WORLD BANK

Energy Efficiency and Renewable Energy Project. Support for Grid Integrated Renewable Energy Generation

LEAST COST RENEWABLE ENERGY MIX

FINAL REPORT

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ALB-ARCHITECT

ABBREVIATIONS

AL	Albania
BAU	Business as Usual
COD	Date of Commissioning
DEM	Digital Elevation Model
ERO	Energy Regulatory Office
FOR	Forced Outage Rate
ME	Montenegro
MK	North Macedonia
MOR	Maintenance Outage Rate
NECP	National Energy and Climate Plan
NPV	Net Present Value
NREAP	National Renewable Energy Action Plan
PV	Photovoltaic
RS	Serbia
O&M	Operation and Maintenance
PEMMDB	Pan-European Market Modelling Data Base
PS	Pumped Storage
SEE	South East Europe
SHPP	Small Hydropower Plant
SRTM	Shuttle Radar Topography Mission
TPP	Thermal Power Plant
TYNDP	Ten Year Network Development Plan
WB	World Bank
XK	Kosovo

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PROJECT AIM AND OBJECTIVE

The aim of this project is to support ERO and MED to assess the least cost options for RE in Kosovo and to assess grid integration needs at the distribution level.

The development of the least cost plan for optimal renewable energy (RE) mix takes several steps. First, the assessment of potential energy sources in Kosovo is determined. This step includes reviewing the existing policies, action plans, RE targets, (pre-)feasibility studies for candidate projects, in order to assess the technical and economic potential for RE in Kosovo. Under this task, the Consultant determined the theoretical, technical and realizable potential, including the associated costs, for new RE generation in Kosovo. Existing and planned conventional generators needs are also assessed and included into the potential generation fleet of Kosovo. Available demand forecasts for Kosovo were analyzed and reviewed to determine demand scenarios up to 2030 for analysis in the long-term optimization model.

The specific objectives of the project are to determine the least cost RE mix to meet RE targets based on least cost planning (Task 1) and to develop a distribution level RE grid integration study to assess the network's capacity to absorb DER and determine optimal investments needs to maintain or improve system reliability (Task 2). This deliverable is a Final report for least cost renewable energy mix under Task 1.

Using a widely accepted and accredited long-term power system planning tool PLEXOS® Market Simulation Software, the Consultant has prepared Kosovo's power system model and determined optimal renewable energy penetration for Kosovo's power system, based on relative costs of all analyzed technologies and taking into account demand forecasts, renewable electricity targets and other technical or regulatory constraints related to the power system operation and development.

DEMAND-SUPPLY BALANCE OF KOSOVO

Electricity generation in Kosovo is almost entirely dependent on two ageing lignite plants: TPP Kosovo A (3 units with a total installed capacity of 610 MW) and TPP Kosovo B (2 units with a total installed capacity of 678 MW). Hydro energy is the main renewable energy source that contributes to the electricity mix, with installed capacity of 108.4 MW. Apart from the hydropower plants, there is one small wind power plant with a capacity of 1.35 MW and in 2018 a larger wind farm of 32 MW was commissioned. In the past two years, few new solar power plants started operating, with total installed capacity of 10 MW. Finally, Kosovo is also importing electricity (via commercial contracts and exchanges) in order to cover its electricity needs.

Based on the data received from the Beneficiaries, total available generation capacity in Kosovo amounts 1,440.4 MW, and total electricity generation in 2020 is expected to reach 5,051.1 GWh.

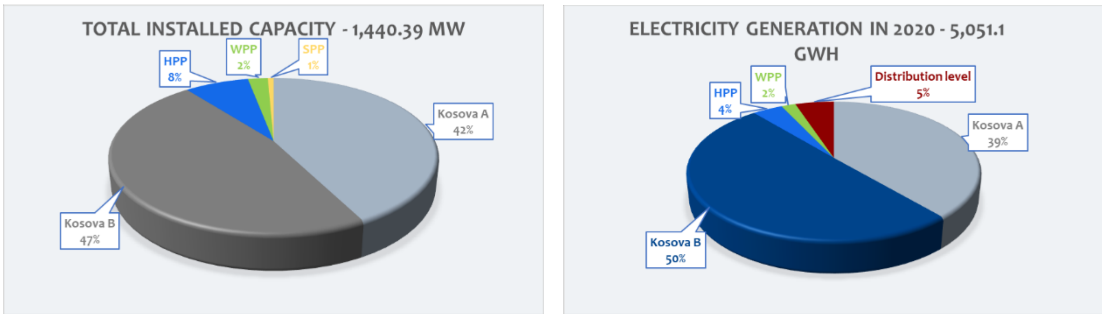


Figure 0-1 Power plants capacity and expected electricity generation in 2020

Pursuant to the EU Directive 2009/28/EC, Kosovo is obliged to meet mandatory RES targets for 2020, as defined and approved by EnC Ministerial Council in 2012. For Kosovo a 25% of RES share in the final gross energy consumption is assumed, broken down in: 14.33% of RES in gross final consumption of electricity (RES-E), 10 % of RES in final consumption of energy in transport (RES-T) and 45.65 % of RES in gross final consumption for heating and cooling (RES-H&C), as set by the National Renewable Energy Action Plan (NREAP).

Every two year, Kosovo is obliged to submit a Report on Progress in the Promotion of Renewable Energy in the Energy Community. The Report assesses the progress in the promotion and use of renewable energy against the trajectory towards the 2020 targets set in the NREAP. So far, three Progress Reports are published in Kosovo and 4th Renewable Energy Progress Report for the period 2018-2019 should be published not later than December 2020. According to Kosovo's 1st, 2nd and 3rd Progress Report, EUROSTAT data and the Energy balance of 2019, RES-E share in gross final electricity production should not go above 10% in 2020, meaning that the realized achievements in RES-E were significantly lower compared to the estimated RES potential in 2020.

ASSESMENT OF RE POTENTIAL IN KOSOVO

Previous studies and data provided by the Beneficiaries were reviewed and analyzed to determine the theoretical, technical and realizable RE potential in Kosovo. To determine the least cost option for system development, it was necessary to analyze all potential generation projects in the power system, from small-scale PV installation to large-scale generators connected to the transmission grid including conventional technologies.

Main parameter for assessing solar resource or comparing two different locations is global solar radiation. Global horizontal irradiation for Kosovo ranges from 1,200 kWh/m2 for mountainous parts of the country, to 1,500 kWh/m2 in the southern part near Gjakova. Energy production is directly related with solar irradiation on a specific location; however, solar resource is not the only factor in the selection of locations, neither in assessing technical potential.

Technical factors, such as terrain configuration, use of land, protected areas etc. play a major role in reduction of areas suitable for solar power plants.

Technical potential, in terms of installed MW, for ground mounted solar power plants is estimated with respect to available suitable area. Available terrain is assessed using DEM (Digital elevation model) with raster precision of 100 x 100 m. For assessing suitability for solar power plants, terrain slope is calculated based on DEM, using build-in functions in a GIS specialized tool. Highly sloped terrain (> 5°) is ruled out as technically unsuitable area for solar power plants. Also, smaller areas, which sum up to several hectares, are also ruled out from further analysis, as a minimum limit was set on 20 ha, in order to be able to accommodate at least a 10 MW solar power plant. In generally, terrain with slope less than 5° covers 415,283 ha, or around 38% of the total area of Kosovo. Furthermore, protected areas, built-up urban areas, water bodies, infrastructure corridors, vineyards, plantation, brownfields, such as dump sites and mineral extraction sites, areas are ruled out of the analysis.

Total suitable area is estimated at around 370,000 ha, and technically usable area is estimated to be 2% of total suitable area, 7,400 ha. Technical and realizable potential of PV is calculated by assuming 2 ha/MW and is estimated at 3,600 MW.

Data for wind speed in Kosovo are taken from Global Wind Atlas and refer to 100 m height above ground level (a.g.l.), and data on the terrain slopes for Kosovo are derived from publicly available SRTM terrain elevation data.

In terms of wind farms, high terrains (e.g. over 1,700 m) present a serious limitation for project realization because of low temperatures outside (e.g. below -10°C for longer periods). Around 5% of the Kosovo territory is over 1,700 m, mostly in national parks Sharr Mountains and Mountains of Nemuna (Prokletije), and these parks are already exclusion areas for wind farms. Analyzed exclusion zones for wind farms regard terrain relief, wind energy potential, protected areas and urban infrastructure, water bodies, urban infrastructure (cities, villages) and transport infrastructure (airports, roads).

Overall area of exclusion is around 4,880 km^2, which amounts to around 45% of Kosovo's territory. Most of the technically appropriate area for wind farms are between 5 and 6 m/s (at 100 m a.g.l.). Since the whole range of wind speeds is not technically feasible, the 3,133 km^2 area presents locations ideal for wind turbines development. The specific factor of 0.5 km^2/MW will be used to convert area to power, meaning 0.5 km^2 is an area suitable for 1 MW (or on each km^2 2 MW can be placed) in a wind farm that is 2 km away from any other wind farm. Using these assumptions, Kosovo has theoretical wind power potential of 6,268 MW. However, to calculate feasible wind energy potential, other specific issues need to be considered: suitability of the terrain cover for wind farms construction, feasibility of the wind farm regarding wind energy potential (wind speed), distance from grid connection point and existing roads, restrictions due to environmental protection,

The results present the most probable overall wind energy technical potential of 1,781 MW. The most probable technical wind power potential could be further reduced in the project realization due to already mentioned potential barriers. Such reduction may result in a realizable potential of around 1,200 MW for Kosovo.

protection of cultural or heritage areas, etc. First two points can be quantified based on wind speed data (Global Wind Atlas) and available data on land cover (CORINE).

The hydropower potential was assessed based on available data and documents provided by the Beneficiaries as well as publicly available documents.
Hydro energy is the main renewable energy source in Kosovo, amounting to an installed capacity of 108.24 MW. Kosovo unfortunately does not have plentiful water resources like other Balkan countries and the wider deployment of small hydropower plants is delayed since the most promising sites are located in protected areas.
The hydrology of water sources consists of four main rivers: Drini i Bardhë (White Drin), Ibri (Ibar), Morava e Binçës (Binačka Morava) and Lepenci (Lepenac). The hydropower potential of these rivers is estimated to approximately 700 GWh/year.
Based on the detailed research of small HPPs conducted by the Government of the Republic of Kosovo in 2006, 2009 and 2010, the north-western part of Kosovo has the highest potential, i.e. the area between Peja and Junik (the rivers of Lumbardhi of Peja, Lumbardhi of Decan, Lumbardhi of Llocan, and Erenik). The south-east part has smaller hydropower potential, i.e. the area between Dragash and Prizren (the rivers of Plava, Lumbardhi i Prizrenit, and Lepenci). The area of northern Mitrovica (the Bajska and Bistrica rivers) has even smaller potential, and the area of east of Llap (Kacandoll river) has the smallest hydropower potential. The list of possible locations for the construction of small hydropower plants, based on the above-mentioned source, allocates around 136 MW of SHPP potential, with respected electricity generation of 657.40 GWh.
However, it was agreed with the Beneficiaries that only the currently planned projects, total of 63.3 MW, will be commissioned until 2030.
The main (big) hydropower potential in Kosovo is the pump storage hydropower plant project Zhur with an estimated installed power of 250 MW. The plant should be located in the south-western part of Prizren, in the stream of Drini i Bardhë (White Drin). The plant is supposed to be used as a storage facility, and its generated electricity will be utilized for peak demand.

ASSESMENT OF THE COSTS

The levelized cost of electricity (LCOE) is a useful tool for comparing the unit costs of different technologies over their operating life. For the purposes of this study, LCOE is determined for each 5-year step during the planning horizon (2025/2030). Figures below show estimated LCOE of power generation options in 2025 and 2030.

The following conclusions can be made for LCOEs over the study period:

- Market prices in neighboring markets are creating a positive environment and can attract project developers.

Using related costs such as investments, FOM, VOM, environmental taxes, fuel, expected connection charges/costs etc. LCOE is calculated for:

- hydro, wind, solar and biomass generation units,
- PS HPP Zhur (250MW),
- TPP Kosova e Re (450MW) and
- WPP Selaci (103.4 MW).

- Solar PVs are expected to see further technological development and cost reductions. Still, development of wind and solar depends on future support schemes.
- Large scale and small hydro are not expected to show further cost reductions. More strict environmental regulation can make these projects more expensive, postpone development and discourage investors due to regulatory risks. Moreover, it was agreed with ERO that just currently planned projects (total of 63.3 MW, Annex 2) will be commissioned until 2030.
- Competitiveness of Kosova e Re is significantly affected by internalization of external costs through CO_2 emission units surcharge.
- Finally, by 2030 the situation will become more favorable for variable renewables like wind and solar, while fuel and CO_2 prices significantly aggravate market position for TPP Kosova e Re.

