the Government's Energy Sector Strategy 2017-2026. ERO established a feed-in tariff of

[21] Projects less than 10 MW in case of small hydro; less than 32 MW in case of wind. For solar PV and biomass, the total installed size would be capped by the RE target in the Energy Sector Strategy for 2017-2026 – 30 MW and 11 MW accordingly.

[22] Energy Strategy of the Republc of Kosovo for 2017-2026, March 2017.

€71.30 per megawatt-hour (MWh) for biomass plants and 10-year guaranteed offtake of electricity. Forestry products and residues, and agricultural waste are assumed to be the source of fuel. The Study also assumes 5 MW of biogas capacity to be constructed by 2021. Livestock manure is assumed to be the primary fuel source. The Gjakova Combined Power and Heat Project,[23] implemented with EU support, is already under development

- Hydropower. The Study assumed 163 MW of new small hydropower plants would be constructed by 2022.[24] This is consistent with the target of 234 MW[25] in the Government's Energy Sector Strategy for 2017-2026. The Government has been developing the small hydropower plants with private sector involvement. ERO developed an authorization procedure and implemented a feed-in tariff of €67.5/MWh to that end. There is a 10-year off-take guarantee for electricity from small hydro plants. As of June 2017, a total of 70 MW of small hydros received final authorization.
- Small-scale solar photovoltaic (PV). The Study assumed 30 MW of solar PV generation capacity to be constructed by 2020 under all new thermal generation options.[26] This is consistent with target set through a decision by the Ministry of Economic Development (MED). ERO adopted a feed-in tariff of €136.4/MWh to that end. There is a 10-year off-take guarantee for electricity from solar PV plants. One small project has already been commissioned and another three projects totaling 9 MW of capacity have received final authorization. The solar PV technology has large potential for further scale-up because the potential is estimated at more than 580 MW as per IRENA estimate.[27] There is strong interest from private investors to pursue utility-scale solar PV projects in the country, including potential combination of solar PV and BESS. A private developer has proposed a project to the Government of Kosovo to build 150 MW solar PV power plant at the depleted lignite mines. The results of a preliminary market sounding by the World Bank suggest that several private developers would be willing to participate in well-structured competitive bidding for new utility-scale solar PV projects combined with BESS.
- Wind power. The Study assumed 150 MW of new wind capacity to be constructed by 2022. To promote development of wind energy, ERO developed an authorization procedure and established a feed-in tariff of €85/MWh with guaranteed off-take of electricity for 12 years. This is a realistic target to be achieved given that 167 MW of wind projects are already in advanced development stage with private investors. As of June 2017, the 105 MW project[28] in the North-East received final authorization (i.e. ready to commence construction) and 32.5 MW project in the East is under construction. Those are the areas with the best resource quality, i.e. capacity factors

[23] 8 MW thermal and 1.5 MW electric capacity.
[24] ERO Annual Reports.
[25] Includes 70 MW of existing small hydro and 163 MW planned.
[26] ERO Annual Reports.
[27] "Cost-Competitive Renewable Power Generation: Potential across South East Europe," IRENA, 2017.
[28] Broken down into several smaller projects to benefit from FiT.

of up to 37%. The wind has significant potential for scale-up, including the areas with average resource quality with capacity factors of around 26 percent.[29]

To bridge the gap between projected demand (inclusive of EE measures) and existing supply coupled with the RE measures outlined above, additional supply options were considered: a scaled-up renewable energy with storage scenario and fossil-fuel options.

RE Scale-Up combined with energy storage. The scale-up of RE would allow Kosovo to improve energy security and reduce the local environmental impacts as well as greenhouse gas emissions. This scenario assumes construction of RE capacity in two phases, which would be economically efficient and would not create overcapacity.

Fossil-fuel options considered include:

[29] World Bank team estimate based on resource data from NASA MERRA database.

[30] Power rating of 120 MW.

[31] 50 MW in 2027 and 40 MW each year in 2028-2030.

[32] Imports in 2023-2024 are estimated at 37-40% of total demand given that one unit of Kosovo B each year would be out for rehabilitation.

[33] Kosovo National Forest Inventory 2012.