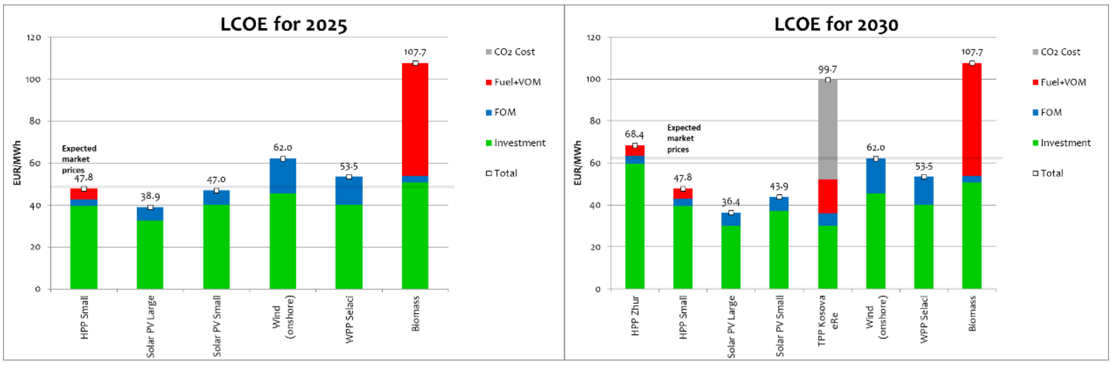


Figure 0-2 Estimated LCOE of power generation options in 2025 and 2030

ELECTRICITY DEMAND FORECASTS

Based on the analysis of available demand forecasts and in line with the discussion with the Beneficiaries, the following demand scenarios were determined - Base and High.
Demand projections in Base scenario are based on Scenario S3 from the Energy Strategy. However, in the forecast given in the Electricity and Thermal Energy Balance, demand for 20203 is 2.4% higher compared to the respective projections of S3 scenario. Thus, the Base Scenario for the electricity demand resulted by increasing the electricity demand in each year of S3 Scenario by 2.4%. As values under S3 were not available for the period after 2026, an extrapolation was used which resulted in electricity demand for Base scenario until 2030. The average annual growth rate for the period up to 2030 is 1.83%.
Demand projections in High scenario assume a fixed annual growth rate (2.3%) starting from the currently available forecast given in the Electricity and Thermal Energy Balance for 2020. Projections of electricity demand for both scenarios are presented in Figure 0-3 along with Scenarios S1-S4 from the Energy Strategy up to 2026.

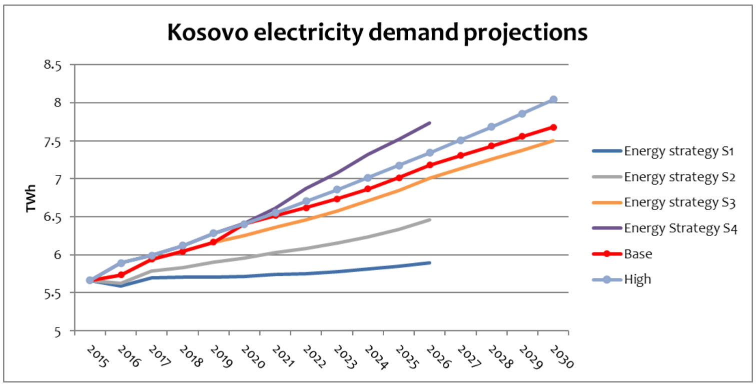


Figure 0-3 Electricity demand projections for Kosovo by 2030

POWER SYSTEM PLANNING TO DETERMINE THE OPTIMAL RENEWABLE ENERGY PENETRATION FOR KOSOVO'S POWER SYSTEM

The long-term planning process has the following main phases:

- Preparation of Kosovo's power system model;
- Definition of development scenarios to analyze;
- Executing the simulations;
- Analyzing results and determining the least cost RE option.

To determine optimal renewable energy penetration, Kosovo's power system model is prepared in the **PLEXOS® Market Simulation Software** tool. The objective of the optimization problem is **to minimize the net present value (NPV) of the total costs of the system over a long-term planning horizon**. The costs included in the objective function consist of annualized build cost for new generating capacities, fuel costs, variable O&M costs, CO_2 emission costs, value of unserved energy and cost of capacity shortage if the required capacity margin is defined. The optimal expansion plan represents therefore the least-cost investment plan that meets the system demand and obeys technical and regulatory constraints with a given set of candidate projects.

The power system of Kosovo is represented by seven nodes in PLEXOS, based on the seven existing distribution areas in Kosovo (Pristina, Peja, Prizren, Ferizaj, Mitrovica, Gjakova and Gjilan). Each node aggregates all the electricity demand and generation of a given distribution area. In that way the constraints on new RE developments and associated costs are modelled on the level of each distribution area. High voltage transmission network is modelled with given limits on transmission capacity. Considering the goal to meet the 2030 RES-E target, the planning horizon includes the period up to 2030, starting from 2020, i.e. a total of 11 years. All the costs and revenues occurring over the planning horizon are discounted to the base year in the model with the assumed 8% discount rate. The final set of scenarios to be analyzed in PLEXOS is determined in agreement with the Beneficiaries and the World bank and presented in Table 0-1.

Table 0-1 Final set of scenarios for analysis in PLEXOS

Scenario name	Scenario parameters		
	Kosovo electricity demand	*TPP Kosova e Re*	*RES-E target*
BaU	Base	In operation	Without target
BaU without TPP Kosova e Re	Base	Not in operation	Without target
S5	Base	In operation	33%
S6	High	In operation	33%
S7	Base	Not in operation	33%
S8	High	Not in operation	33%

Results for generation expansion of Kosovo's power system are analyzed based on the outputs of the long-term system optimization process performed using PLEXOS. The results of the optimization process give detailed outputs such as generation investment plan, total installed capacity and firm capacity in each scenario. All scenarios are also optimized in PLEXOS on a medium and short-term level using hourly resolution for simulations.

In each scenario, there is a cap in the model on annual level for new builds of solar and wind power plants (50 MW each), biomass (5 MW) as well as for batteries (50 MW). It is common to put such limitation on annual level in the model to avoid unrealistic builds which could not be technically feasible over the short time horizon considering the existing trends, technical and administrative/procedural issues of the analyzed country.

To meet the growing demand, a total of **1,936.7 MW** of new generation capacity (including batteries) is built over the planning horizon in **BaU scenario**. Total installed capacity in 2030 is 2,688.9 MW (including batteries), out of which 46% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in total capacity, 20% and 19% respectively, which corresponds to 537.2 MW of wind power plants and 510 MW of PV plants. The total electricity generation increases from 5.6 TWh in 2020 to around 6.7 TWh in 2030. In all years, except for 2023 and 2024, net interchange (imports-exports) is lower than 15% of total electricity demand, which is set as a constraint in the model. RES-E share in the total electricity demand in 2030 amounts to 36.3%.

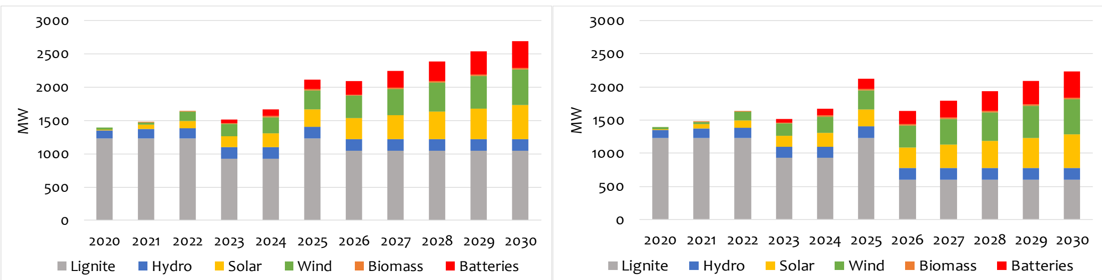
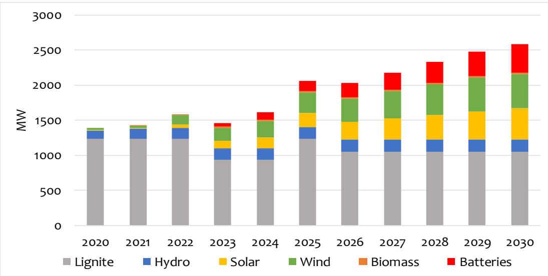


Figure 0-4 Total installed capacity by technology in BaU and BaU without Kosova e Re scenarios

A total of **1,486.7 MW** of new generation capacity (including batteries) is built over the planning horizon in **BaU without TPP Kosova e Re scenario**. By and after 2026, generation investment plan is the same as in BaU scenario, resulting in 503.4 MW of new wind power plants and 500 MW of new solar power plants in 2030. In this scenario there is no TPP Kosova e Re so the new capacity in 2026 refers to solar and wind power plants, and also batteries. Total installed capacity in 2030 is 2,238.9 MW (including batteries), out of which 55% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in the total capacity in 2030, 24% and 23% respectively. Total electricity generation increases from 5.6 TWh in 2020 to around 5.9 TWh in 2030. From 2026 on, the two units of TPP Kosovo B are the only thermal units in operation, which affects the increase of net imports to around 25% compared to the projected annual demand. Similar to the BaU scenario, RES-E share in the total electricity demand in 2030 amounts to 36.6%.

In **Base with TPP Kosova e Re scenario (S5)** the projected electricity demand in Kosovo is set according to the Base demand scenario, commissioning of TPP Kosova e Re is envisaged in 2026 and **the RES-E target is set to 33% in 2030**. To meet the growing demand, a total of **1,826.7 MW** of new generation capacity (including batteries) is built over the planning horizon. Total installed capacity in 2030 is 2,578.9 MW (including batteries), out of which 44% refers to renewable energy sources. Wind power plants capacity (487.2 MW) corresponds to the share of 19% in total capacity, which is higher compared to the share of solar power plants (17%), with total of 440 MW in installed capacity. Total electricity generation increases from 5.6 TWh in 2020 to around 6.7 TWh in 2030. In 2023 and 2024 net imports are 32% and 28% compared to the total annual demand. In other years the value of net interchange is lower or equal to 15%.



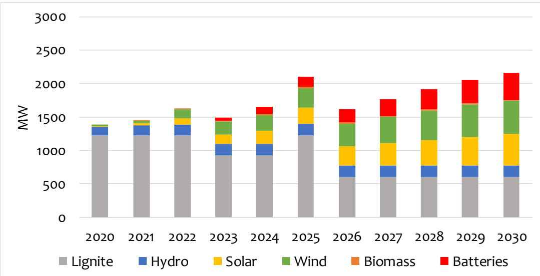


Figure 0-5 Total installed capacity by technology in S5 and S7 scenario

In **Base without TPP Kosova e Re scenario (S7)** assumptions regarding the projected electricity demand and RES-E target are the same as in S5 scenario, but the realization of TPP Kosova e Re project is not envisaged during the entire planning horizon. A total of **1,406.7 MW** of new generation capacity (including batteries) is built over the planning horizon. Total installed capacity in 2030 is 2158.9 MW (including batteries), out of which 54% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in total capacity, 23% and 22% respectively, which corresponds to 487.2 MW of wind power plants and 480 MW of PV plants. Total electricity generation increases from 5.6 TWh in 2020 to around 5.9 TWh in 2030.In the case of Base without TPP Kosova e Re scenario, short-term optimization results have showed the same trends regarding the unserved energy as in BaU without TPP Kosova e Re scenario. Unserved energy occurs in the period from 2026 when TPP Kosovo A is decommissioned and TPP Kosovo B is the only thermal power plant in operation. Thus, net import constraint is relaxed and average annual net import amounts 25% compared to the projected annual demand from 2026 to 2030.

In **High with TPP Kosova e Re scenario (S6)** the projected electricity demand in Kosovo is set according to the High demand scenario, commissioning of TPP Kosova e Re is envisaged in 2026 and the RES-E target is set **to 33% in 2030**. A total of **1,866.7 MW** of new generation capacity (including batteries) is built over the planning horizon. Total installed capacity in 2030 is 2,618.9 MW (including batteries), out of which 45% refers to renewable energy sources. Wind power plants with total installed capacity of 537.2 MW have a share of 20% in total capacity, while 440 MW of solar power plants represent 17% of the total capacity in 2030.

Total electricity generation increases from 5.6 TWh in 2020 to around 7 TWh in 2030. In 2030 total electricity demand is slightly higher than 8 TWh, according to High demand scenario. In 2023 and 2024 net interchange is 34% and 30% compared to the total demand, while in all other years of the planning horizon net interchange is lower or equal to 15% of demand.

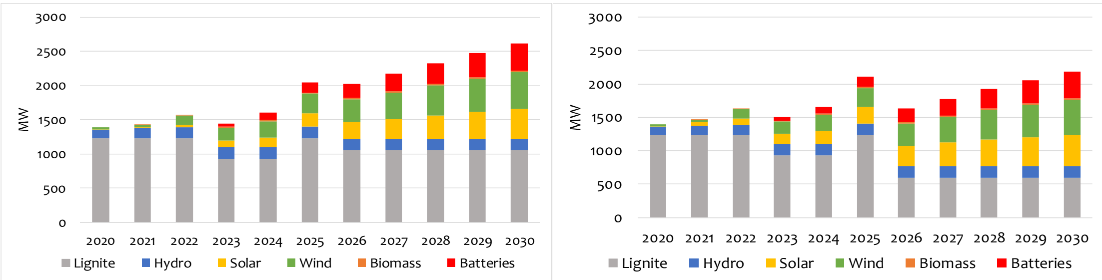


Figure 0-6 Total installed capacity by technology in S6 and S8 scenario

In **High without TPP Kosova e Re scenario (S8)** assumptions regarding the projected electricity demand and RES-E target are the same as in S6 scenario, but the realization of TPP Kosova e Re project is not envisaged during the entire planning horizon. A total of **1,436.7 MW** of new generation capacity (including batteries) is built over the planning horizon. Total installed capacity in 2030 is 2,188.9 MW (including batteries), out of which 54% refers to renewable energy sources. Wind and solar power have shares of 25% and 21% in total capacity, which corresponds to 537.2 MW of wind power plants and 460 MW of PV plants. Total electricity generation increases from 5.6 TWh in 2020 to around 6.1 TWh in 2030. Average annual net import amounts 25% from 2026 to 2030 compared to the projected annual demand.

In all scenarios biomass power plants (maximum of 20 MW) are built by 2024, and all small hydro power plants (63.3 MW) are built by 2023. Committed units have predefined year of commissioning, so the main differences in generation expansion plans are in new builds of generic solar and wind power candidates in different scenarios. Also, 400 MW of batteries is built, which is the maximum that can be built over the planning horizon considering the annual constraint of 50 MW.

All analyzed supply scenarios are compared based on their total costs that consist of the following components: generation build costs, fuel costs, variable O&M costs, CO_2 emission costs, fixed O&M costs, net import costs; and costs of local environmental pollution.

Cumulative generation build costs for the six scenarios until 2030 are presented in Figure 0-7Figure 5-42. These costs include build costs of new generation capacities and batteries. Scenarios in which TPP Kosova e Re is built in 2026 have higher cumulative investment costs, which range from EUR 2.32 billion in Base with TPP Kosova e Re scenario to EUR 2.43 billion in BaU scenario. In scenarios without TPP Kosova e Re these costs range from EUR 1.35 billion to EUR 1.44 billion, depending on the scenario.

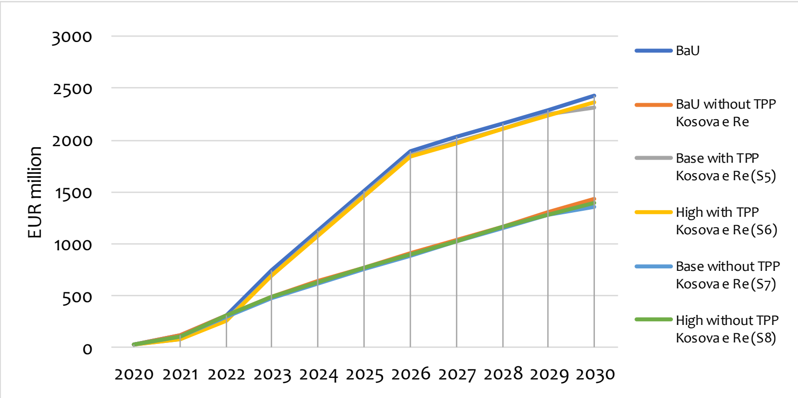


Figure 0-7 Cumulative build costs

To calculate the Net Present Value of each scenario all future costs are discounted to their value of the year 2020 applying the reference discount rate of 8%. The structure **of total NPV of costs** is presented in the following table.

Table 0-2 Total net present value of costs (EUR million)

Scenario	Build cost	Fuel cost	Variable O&M cost	Emission cost	Fixed O&M cost	Net import cost	Total NPV of costs
BaU	1,682	476	134	536	350	326	**3,505**
BaU without TPP Kosova e Re	979	473	128	529	306	514	**2,928**
Base with TPP Kosova e Re (S5)	1,612	481	136	553	344	344	**3,470**
High with TPP Kosova e Re (S6)	1,633	491	138	581	345	373	**3,561**
Base without TPP Kosova e Re (S7)	934	473	129	542	303	522	**2,903**
High without TPP Kosova e Re (S8)	959	483	130	564	305	556	**2,997**

For the six analyzed scenarios the NPV value of build costs ranges from EUR 0.9 billion to EUR 1.68 billion. The differences between other components of costs, such as fuel costs or VO&M are lower. The lowest net present value of total cost has the Base without TPP

Kosova e Re scenario, which has the lowest NPV of build costs, the lowest generation and consequently the lowest NPV of fuel costs and other O&M costs.

NPV was also calculated considering the local environmental pollution costs. The lowest NPV of total cost has Base without TPP Kosova e Re(S7) scenario when local environmental costs are included in the total costs, and the highest High with TPP Kosova e Re scenario (S6). NPV of costs that can be presented per technology type, such as build costs, fuel costs, and O&M costs is also provided in the study.

Additionally, a sensitivity analysis is made for two project candidates, PS HPP Zhur (250 MW) and utility scale PV park (500 MW). Given that there is significant uncertainty in the realization of these projects, it was decided to include these power plants as part of a sensitivity analysis in just one of the analyzed scenarios. The selected scenario for sensitivity analysis is Base without TPP Kosova e Re scenario, considering the lowest NPV of the total costs compared to the other scenarios, as well as low probability of TPP Kosova e Re project realization. Long-term optimization results for Base without TPP Kosova e Re scenario with PS HPP Zhur committed in 2027 show that a total of **1,656.7 MW** of new generation capacity (including batteries) is built over the planning (2020-2030), or 250 MW in comparison to S7 scenario without PS HPP Zhur. The same scenario with included utility-scale PV at depleted mine show that a total of **1,436.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030). In comparison to the S7 scenario without PV at depleted mine, that is 30 MW more. Comparison of NPV of total costs in S7 with the two scenarios analysed (large-scale utility PV and PS HPP Zhur) was made. The highest NPV refers to scenario S7 with PS HPP Zhur due to the highest NPV of build costs.

In addition to previously presented analyses, four scenarios based on **Base with TPP Kosova e Re (S5)** were also analyzed in PLEXOS, following the request of Ministry of Economy and Environment of Kosovo (MOE). The focus of these scenarios was to examine the impact of new gas unit on the least cost RE expansion and to analyze this option with and without Co_2 price in the model.

In all scenarios committed units are TPP Kosova e Re (450 MW) in 2026, and new gas unit (200 MW) in 2027. Model chooses to build biomass units from 2021 to 2024, while all small hydro power plants (63.3 MW) are built by 2023. In all scenarios model must build 50 MW of batteries in 2023.

All four scenarios have new gas unit (200 MW) planned to be commissioned in 2027 and 50 MW of batteries built in 2023. In two scenarios RES-E target is set to 33% as in original S5 scenario, while in the other two scenarios RES-E target is set to 25%. One of the parameters analyzed in these scenarios is introduction of the CO_2 price in Kosovo, which is used to additionally diversify scenarios.

Table 0-3 Main assumptions in additional scenarios based on the S5 scenario

	S5.1	S5.2	S5.3	S5.4
New gas unit	200 MW in 2027	200 MW in 2027	200 MW in 2027	200 MW in 2027

CO_2 price in Kosovo	Yes (from 2025)	No	Yes (from 2025)	No
Batteries	50MW in 2023	50 MW in 2023	50MW in 2023	50 MW in 2023
RES-E share in 2030	33%	33%	**25%**	**25%**

Wind and solar capacities are built with the objective to fulfill the RES-E target of 33% in S5.1 and S5.2, and 25% in S5.3 and S5.4, respectively. Thus, in first two scenarios model choses to build 440 MW of solar power plants and 350 MW of wind power plants. With the committed WPP Selaci, the total wind capacity is 453.4 MW in 2030. In scenarios S5.3 and S5.4 total capacity of solar and wind power plants in 2030 is lower, due to lower RES-E target, around 300 MW per each technology.

For the four analyzed scenarios the NPV value of build costs ranges from EUR 1.42 billion to EUR 1.59 billion. Build costs are higher in scenarios with higher RES-E target (33%), due to greater investments in RE. Fuel costs and variable O&M costs are higher in scenarios without CO2 price, due to greater engagement of thermal power plants.

1 INTRODUCTION

This is the Draft Report of the project ***Support for Grid Integrated Renewable Energy Generation*** which follows the proposal originally submitted by EXERGIA S.A. (GR) in joint venture with EIHP (HR), and Alb-Architect (XK). The main Beneficiaries of the project are the Ministry of Economic Development (MED) and the Energy Regulatory Office (ERO) of Kosovo. The project is financed by the World Bank group.

1.1 Project aim and objectives

As per the ToR, the overall objective of this project is "*to support ERO and MED to assess the least cost options for RE in Kosovo and to assess grid integration needs at the distribution level.*"

The specific objectives of the Project are:

- determine the least cost RE mix to meet RE targets based on least cost planning (**Task 1**);
- distribution level RE grid integration study to assess the network's capacity to absorb DER and determine optimal investments needs to maintain or improve system reliability (**Task 2**).

This deliverable is a Final report for least cost renewable energy mix under Task 1 and in the following sub-section, a brief description of Task 1 is presented.

1.1.1 Task 1

Task 1 is organized in the following sub-tasks:

- Subtask 1.1 and 1.2: Data collection, review and revision of national RE policy. These subtasks were completed in the inception phase of the project and the results were incorporated in the Inception report delivered on April 9, 2020. Feedback received from the Beneficiaries was incorporated in the revised version of the Inception report submitted on July 31st
- Sub-task 1.3: Assessment of RE potential in Kosovo
- Sub-task 1.4: Assessment of the costs and determination of RE supply curve for each technology
- Sub-task 1.5: Assessment of the available demand forecasts. This subtask is also completed in the inception phase and two demand scenarios, Base and High, were determined in the agreement with the Beneficiaries. The results are presented in chapter 4 .
- Sub-task 1.6: Power system planning to determine the optimal renewable energy penetration for Kosovo's power system
- Sub-task 1.7: Report preparation, revision and finalization

The development of the least cost plan for optimal renewable energy (RE) mix takes several steps. First, the assessment of potential energy sources in Kosovo is determined. This step includes reviewing the existing policies, action plans, RE targets, (pre-)feasibility studies for candidate projects, weather and hydrology data, in order to assess the technical and economic potential for RE in Kosovo. Under this task, the Consultant determined the theoretical, technical and realizable potential, including the associated costs, for new RE generation in Kosovo. Existing and planned conventional generators needs are also assessed and included into the potential generation fleet of Kosovo.

Using a widely accepted and accredited long-term power system planning tool, the Consultant has prepared Kosovo's power system model and determined the most optimal renewable energy penetration for Kosovo's power system, based on relative costs of all analysed technologies and taking into account demand forecasts, renewable targets and other technical or regulatory constraints of the power system.

1.2 Current demand-supply balance of Kosovo

Kosovo is one of the smallest power systems in the SEE region, while having a rich domestic coal resource at the same time. Lignite has been used for years to produce and supply electricity. Currently, electricity generation in Kosovo is almost entirely dependent on two ageing lignite plants: TPP Kosovo A (3 units with a total installed capacity of 610 MW) and TPP Kosovo B (2 units with a total installed capacity of 678 MW).

Hydro energy is the main renewable energy source that contributes to the electricity mix, accounting for around 10% of Kosovo's electricity generation in 2019, amounting to an installed capacity of 108.42 MW. Recently, some new small plants have started operating, but it should be noted that Kosovo does not have plentiful water resources like other Balkan countries. Further, the wider deployment of small hydropower plants (a form of renewable energy that could potentially be developed) is delayed since the most promising sites are located in environmentally protected areas. Apart from the hydropower plants, there is one small wind farm with a capacity of 1.35 MW and in 2018 a larger windfarm of 32 MW was commissioned. In the past two years, few new solar power plants started operating, amounting to an installed capacity of 10 MW. Finally, Kosovo is also importing electricity (via commercial contracts and exchanges) in order to cover its electricity needs.

Based on data received from the Beneficiaries, the total available generation capacity in Kosovo is presented in Table 1-1 and Figure 1-1.

Table 1-1 Power generation capacity in Kosovo

	Installed capacity [MW]	In operation since
A3	200	1970
A4	200	1971
A5	210	1975
Total Kosovo A	***610***	-
B1	339	1983
B2	339	1984
Total Kosovo B	***678***	-
Total HPPs[1]	***108.42***	-
PV LLT	0.10	2015
PV Onix	0.50	2016
PV Birra Peja	3.00	2018
PV FFK	3.00	2018
PV Eling	0.40	2019
PV SGE	3.00	2019
Total SPPs	***10.00***	-
WPP Kitka	32.40	2018
WPP Golesh	1.35	2010
Total WPP	***33.75***	-
Total	**1,440.39**	-

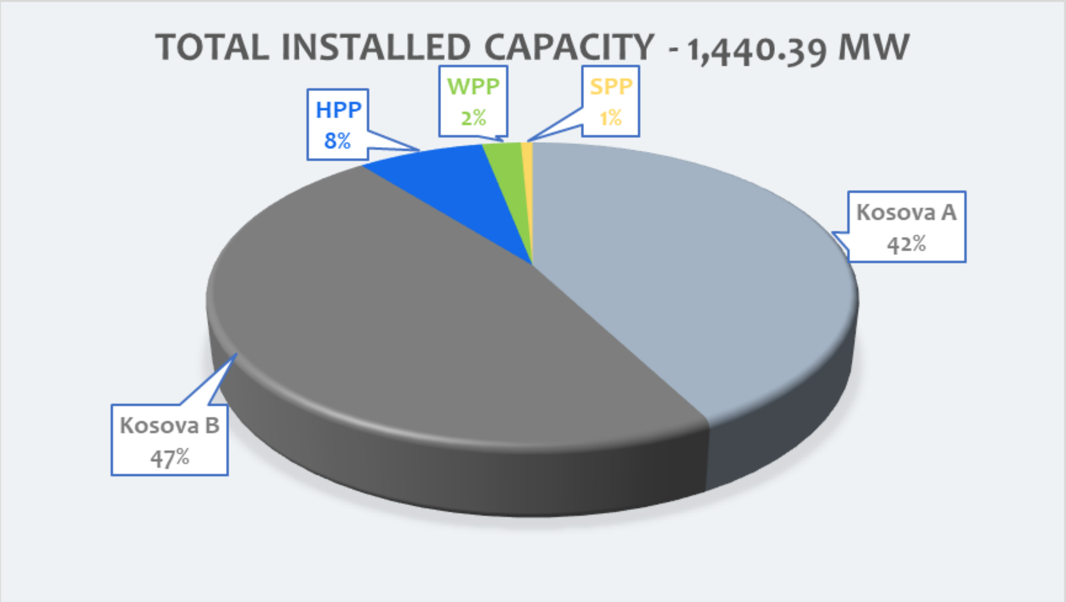


Figure 1-1 Power generation capacity in Kosovo

[1] Detailed list of committed HPPs is enclosed in ANNEX 4

Remaining units at Kosovo A are expected to be decommissioned until 2026 at the latest. At the same time, TPP Kosovo B units are planned to undergo revitalisation and extend operation until 2039.