[34] Alternating current (AC) rated capacity factors are used for solar PV throughout this report to ensure comparability with other generation technologies, which have AC rated capacity factors.

a. *Construction of a new 300 MW or 450 MW dual fuel power plant*. Kosovo does not have any local natural gas resources, and currently does not have the infrastructure for gas imports and distribution. Importing gas for power generation would require extending existing pipelines from the neighboring countries. This creates substantial implementation challenges. In addition to the pipeline, natural gas supply contracts would need to be secured, a requirement that could be complicated by the relatively low demand and the high seasonality of demand. To account for the uncertainty over the timing and the source of natural gas supply, the Study assumed that a dual fuel Combined Cycle Gas Turbine (CCGT) power plant would be built. The CCGT plant would initially burn diesel and then switch to natural gas once natural gas becomes available. This option exposes consumers to significant electricity price risks in the event the required gas supply infrastructure construction is delayed, or long-term gas import contracts cannot be secured.

b. *Installation of 300 MW or 450 MW of reciprocating engines using heavy fuel oil (HFO)*. Kosovo imports all the oil products it consumes, and such a supply option would therefore expose electricity tariffs to oil price risks. The Study considered 300 MW and 450 MW net-capacity fuel oil plants, consisting of a series of reciprocating engines.

c. *Construction of a new 300 MW subcritical, 450 MW supercritical, and 450 MW USC coal plant, which could also support biomass co-firing ratio of up to 10 percent*. Domestic lignite reserves are estimated to amount to 12.4 billion tons, of which 10.9 billion tons are exploitable.[35] The Study does not presume a specific technology choice for a new 300 MW or 450 MW lignite plant in Kosovo. The new lignite plants were assumed to be compliant with European Union directives and specifically the Industrial Emissions Directive (IED) and the relevant European Union (EU) requirements. This analysis assumes a 10 percent co-firing ratio, which would require Kosovo to import biomass (wood pellets) since domestic biomass reserves would not be sufficient to supply the plant's fuel needs.

d. *Reconstruction of Kosovo A*. The Study considered the option of reconstructing two units at Kosovo A, which will allow increasing available generation capacity to 450 MW. The reconstructed units were assumed to be compliant with the relevant EU requirements regarding emissions, and performance levels resembling those of other reconstructed units in Europe. Once the new reconstructed units are put into operation, the remaining three old units would be decommissioned.

Kosovo may reduce, but cannot eliminate, dependence on imports. Kosovo is dependent on imports to meet seasonal and daily peaks. In the past, Kosovo has imported anywhere from 9 to 17 percent of its total electricity demand per year. Historically, the highest amount of imports took place in the winter months given peak demand for electricity (driven by electric heating) and in summer due to maintenance of existing coal projects. Even with the large new thermal capacity (e.g. 450 MW plants), the Study results show that imports would be needed given large unit sizes and their inflexibility to quickly adjust the generation upwards or downwards.

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[35] Mining Strategy of the Republic of Kosovo for 2012–2025, Ministry of Economic Development, Pristina, 2012.

Results of Economic Evaluation of Supply Scenarios

The results of economic evaluation are presented in Table 7, Table 8, and Table 9 below. They correspond to the present values exclusive of all externalities, inclusive of local environmental externalities only, and inclusive of both local and global environmental externalities, respectively.

- Least Economic Cost Exclusive of Externalities (local and global)

Reconstruction of Kosovo A power plant (450 MW) combined with extensive EE and scale-up of RE is the least economic cost supply scenario to meet the forecast demand if no externalities are taken into account. The 300 MW fossil-fuel plant scenarios and the RE Scale-Up with Storage scenario have present values of 5.5 to 13.5 percent higher compared to reconstruction of Kosovo A. However, it should be noted that such reconstruction projects carry significant technical and cost overrun risks.

Table 7: Summary of Present Values of the Supply Costs Exclusive of All Externalities (in Million €)

Cost Item	Kosovo A Reconst.	Sub-C Coal 300 MW	RE Scale-Up with Storage	Dual Fuel 300 MW	Fuel Oil 300 MW	Super-C Coal 450 MW	USC Coal 450 MW	Dual Fuel 450 MW	USC Coal with Biomass 450 MW	Fuel Oil 450 MW
Present value of CAPEX	1,706	1,791	1,806	1,576	1,467	2,044	2,085	1,660	2,102	1,542
Present value of imports	320	318	694	324	325	268	268	206	298	208
Present value of total O&M	1,666	1,791	1,477	2,165	2,396	1,921	1,911	2,407	1,981	2,661
Present value of total costs	**3,691**	**3,899**	**3,978**	**4,064**	**4,188**	**4,233**	**4,265**	**4,272**	**4,381**	**4,411**
Difference from least cost (%)	**-**	**5.65%**	**7.77%**	**10.11%**	**13.46%**	**14.70%**	**15.55%**	**15.75%**	**18.70%**	**19.50%**

Source: World Bank team estimate.