Availability of firm and reliable capacity is the main issue threatening security of supply in Kosovo. The Generation expansion taking place in the next 5 years will have a direct influence on quality, reliability and costs of power supply for the coming decades. Figure 1-2 shows the production of electricity over the period 2008-2018.

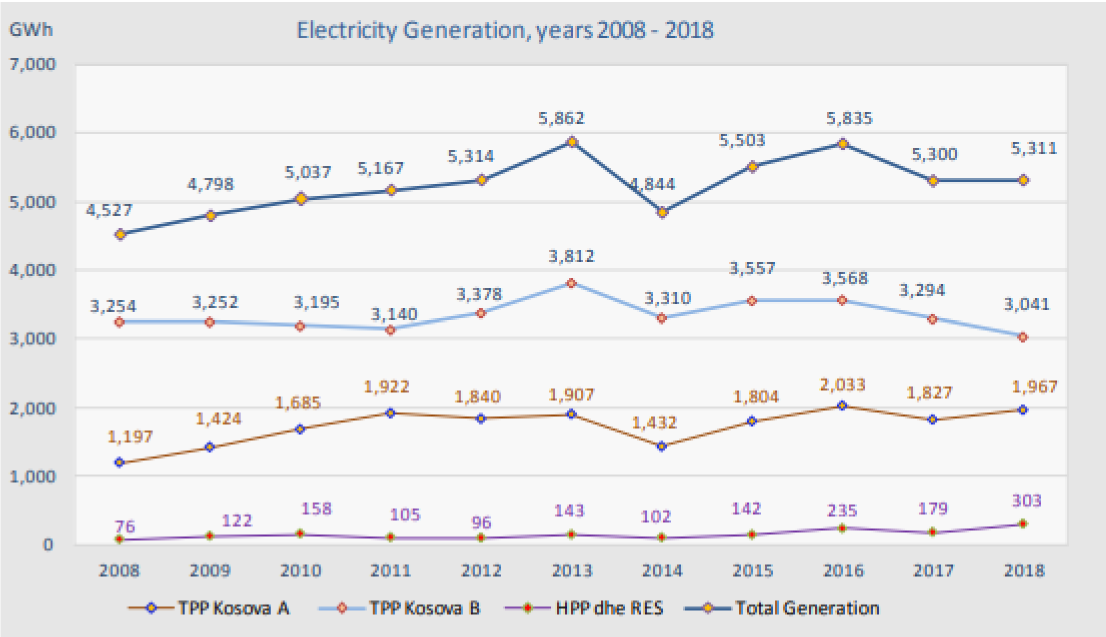


Figure 1-2 Electricity Production in the period 2008 – 2018 (Source: Statement of Security of Supply, Energy Regulatory Office, June 2019)

Based on data published by Kosovo Agency of Statistics[2] (Table 1-2), the gross amount of electricity produced in power plants in 2019 was 6,036.6 GWh (326.5 GWh in hydro power plants). In 2019 Kosovo imported 1,597.8 GWh of electricity and exported 1,457.1 GWh of electricity.

Table 1-2 Electricity production in power plants, import and export of electricity in 2019

GWh	Gross electricity production in TC	Electricity production in HPPs	Import of electricity	Export of electricity
2019	6,036.6	326.5	1,597.8	1,4571.1

According to the Electricity and thermal energy balance 2020[3], the annual generation of electricity from hydro, wind and solar power plants, connected to the distribution system

[2] Energy balance Q4 2019, Kosovo Agency of Statistics, February 2020
[3] Electricity and thermal energy balance 2020, Energy Regulatory Office, Prishtina, December 2019

is expected to amount to around 258.6 GWh. The amount of electricity entering the transmission system, generated from TPP Kosovo A, TPP Kosovo B, HPP Ujmani, HPP Kaskada e Lumbardhit and Wind Park Kitka for 2020, is expected to reach 4,792.5 GWh. Therefore, the entire national generation, including HPPs connected to distribution and wind generators as well as solar panels is expected to be 5,051.1 GWh, as presented in Figure 1-3.

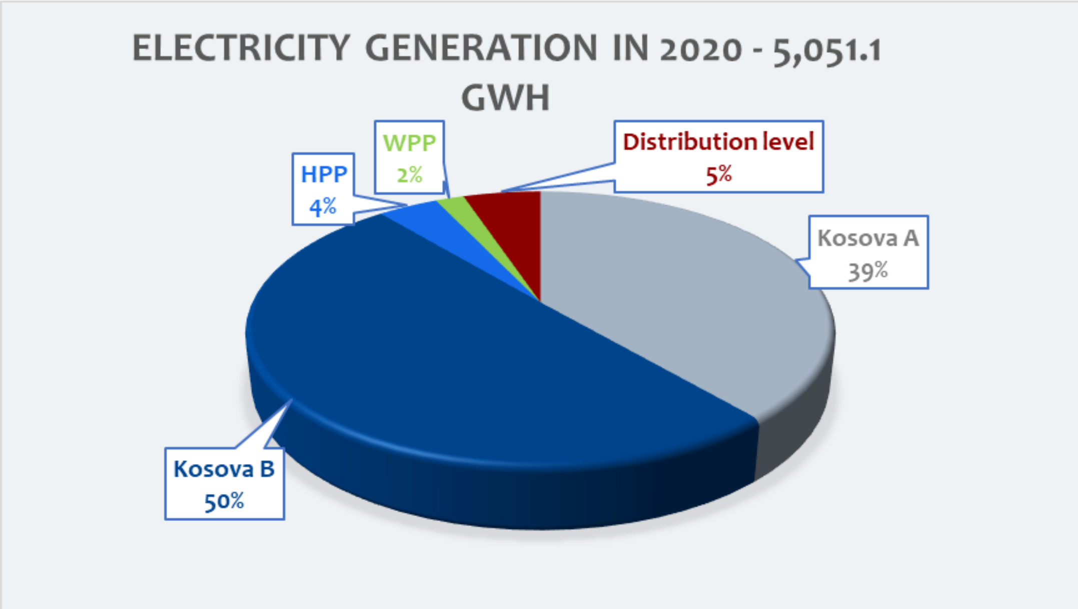


Figure 1-3 Expected electricity generation in 2020, GWh

1.3 Renewable energy targets

Pursuant to the EU Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, as a member of the Energy Community, Kosovo is obliged to meet mandatory RES targets for 2020 defined and approved by EnC Ministerial Council in 2012. For Kosovo a 25% of RES share in the final gross energy consumption[4] is assumed, broken down in:

- **14.33% of RES in gross final consumption of electricity (RES-E)**
- 10 % of RES in final consumption of energy in transport (RES-T) and
- 45.65 % of RES in gross final consumption for heating and cooling (RES-H&C),

[4] As per Article 2 of Directive 2009/28/EC, '*gross final consumption of energy*' means the energy commodities delivered for energy purposes to industry, transport, households, services including public services, agriculture, forestry and fisheries, including the consumption of electricity and heat by the energy branch for electricity and heat production and including losses of electricity and heat in distribution and transmission.

as set by the National Renewable Energy Action Plan (NREAP). An even higher target of 29.47% was set voluntary by Administrative Instruction for RES targets in 2013, with 25.64% RES-E share while RES-T and RES-H&C remain the same.

In the electricity sector, 25.64 % of RES in gross final electricity consumption was planned to be achieved through the construction of the new generation capacities: development of small and large hydro power plants (240 MW in small hydro power plants, 305 MW in HPP Zhuri), 150 MW in wind power plants, 14 MW in biomass power plants, and 10 MW in photovoltaic plants. The electricity sector contributes to the overall RES target with 10.1 %.

Table 1-3 provides an estimation of the RES potential in Kosovo for the period 2009-2020 in GWh, under the scenario where Kosovo should follow a higher growth in prospective RES penetration (29.47%) by 2020.

Table 1-3 Estimation of the RES-E potential in Kosovo, 2009-2020, GWh

Year	sHPP (< 1 MW)	sHPP (1 MW – 10 MW)	HPP (> 10 MW)	PV	Wind-onshore	Solid biomass
2009	9	32	88			
2010	9	36	110		0	
2011	9	24	71		0	
2012	15	36	81		3	
2013	14	35	82		3	
2014	15	304	82	6	63	15
2015	14	665	82	8	141	30
2016	15	709	82	12	181	45
2017	35	734	480	14	222	60
2018	56	810	476	13	262	75
2019	58	895	476	19	282	90
2020	87	1,045	476	21	302	105

Pursuant to the Article 22 of the EU Directive 2009/28/EC, every two year, Kosovo is obliged to submit a Report on Progress in the Promotion of Renewable Energy in the Energy Community. The Report assesses the progress in the promotion and use of renewable energy against the trajectory towards the 2020 targets set in the NREAP. So far, three Progress Reports are published in Kosovo, for the period 2012-2013, 2014-2015 and 2016-2017.

According to the 3rd Renewable Energy Progress Report for period 2016-2017, published in December 2018, RES share in the final gross consumption of Kosovo in 2017 was 23.59%. However, **RES share in gross final consumption of electricity (RES-E) was 3.18%**. The lower share is justified by the decreased electricity production from the largest hydropower stations due to worsened hydrological conditions compared to 2016. This implies the necessity for new RES capacities in order to meet RES-E targets. In terms of installed capacity, Kosovo has seen some extra capacity added ito its hydropower production in the last reporting year (2017), when the HPP Brezovica (Municipality of Shtërpca, 2.01 MW) was commissioned. Furthermore, several solar PV projects with total a installed capacity of 602 kilowatt (2016 and 2017 respectively) started delivering solar power to the national grid of Kosovo. According to the EUROSTAT, RES-E share in 2018 was 4.2%.

According to Kosovo's 1st, 2nd and 3rd Progress Report and EUROSTAT data, the realised achievements in RES-E were compared to the estimated RES potential that is shown in Table 1-4 and Figure 1-4.

Table 1-4 Estimated RES potential and realised achievements

Year	RES-E target	RES-E Target Voluntary	Realized	EUROSTAT
2009	2.4%	2.4%	0.0%	1.1%
2010	2.8%	2.8%	0.0%	1.4%
2011	1.7%	1.7%	0.0%	1.4%
2012	2.2%	2.2%	1.6%	1.5%
2013	2.1%	2.1%	2.3%	1.6%
2014	5.1%	7.3%	2.6%	1.9%
2015	5.6%	13.8%	2.4%	1.8%
2016	6.6%	15.0%	4.3%	4.0%
2017	13.2%	21.6%	3.2%	3.6%
2018	14.4%	23.2%		4.2%
2019	14.1%	23.4%		
2020	14.3%	25.6%		

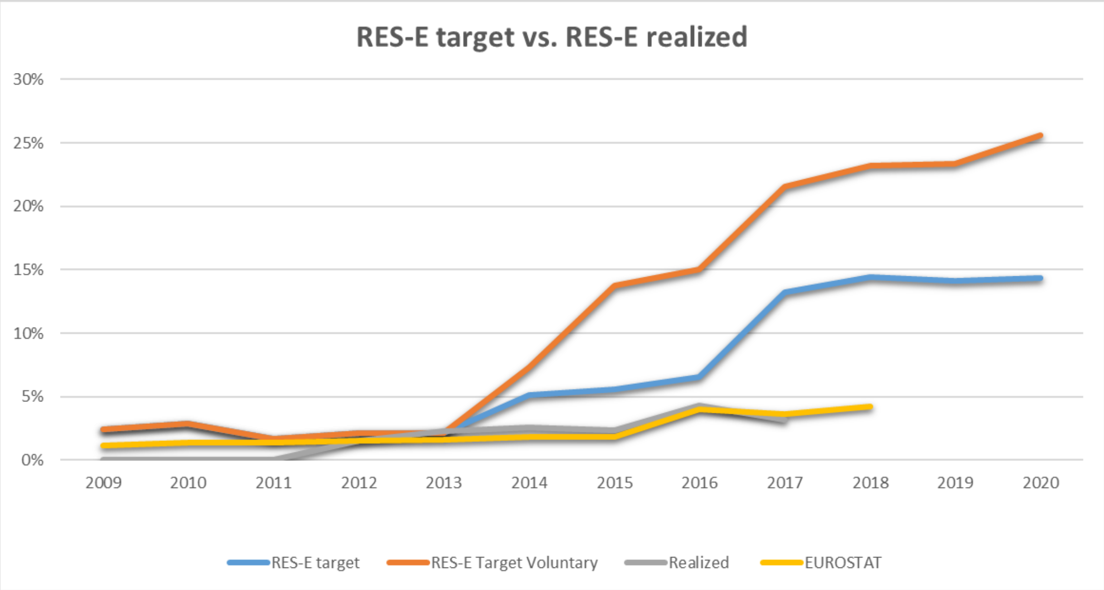


Figure 1-4 Estimated RES potential and realised achievements

It is important to notice that there is a huge difference between expected and realised achievements in terms of RES-E share. 4th Renewable Energy Progress Report for the period 2018-2019 should be published not later than December 2020, but according to the

Energy balance of 2019, RES-E share in gross final electricity production should not go above 10%.

RES targets for 2030, including RES-E target, will be set in the Integrated National Energy and Climate Plan for 2021 to 2030 (NECP), pursuant to the Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action. The finalization of the draft NECP is planned for October, but not later the end of 2020. Because of the Covid 19 pandemic the Working Group on NECP has not convened since January 2020, hence has made no progress in setting up national targets for the share of renewable energy neither in the gross final energy demand nor in the gross electricity demand of Kosovo. Given that the RES-E target up to 2030 is one of the main inputs for this project's execution, it was set according to the methodology explained in section 5.2.2.

2 ASSESSMENT OF RE POTENTIAL IN KOSOVO

Previous studies and data provided by the Beneficiaries were reviewed and analysed to determine the theoretical, technical and realizable RE potential in Kosovo. To determine the least cost option for system development, it was necessary to analyse all potential generation projects in the power system, from small-scale PV installation to large-scale generators connected to the transmission grid including conventional technologies.

Considering the latest available technology for RES utilization, the potential of RES was investigated through the levelized cost of electricity (LCOE) in chapter 3 .

2.1 Solar energy

Solar energy is the primary source for most of energy forms and main source of life on Earth. It is practically inexhaustible however, low flux, time variability and high cost of technical equipment limited the use of solar energy for generation purposes. In the light of recent trajectories towards low-carbon economy, with higher use of active solar systems which further stipulated technological development and higher production capacities, cost of energy from solar power plants was decreased drastically in the last two decades, and currently is very close, or below regular market energy prices.

Solar energy can be used through passive solar technologies, primary applied in architecture for increasing solar gains in the winter and decreasing overheating during the summer, or in some form of active solar use, such as solar thermal systems, photovoltaic systems or concentrated solar power. Each of these technologies has requirements for use, such as terrain configuration (slope, orientation), level of direct radiation, etc.

Main parameter for assessing solar resource or comparing two different locations is global solar radiation. Global horizontal irradiation for Kosovo ranges from 1,200 kWh/m^2 for mountainous parts of the country, to 1,500 kWh/m^2 in the southern part near Gjakova (Figure 2-1). These numbers are in line with neighboring countries. Areas with highest potential of solar energy are in the lowland part of the country, i.e. western and central part.

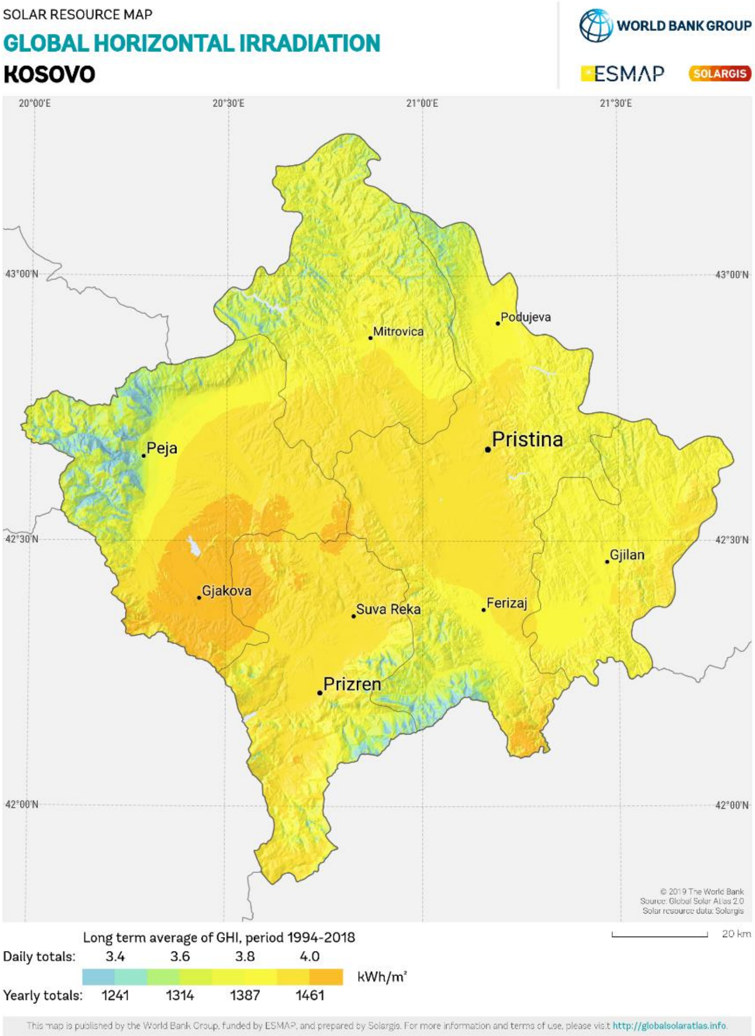


Figure 2-1 Solar radiation map of Kosovo (source: SOLARGIS)

Table 2-1 shows monthly and annual irradiation on horizontal plane, in kWh/m², for several locations in Kosovo. Data for Sharr Mountains are extreme minimum, just for comparison.

Table 2-1 Monthly and annual irradiation on horizontal plane (kWh//m²)

	Gjakove	Mitrovice	Peje	Pristine	NP Sharr Mountains
Jan	46.06	43.33	44.22	41.41	23.39
Feb	59.22	58.58	57.71	57.99	29.69
Mar	103.44	101.90	99.65	103.37	56.78
Apr	144.65	138.45	139.89	139.32	93.32
May	182.81	174.22	174.60	176.27	129.71
Jun	201.79	192.81	189.91	195.04	161.08
Jul	222.12	211.89	210.63	214.86	169.54
Aug	199.11	188.79	187.89	190.52	126.47
Sep	131.52	126.92	126.30	129.62	74.14

Oct	90.04	88.71	86.58	89.06	40.22
Nov	55.38	54.48	52.97	55.06	25.82
Dec	39.27	38.70	37.23	37.31	20.81
Total	1,475.40	1,418.77	1,407.57	1.429.83	950.96

Although irradiation on horizontal plane is the main parameter when comparing different locations for assessing energy production from solar systems, irradiation on tilted plane plays a more important role. In order to maximize energy yield, solar collectors are usually placed at an optimal angle and oriented to south which in general increases absorption of solar irradiation by some 15 – 20%, compared to horizontal plane. Other technical solutions include placing the modules back to back at an east-west orientation to increase yield during off-peak hours. In any case, correct placement is a question of financial optimum and design of a PV power plant.

Table 2-2 shows monthly and annual irradiation for optimum angle, in kWh/m^2, for several locations in Kosovo. Again, data for Sharr Mountains are extreme minimum values shown for comparison.

Table 2-2 Monthly and annual irradiation – optimum angle (kWh//m^2)

	Gjakove	Mitrovice	Peje	Pristine	NP Sharr Mountains
Jan	71.23	67.52	67.91	61.71	22.97
Feb	80.22	79.42	76.86	78.36	29.15
Mar	125.56	124.63	120.37	126.58	57.49
Apr	157.63	150.25	152.06	151.50	95.66
May	182.26	173.28	174.44	175.88	132.27
Jun	192.79	184.05	182.70	186.46	163.00
Jul	217.17	206.61	206.82	209.97	173.16
Aug	213.30	201.66	201.13	203.65	131.19
Sep	157.06	151.07	150.07	154.47	76.84
Oct	124.22	122.90	118.89	122.76	39.48
Nov	86.78	86.34	81.77	86.75	25.35
Dec	63.23	63.50	58.39	59.56	20.43
Total	1,671.45	1,611.21	1,591.41	1,617.64	966.99

Energy production is directly related with solar irradiation on a specific location; however, solar resource is not the only factor in the selection of locations, neither in assessing technical potential. Technical factors, such as terrain configuration, use of land, protected areas etc. play a major role in reduction of areas suitable for solar power plants.

Technical potential, in terms of installed MW, for ground mounted solar power plants is estimated with respect to available suitable area.

Available terrain is assessed using DEM (Digital elevation model) with raster precision of 100 x 100 m. Terrain is analyzed in detail to assess wind energy potential. For assessing suitability for solar power plants, terrain slope is calculated based on DEM, using build-in functions in a GIS specialized tool.

Figure 2-2 shows the variation of terrain slope in Kosovo (larger extend is presented, due to the constraints of calculation methods). Most of the country's mountainous part has a terrain slope of more than 10°, which is technically inappropriate for large scale solar power plants. Lowland and relatively flat areas are situated in the western and central part of the country and correspond to areas with somewhat higher solar potential.

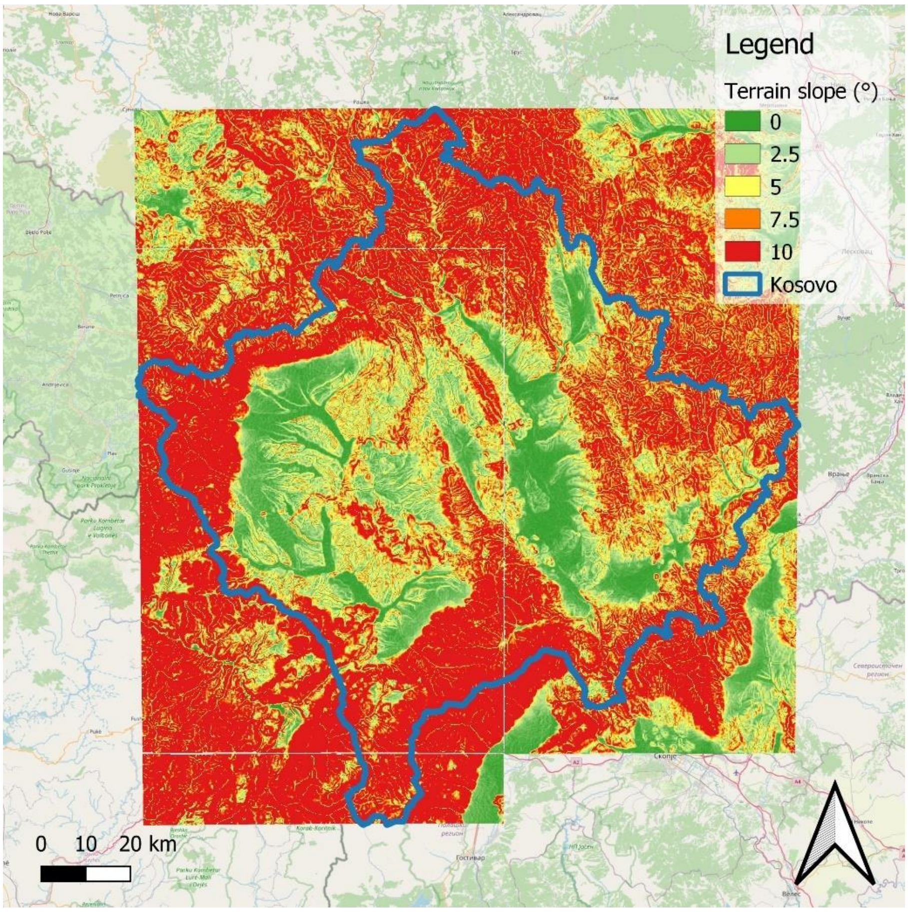


Figure 2-2 Terrain slope in Kosovo

Highly sloped terrain (> 5°) is ruled out as technically unsuitable area for solar power plants. Also, smaller areas, which sum up to several hectares, are also ruled out from further analysis, as a minimum limit was set on 20 ha, in order to be able to accommodate at least a 10 MW solar power plant. In generally, terrain with slope less than 5° covers 415,283 ha, or around 38 % of the total area of Kosovo.

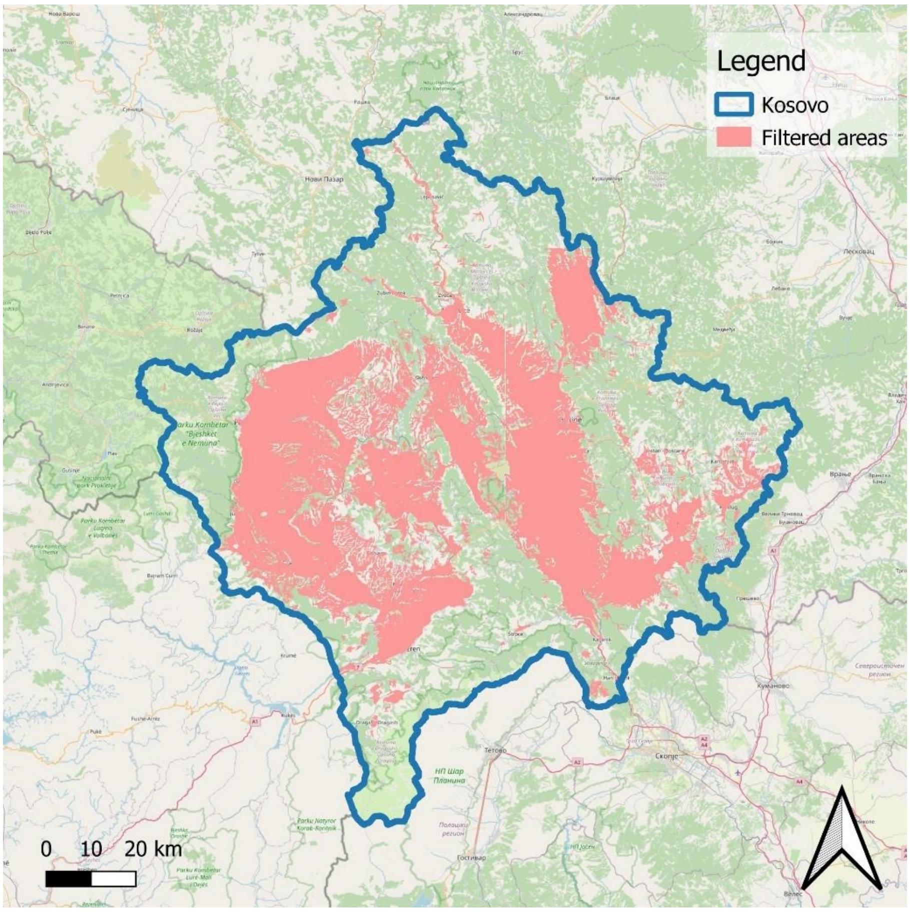


Figure 2-3 Filtered areas by slope and fragment size

Furthermore, protected areas (national parks, nature reserves – see Figure 2-10) are ruled out of the analysis, although most of these areas correspond to highly sloped terrain, already ruled out based on DEM analysis, leaving only a small part of protected areas (2,500 ha) to be considered.