Any new fossil fuel capacity above 300 MW would increase costs for the power system. It should be noted that any 450 MW Thermal Scenarios would be about 15–20 percent more expensive compared to the least-cost scenario, thereby entailing significant additional costs for the country, whether paid by consumers or the Government.

The 450 MW Supercritical Coal, and 450 MW USC Coal Scenarios are more expensive because only a fraction of their capacity would be used to meet incremental demand;[36] the remaining capacity would be used to displace generation from existing Kosovo B plant

[36] Under 450 MW Supercritical Coal Scenario, imports would significantly reduce and reach 4.5–6.0 percent of total demand. However, imports would not be eliminated entirely given that large coal units are not well suited for quickly changing the output to respond to hourly changes in demand.

given that the new coal plant would be more efficient. This would lead to surplus capacity in the power system. The 450 MW Dual Fuel, Fuel Oil, and USC Coal with Biomass Co-firing scenarios are more expensive because, in additional to surplus capacity, they have higher fuel costs.

- Least Economic Cost Inclusive of Local Environmental Externalities

300 MW Subcritical Coal Scenario becomes the least cost by a narrow margin of 0.6 percent over the RE Scale-Up with Storage Scenario and 1.5 percent over the Kosovo A Reconstruction Scenario when local environmental costs are accounted for in economic analyses. The ranking changes due to high environmental costs of the Kosovo A Reconstruction Scenario because this scenario has (a) the third largest amount of coal-based generation (after 450 MW Supercritical Coal and 450 MW USC Coal Scenarios) among all scenarios; and (b) the largest share of generation by Kosovo A and Kosovo B plants (with highest environmental costs) in the total electricity supply. Under other scenarios, the share of generation from Kosovo A and Kosovo B is smaller because Kosovo A is assumed to be retired.

Table 8: Summary of Present Values of the Supply Costs Inclusive of Local Environmental Externalities (in Million €)

Cost item	Sub-C Coal 300 MW	RE Scale-Up with Storage	Kosovo A Reconst.	Super-C Coal 450 MW	USC Coal 450 MW	Dual Fuel 300 MW	Fuel Oil 300 MW	Dual Fuel 450 MW	USC Coal with Biomass 450 MW	Fuel Oil 450 MW
Present value of CAPEX	1,791	1,806	1,706	2,044	2,085	1,576	1,467	1,660	2,102	1,542
Present value of imports	318	694	320	268	268	324	325	206	298	208
Present value of total O&M	1,791	1,477	1,666	1,921	1,911	2,165	2,396	2,407	1,981	2,661
Present value of local externalities	2,427	2,386	2,731	2,234	2,234	2,521	2,579	2,530	2,530	2,596
Present value of total costs	**6,327**	**6,364**	**6,422**	**6,467**	**6,499**	**6,585**	**6,767**	**6,802**	**6,911**	**7,007**
Difference from least cost (%)	**-**	**0.59%**	**1.51%**	**2.22%**	**2.72%**	**4.08%**	**6.96%**	**7.51%**	**9.23%**	**10.75%**

Source: World Bank team estimate.

It is worth noting that the present values of most of the scenarios are within a range of 4 percent (or about €260 million) when local environmental costs are accounted for. This makes the ranking of such scenarios more sensitive to modest changes in input assumptions, while the relative cost differences among the scenarios remain small (see sensitivity analysis).

The local environmental costs are an important element in the decision-making regarding the preferred supply scenario because they inflict economic costs on the country and the sub-region, and ultimately those costs would be borne either by the consumers of electricity (as tax payers) in Kosovo, the Government of Kosovo, and the neighboring countries.