Other unsuitable areas for large scale power plants include already built-up urban areas, water bodies, infrastructure corridors, vineyards, plantation etc. Brownfields, such as dump sites and mineral extraction sites are not ruled out as unsuitable areas, as solar power can be used to recover these sites after the end of their original use. These areas are presented in Figure 2-11. An overlay of protected areas and other unsuitable areas is presented in Figure 2-4. Out of 415,000 ha flat terrain, protected areas and other unsuitable areas covers 51,000 ha, or 12 % of flat terrain.

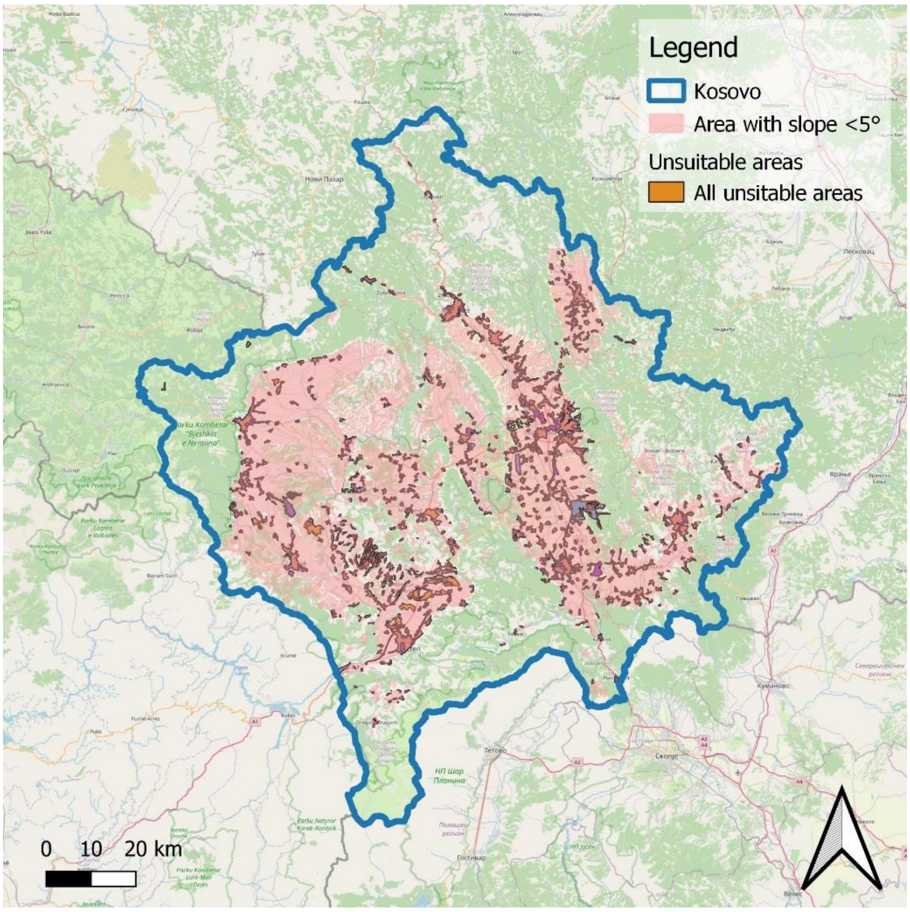


Figure 2-4 Overlay - areas with slope less than 5°and other unsuitable areas

Total suitable area is estimated at around 370,000 ha, and technically usable area is estimated to be 2% of total suitable area, 7,400 ha. Technical potential of PV is calculated by assuming 2 ha/MW and is estimated at 3,600 MW.

Table 2-3 Estimation of technical potential for PV

Technical potential for PV	
Area with slope < 5° [ha]	415,283
Of which:	
Protected areas [ha]	2,482
Other unsuitable areas [ha]	48,575
Total suitable area [ha]	369,190
Technically usable area (2 % of suitable area) [ha]	7,384
Estimated technical capacity [MW] (2 ha/MW)	**3,600**

2.2 Wind energy

Data for wind speed in Kosovo are taken from Global Wind Atlas and refer to 100 m height above ground level (a.g.l.). Map of average wind speed in Kosovo is shown in Figure 2-5 with wind speed distribution in Figure 2-6.

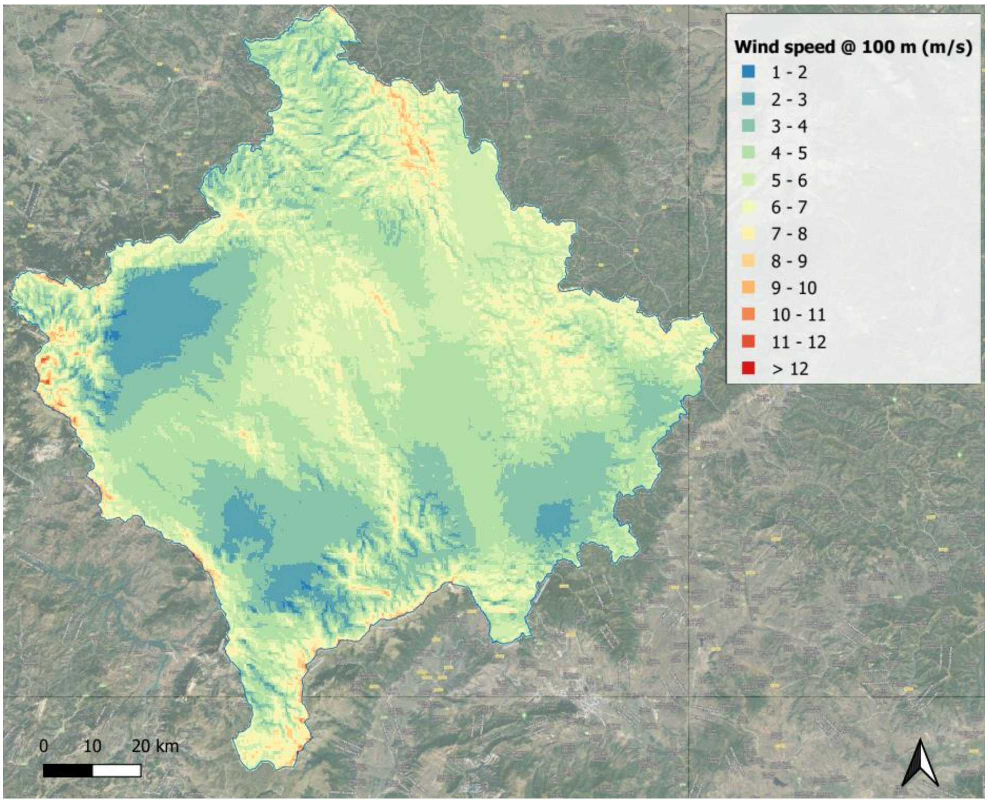


Figure 2-5 Wind speed at 100 m a.g.l. in Kosovo (source: https://globalwindatlas.info/)

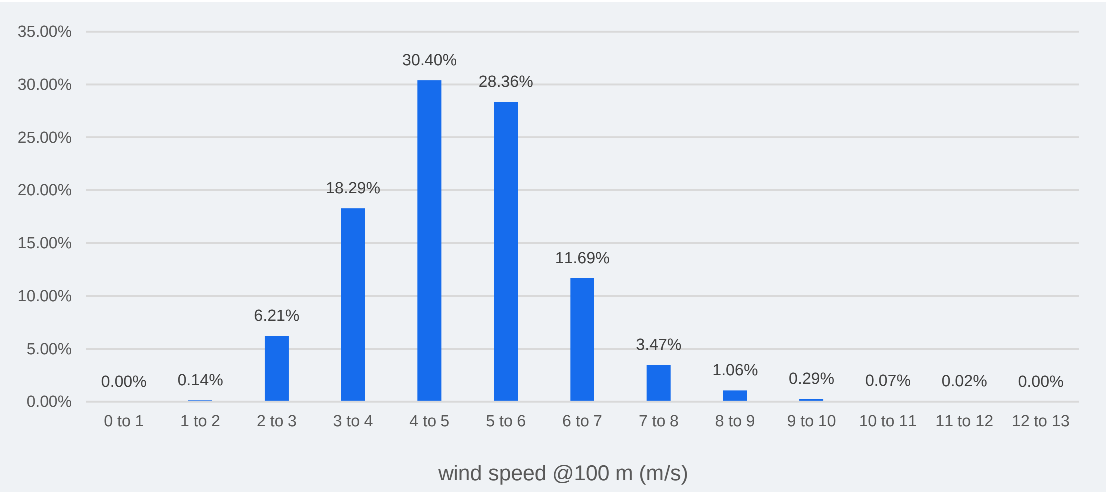


Figure 2-6 Distribution of wind speed at 100 m a.g.l. for Kosovo

Around 17% of the area (1,850 km²) in Kosovo (10,887 km²) has average wind speed over 6 m/s at 100 m a.g.l.

Terrain elevation in Kosovo (Figure 2-7) ranges from around 270 m to 2,630 m above sea level (a.s.l.). Some precision is lost in the terrain model (e.g. highest peak of Kosovo is Maja e Njeriut (Rudoka e madhe) at 2,658 m a.s.l.). Digital elevation model (DEM) is derived from publicly available Shuttle Radar Topography Mission (SRTM[5]) terrain elevation data.

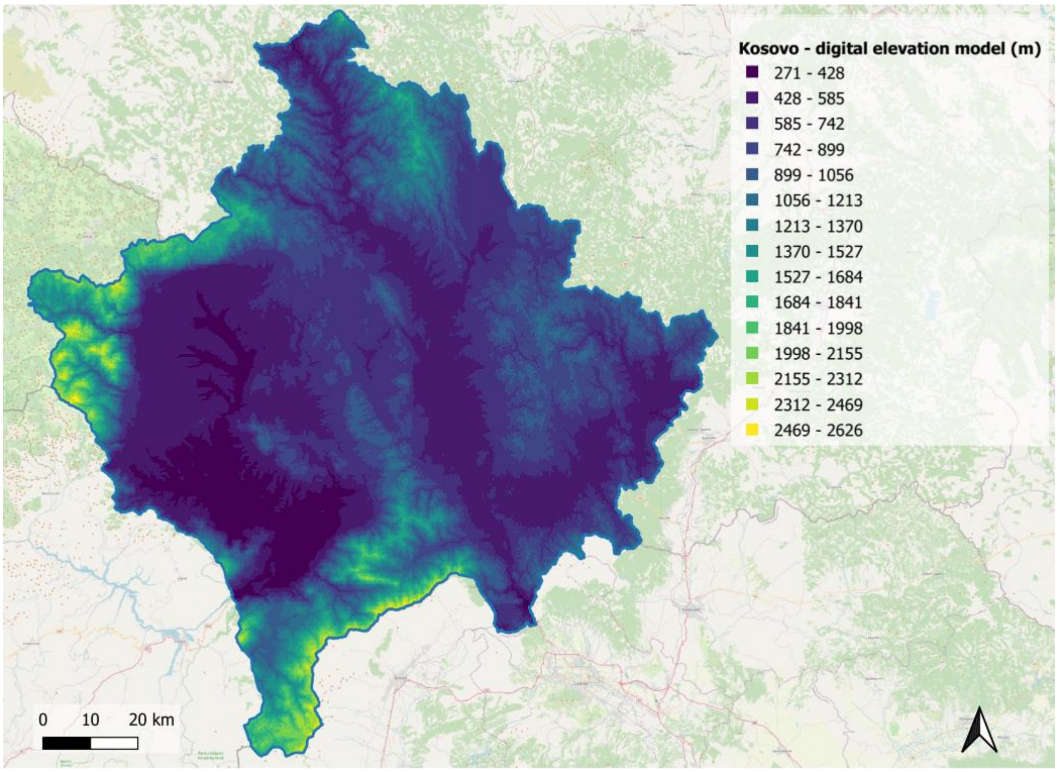


Figure 2-7 Digital elevation model of Kosovo

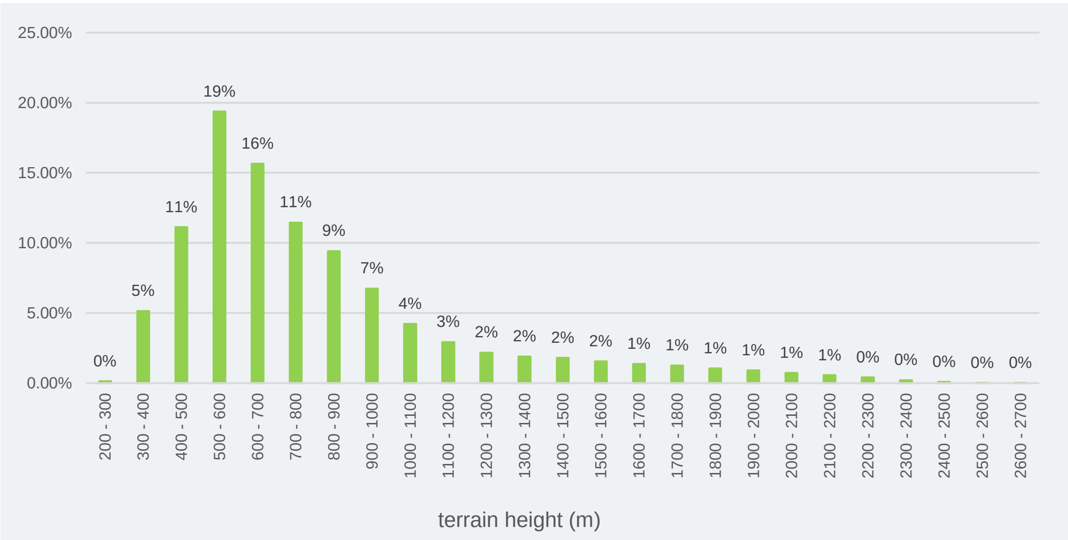


Figure 2-8 Distribution of terrain height for Kosovo (m)

In terms of wind farms, high terrains (e.g. over 1,700 m) present a serious limitation for project realization because of low temperatures outside (e.g. below -10°C for longer

[5] The Shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-global scale and generate the most complete high-resolution digital topographic database of Earth.

periods). These working conditions may cause damages on operating envelope and require more interventions on wind turbines.