It should be noted that the dispatch is modeled based on the variable costs of projects and the local environmental costs are added to the total economic supply costs by multiplying the generation from each polluting plant by the estimated local environmental cost per kWh.

- Least Economic Cost Inclusive of Local and Global Environmental Externalities

When the social cost of carbon is added to the economic analysis, the RE Scale-Up with Storage Scenario becomes the least cost by a margin of 4 percent ahead of a group of several thermal scenarios whose present values are within 1.5 percent of each other. The social cost of carbon changes the ranking for the 300 MW Subcritical Coal Scenario because the cost of its global externalities is the highest (high carbon emissions from the 300 MW plant and Kosovo B) Reconstruction of Kosovo A becomes more expensive when the social cost of carbon is included because it has the largest share of generation from Kosovo A (high carbon emissions) among all scenarios. The RE Scale-Up with Storage Scenario becomes least cost because the cost of its global externalities is considerably lower than the fossil-fuel plants.

Differences in the present values of thermal scenarios become non-material when the social cost of carbon is added to the economic costs. Specifically, with the social cost of carbon, the present values of all fossil-fuel scenarios are within 6.2 percent. The present values of all thermal scenarios are, however, at least 4 percent higher than the present value of the RE Scale-Up with Storage.

Table 9: Summary of Present Values of the Supply Costs Inclusive of Local and Global Environmental Externalities (in Million €)

Cost item	RE Scale-Up with Storage	USC Coal 450 MW	Super-C Coal 450 MW	Dual Fuel 300 MW	Sub-C Coal 300 MW	Kosovo A Reconst.	Dual Fuel 450 MW	Fuel Oil 300 MW	Fuel Oil 450 MW	USC Coal with Biomass 450 MW
Present value of CAPEX	1,806	2,085	2,044	1,576	1,791	1,706	1,660	1,467	1,542	2,102
Present value of imports	694	268	268	324	318	320	206	325	208	298
Present value of total O&M	1,477	1,911	1,921	2,165	1,791	1,666	2,407	2,396	2,661	1,981
Present value of local externalities	2,386	2,234	2,234	2,521	2,427	2,731	2,530	2,579	2,596	2,530

Cost Item	RE Scale-Up with Storage	USC Coal 450 MW	Super-C Coal 450 MW	Dual Fuel 300 MW	Sub-C Coal 300 MW	Kosovo A Reconst.	Dual Fuel 450 MW	Fuel Oil 300 MW	Fuel Oil 450 MW	USC Coal with Biomass 450 MW
Present value of global externalities	3,038	3,282	3,343	3,252	3,516	3,497	3,236	3,319	3,313	3,458
Present value of total costs	**9,401**	**9,781**	**9,810**	**9,837**	**9,843**	**9,919**	**10,038**	**10,087**	**10,320**	**10,369**
Difference from least cost (%)	**-**	**4.04%**	**4.35%**	**4.63%**	**4.70%**	**5.50%**	**6.78%**	**7.29%**	**9.77%**	**10.29%**

Source: World Bank team estimate.

Results of Sensitivity Analyses

- Least Economic Cost Scenario Exclusive of Externalities

The Kosovo A Reconstruction Scenario remains least cost even in cases of significant variation of key variables and assumptions.

Table 10: Results of Sensitivity and Switching Value Analyses, Exclusive of Externalities

Sensitivity	
Electricity demand growth of 3.31 percent/year (high case) vs. 1.60 percent under base case	Kosovo A Reconstruction remains least cost.
Electricity demand growth of 0.73 percent/year (low case) vs. 1.60 percent under base case	Kosovo A Reconstruction remains least cost.
Discount rate of 4.4 percent vs. base case of 6.4 percent	Kosovo A Reconstruction remains least cost.
Discount rate of 10.4 percent vs. base case of 6.4 percent	Kosovo A Reconstruction remains least cost.
30 percent higher hourly import prices	Kosovo A Reconstruction remains least cost.
25 percent higher economic price of lignite	Kosovo A Reconstruction remains least cost.
Early, later, or no gas availability	Kosovo A Reconstruction remains least cost.
Switching Value for Capital Costs	
56 percent capital cost decrease of RE Scale-Up with Storage Scenario	RE Scale-Up with Storage Scenario would become least cost.
56 percent capital cost increase of Kosovo A Reconstruction Scenario	300 MW Subcritical Coal Scenario would become least cost

Source: World Bank team estimate.

- Least Economic Cost Scenario Inclusive of Local Externalities

The 300 MW Subcritical Coal Scenario remains least cost even in cases of significant variation of key variables and assumptions, except when using a higher discount rate and when CAPEX costs for the RE Scale-Up with Storage Scenario are reduced by 15 percent.

Table 11: Results of Sensitivity and Switching Value Analyses, Inclusive of Local Externalities

Sensitivity	
Electricity demand growth of 3.31 percent/year (high case) vs. 1.60 percent under base case	300 MW Subcritical Coal Scenario remains least cost.
Electricity demand growth of 0.73 percent/year (low case) vs. 1.60 percent under base case	RE Scale-Up with Storage Scenario becomes least cost, but only by 0.1 percent over 300 MW Subcritical Coal Scenario.
Discount rate of 4.4 percent vs. base case of 6.4 percent	300 MW Subcritical Coal Scenario remains least cost.
Discount rate of 10.4 percent vs. base case of 6.4 percent	RE Scale-Up with Storage becomes least cost and 300 MW Subcritical Coal Scenario becomes the second lowest cost. This is because the scaled-up wind is built later in the modeling period (2027–2030) and are therefore discounted further than plants built for 2023.
Non-technical losses reduce to 0 by 2025 vs. 2.95 percent by 2030	300 MW Subcritical Coal Scenario remains least cost.
Early, later, or no gas availability	300 MW Subcritical Coal Scenario remains least cost.
15 percent lower CAPEX costs for scaled-up solar PV, wind, and storage	RE Scale-Up with Storage becomes least cost by 0.1 percent over 300 MW Subcritical Coal Scenario.
50-percent higher local environmental costs for pre-reconstruction Kosovo A and pre-rehabilitation Kosovo B, and post-rehabilitation Kosovo B	300 MW Subcritical Coal Scenario remains least cost.

Source: World Bank team estimate.

- Least Economic Cost Scenario Inclusive of Local and Global Externalities

The RE Scale-Up with Storage Scenario (inclusive of costs of all externalities) would remain least cost even in cases of significant variation of key variables and assumptions.

Table 12: Results of Sensitivity and Switching Value Analyses, Inclusive of Local and Global Externalities

Sensitivity	
Electricity demand growth of 0.73 percent/year (low case) vs. 1.60 percent under base case	RE Scale-Up with Storage Scenario remains least cost.
Electricity demand growth of 3.31 percent/year (high case) vs. 1.60 percent under base case	RE Scale-Up with Storage Scenario remains least cost.
Discount rate of 4.4 percent vs. base case of 6.4 percent	RE Scale-Up with Storage Scenario remains least cost.
Discount rate of 10.4 percent vs. base case of 6.4 percent	RE Scale-Up with Storage Scenario remains least cost.
30 percent higher hourly import prices	RE Scale-Up with Storage Scenario remains least cost.
25 percent higher economic price of lignite	RE Scale-Up with Storage Scenario remains least cost.
High social cost of carbon	RE Scale-Up with Storage Scenario remains least cost.

Sensitivity	
Non-technical losses reduce to 0 by 2025 vs. 2.95 percent by 2030	RE Scale-Up with Storage Scenario remains least cost.
Early, later, or no gas availability	RE Scale-Up with Storage Scenario remains least cost.
Switching Values for Capital Costs	
74 percent capital cost increase for RE Scale-Up with Storage Scenario	450 MW USC Coal Scenario would become least cost.
51 percent capital cost decrease for 450 MW USC Coal Scenario	450 MW USC Coal Scenario would become least cost.
58 percent capital cost decrease for 450 MW Supercritical Coal Scenario	450 MW Supercritical Coal Scenario would become least cost.
Switching Values for Fuel Prices	
80 percent decrease in natural gas prices, combined with 75 percent decrease in diesel prices	300 MW Dual Fuel Scenario would become least cost.
Switching Values for Hourly Import Prices	
90 percent increase in hourly import prices	450 MW USC Coal Scenario would become least cost.

Source: World Bank team estimate.