However around 5% of the Kosovo territory is over 1,700 m, mostly in national parks Sharr Mountains and Mountains of Nemuna (Prokletije), and these parks are already exclusion areas for wind farms. Hence high terrains are not considered again as an exclusion criterion in further analyses. Analyzed exclusion zones for wind farms regard terrain relief, wind energy potential, protected areas and urban infrastructure.

Data on the terrain slopes for Kosovo are derived from publicly available SRTM[6] terrain elevation data, Figure 2-9.

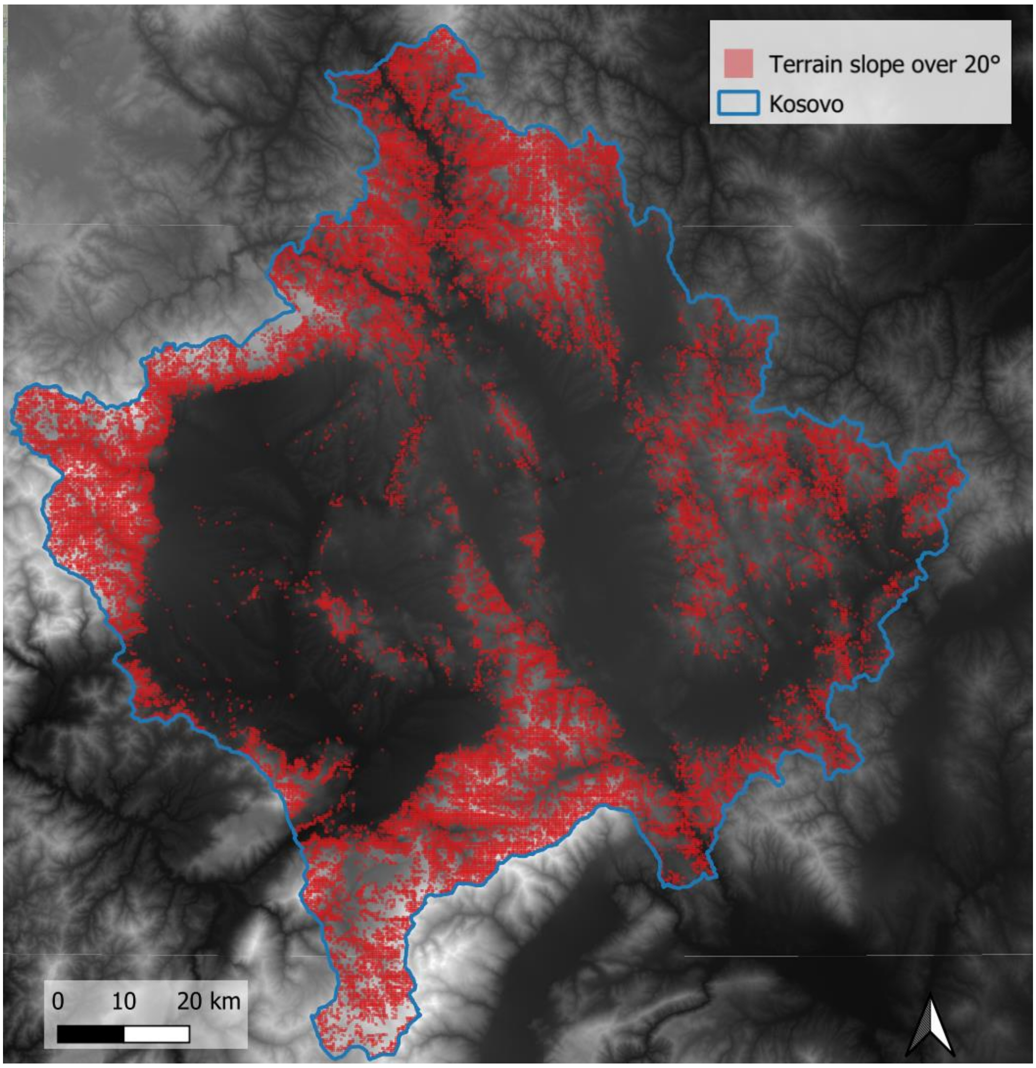


Figure 2-9 Areas with terrain slope over 20° (based on the SRTM map below)

Wind turbines operate in wind speeds ranging from around 5 m/s to 10 m/s at hub height. Hub heights of modern wind turbines are mostly over 100 m tall reaching over 160 m. In that sense, building of such high structures requires certain portions of ground that are not too steep for transporting equipment and erecting the wind turbine tower, nacelle and

[6] The Shuttle Radar Topography Mission is an international research effort that obtained digital elevation models on a near-global scale and generate the most complete high-resolution digital topographic database of Earth.

rotor. Furthermore, steep terrain induces inclined air flows that are not appropriate for wind turbine operation. Hence, due to technical reasons parts of the terrain with slope over 20° are regarded as inappropriate for wind turbines.

Protected areas in Kosovo are shown in Figure 2-10.

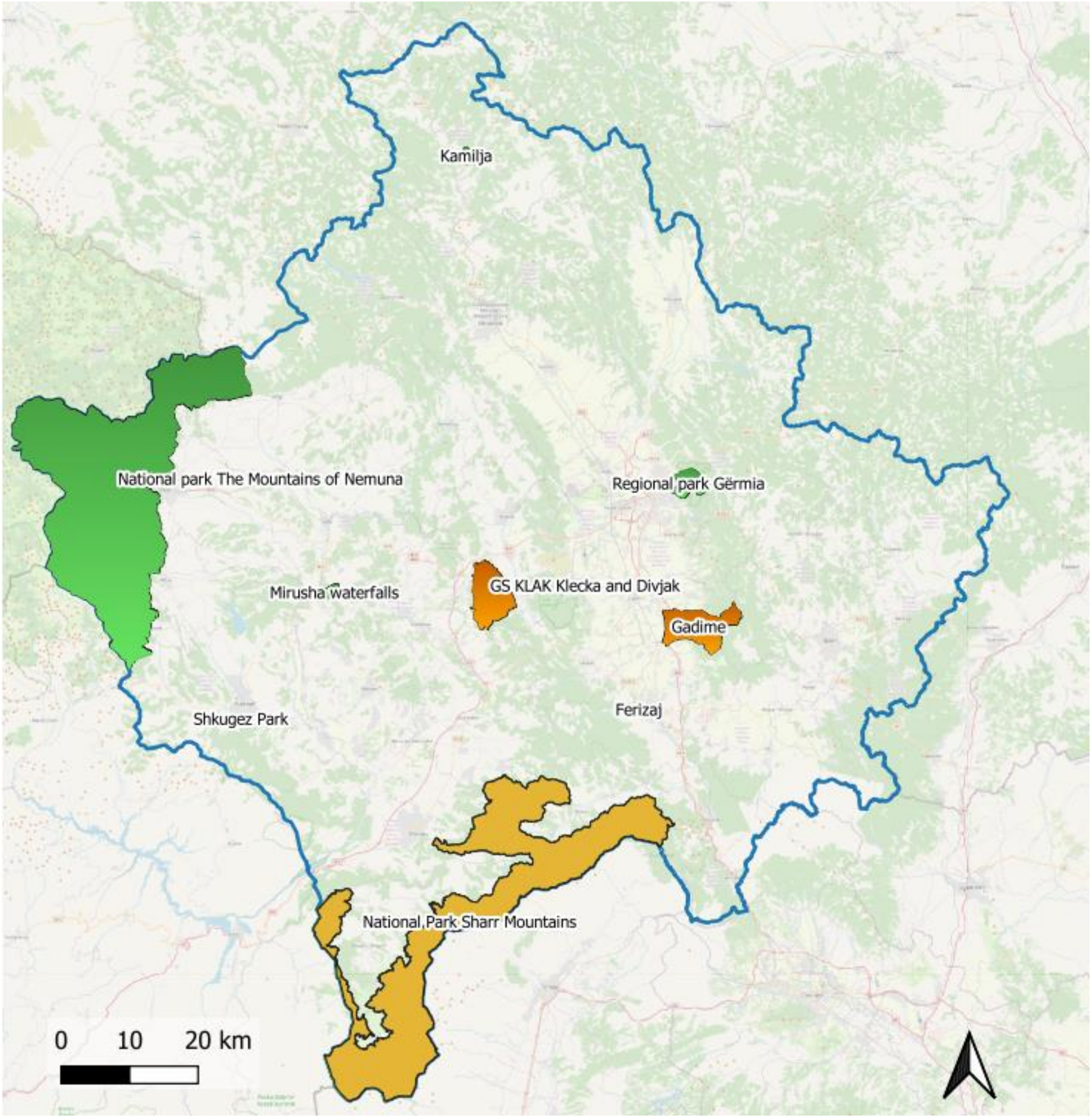


Figure 2-10 Protected areas in Kosovo (source: http://geoportal.rks-gov.net/wms)

Water bodies, urban infrastructure (cities, villages) and transport infrastructure (airports, roads) also present areas that are not appropriate for developing wind farms, Figure 2-11.

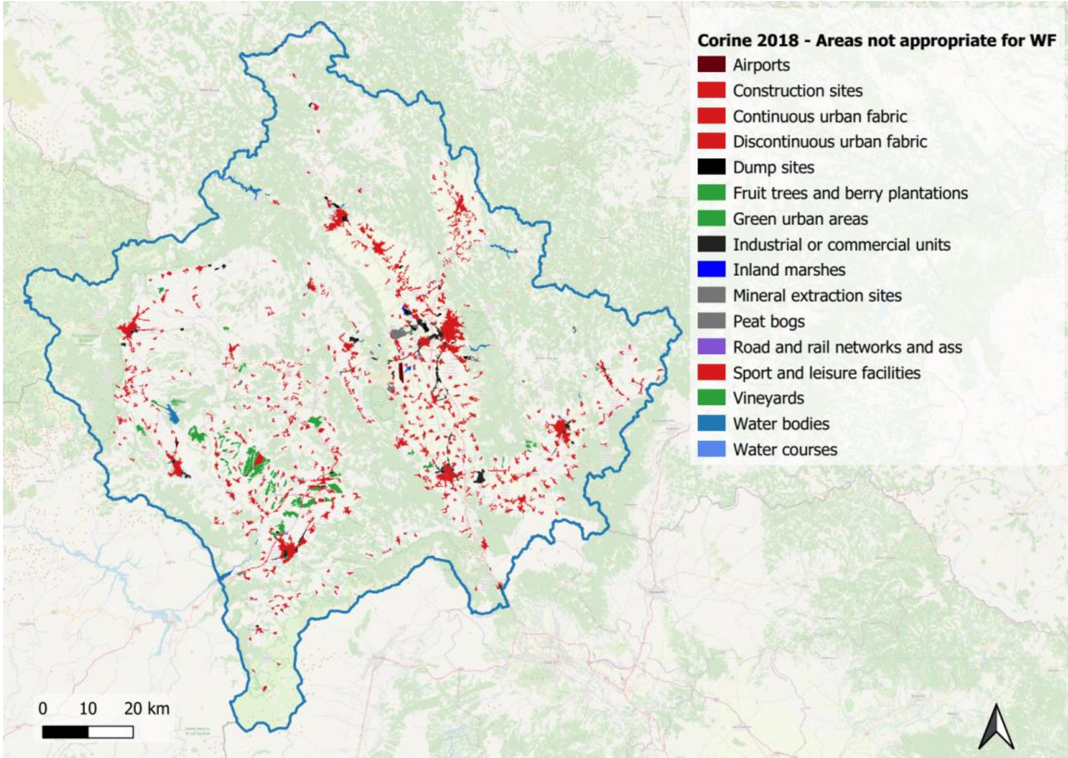


Figure 2-11 Areas not appropriate for wind farms (source: https://land.copernicus.eu/)

Figures 2-9, 2-10, 2-11 and Figure 2-12 jointly present exclusion areas for wind turbines.