Conclusions

The principal conclusions in this Study are based on the economic analyses and some qualitative factors that should be taken into account when deciding on the preferred supply expansion scenario.

a. ***Reconstruction of Kosovo A emerge as the scenarios with lowest cost borne by the domestic economy.*** Kosovo A Reconstruction is least cost without any externalities. With local environmental externalities, Kosovo A Reconstruction costs 1.5 percent more and ranks the third lowest, behind RE Scaled-Up with Storage Scenario. As mentioned earlier, local environmental costs cover both domestic and cross-border externalities, and as such are not constrained only to Kosovo, but affect its neighbors.

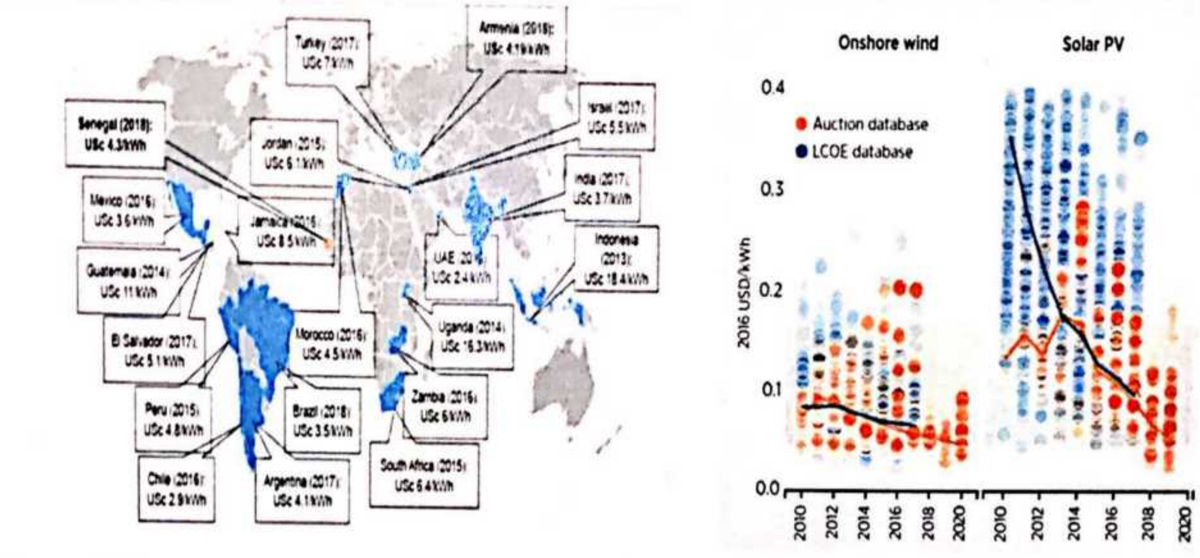
b. ***300 MW Subcritical Coal Scenario is least cost only when local environmental costs are included.*** 300 MW Subcritical Coal Scenario is least cost once local environmental costs are added. As mentioned earlier, local environmental costs cover both domestic and cross-border externalities, and as such are not constrained only to Kosovo, but affect its neighbors.

c. ***The RE Scale-Up with Storage Scenario is least-cost by about €380 million, or 4 percent, over the 450 MW USC Coal Scenario once local and global environmental externalities are considered.*** This is due to the following factors:

   (i) Lower CAPEX costs than new 450 MW Supercritical or USC coal plants. There has been significant reduction in capital costs of solar PV, wind, and storage technologies since 2010. BESS capital costs reduced by 50 percent since 2016.[37]

[37] Lazard's Levelized Cost of Storage Reports and data obtained from suppliers.

Figure 7: Reduction in Solar PV and Wind Prices



Source: IRENA reports.

(ii) The lowest global and second-lowest local environmental costs. The result is robust as confirmed by sensitivity analyses, which suggests that this scenario remains least cost even in case of significant variation of key inputs and assumptions.

d. ***Any 450 MW scenario will create capacity surplus***. If the Government decides to construct a new 450 MW thermal power plant, then it would create significant additional costs for the country. The 450 MW scenarios would create capacity surpluses, which are not needed most of the time to meet the domestic demand.

e. ***The 450 MW Fuel Oil and 450 MW USC with Biomass Co-firing are among the most expensive scenarios***. Those scenarios have the highest O&M and capital costs, respectively. They also have two of three highest local environmental costs, and rank in the bottom half for carbon costs.