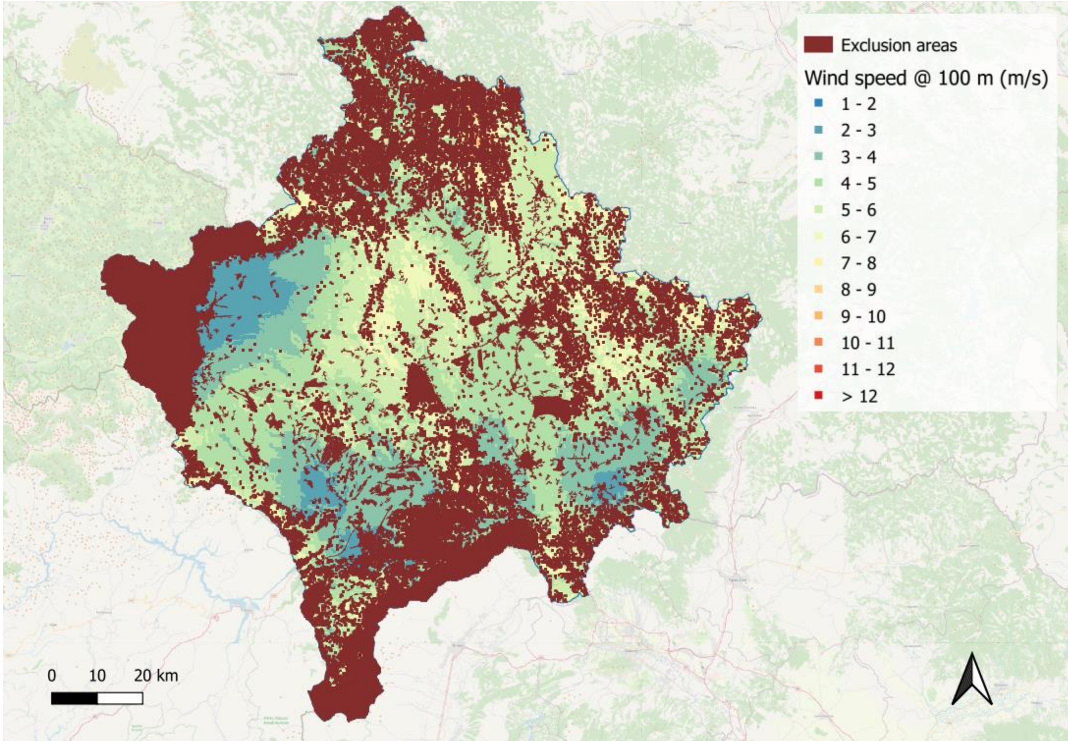


Figure 2-12 Exclusion areas for wind turbines on a wind speed map

Overall area of exclusion is around 4,880 km^2, which amounts to around 45% of Kosovo's territory.

Since the whole range of wind speeds is not technically feasible, the final map of suitable wind speed range is shown in Figure 2-13. Note that the symbols for wind speed ranges differ from the previous ones.

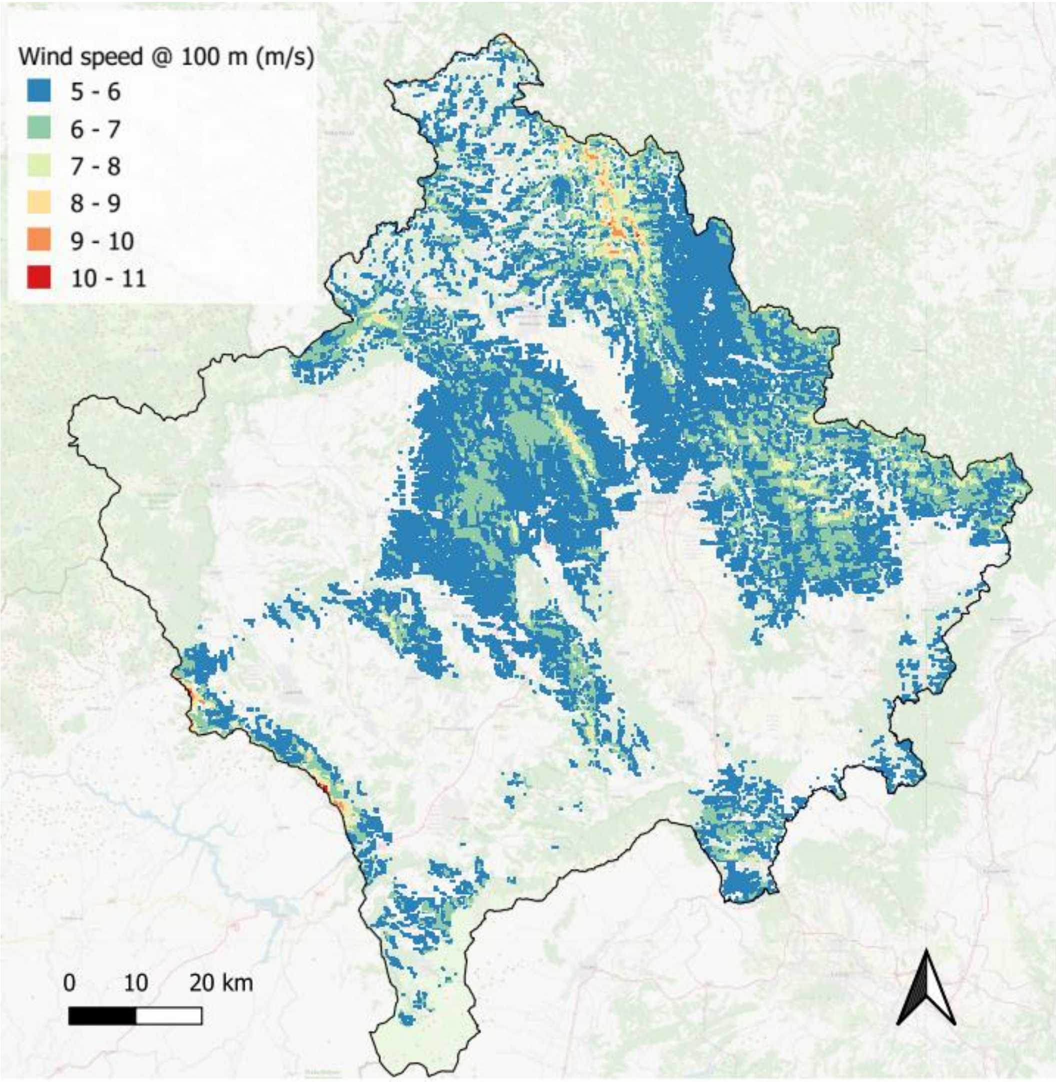


Figure 2-13 Wind speed in the range from 5 m/s to 11 m/s outside exclusion zones

Table 2-4 Areas with wind speed ranges

Wind speed ranges at 100 m (m/s)	Area (km²)
5 - 6	2,182
6 - 7	776
7 - 8	138
8 - 9	30
9 - 10	7
10 - 11	1
Total	**3,134**

Figure 2-13 and Table 2-4 show that the most of the technically appropriate area for wind farms are between 5 and 6 m/s (at 100 m a.g.l.). Figure 2-14 shows the loss of area appropriate for wind farms if technical limit regarding wind speed is between 6 m/s and 10 m/s. Note that the symbols for wind speed ranges differ from the previous ones.

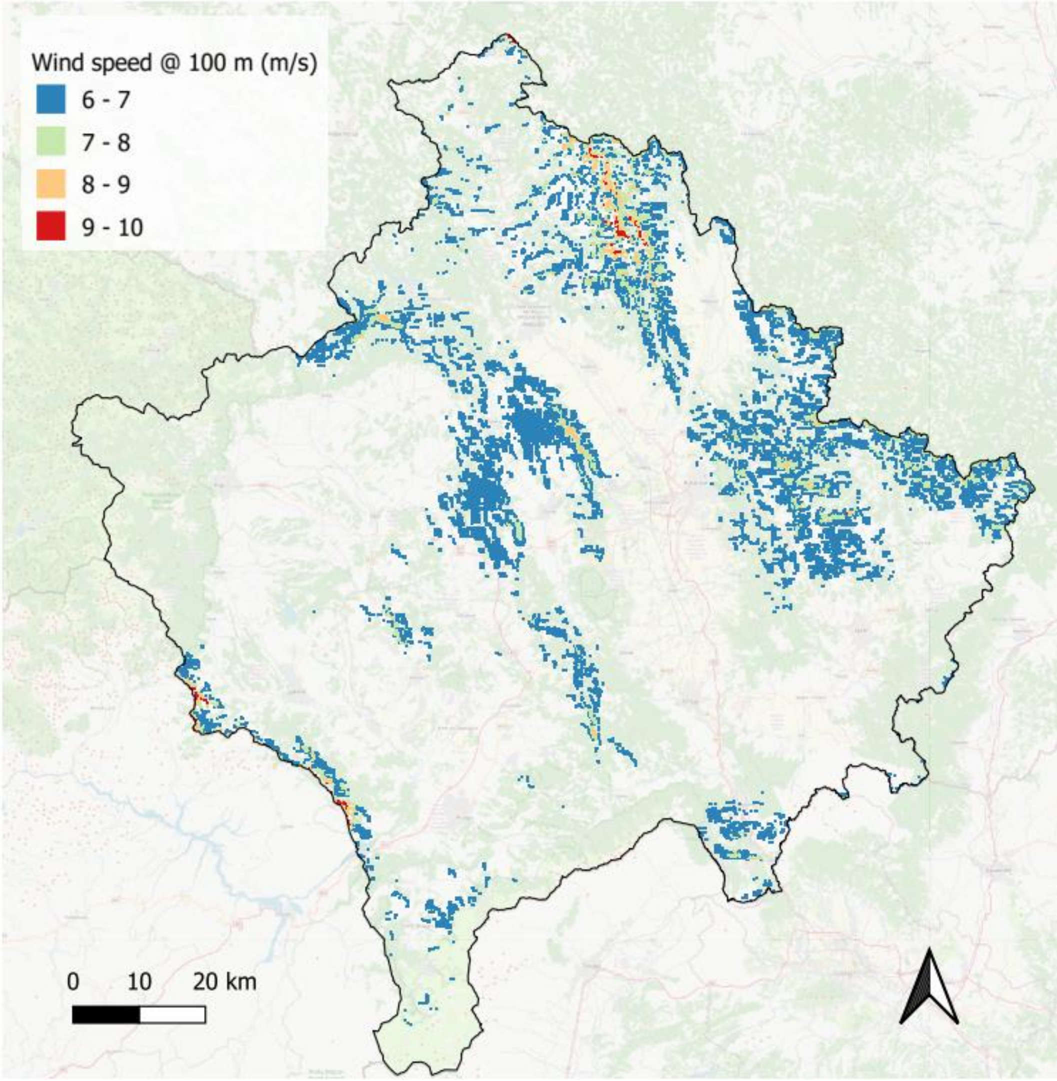


Figure 2-14 Wind speed in the range from 6 m/s to 10 m/s outside exclusion zones

The 3,133 km² area shown in Figure 2-13 presents locations ideal for wind turbines development. To assess the energy potential as overall capacity in this area, the following must be considered:

- wind farms using larger wind turbines require less area than those with small turbines for the same installed capacity,
- for the same area installed capacity of a wind farm may vary depending on the wind farm layout: lined layout on the mountain ridge, dispersed layout on tops of small hills or concentrated layout on a plateau or a plain,
- wind direction – is it concentrated in one sector or dispersed over two or more directional sectors; is the dominant sector perpendicular to the wind farms layout or not, etc.
- distance from other wind farms in the area.

Hence, the assumption of the specific power conversion factor is very sensitive and can easily vary significantly. The specific factor of **0.5 km²/MW** will be used to convert area to power, meaning 0.5 km² is an area suitable for 1 MW (or on each km² 2 MW can be placed) in a wind farm that is 2 km away from any other wind farm.

Using an ideal area (3,134 km²) and 0.5 km²/MW as specific power conversion factor, Kosovo has theoretical wind power potential of 6,268 MW.

However, to calculate feasible wind energy potential, other specific issues need to be considered:

- suitability of the terrain cover for wind farms construction (e.g. areas covered with grass are much more suitable than high forests),
- feasibility of the wind farm regarding wind energy potential (wind speed),
- distance from grid connection point,
- distance from existing roads,
- restrictions due to environmental protection (e.g. birds and bats), protection of cultural or heritage areas, etc.

First two points can be quantified based on wind speed data (Global Wind Atlas) and available data on land cover (CORINE).

Probability for wind farm construction depending on wind speed is presented in Table 2-5.

Table 2-5 Wind speed and consequent probability for constructing a windfarm

Wind speed range	Area (km²)	Probability for constructing a windfarm
5 to 6 m/s	2,182	40%
6 to 7 m/s	776	70%
7 to 8 m/s	138	100%
8 to 9 m/s	30	100%
9 to 10 m/s	7	100%
10 to 11 m/s	1	100%
Total area (km²)	**3,134**	

Around 95% of Kosovo is covered by land covers presented in Table 2-6. For each of them, the probability of wind farm development is assumed. In general, the higher and denser the vegetation, the less probable wind farm construction is.

Table 2-6 Land covers and consequent probability for constructing a windfarm

Type of land cover	Areas in Kosovo (km²)	Areas appropriate for wind farms (km²)	Probability of constructing a windfarm
Broad-leaved forest	4,015	1,374	25%
Coniferous forest	214	19	25%
Mixed forest	115	18	25%
Transitional woodland-shrub	900	285	50%
Complex cultivation patterns	1,456	317	80%
Non-irrigated arable land	1,291	370	90%
Land principally occupied by agriculture, with significant areas of natural vegetation	1,170	444	90%
Sclerophyllous vegetation	0	-	90%
Natural grasslands	706	189	100%
Sparsely vegetated areas	176	63	100%
Pastures	170	46	100%
Moors and heathland	52	1	100%
Burnt areas	28	9	100%
Bare rocks	7	0	100%
Total area (km²)	**10,300**	**3,134**	

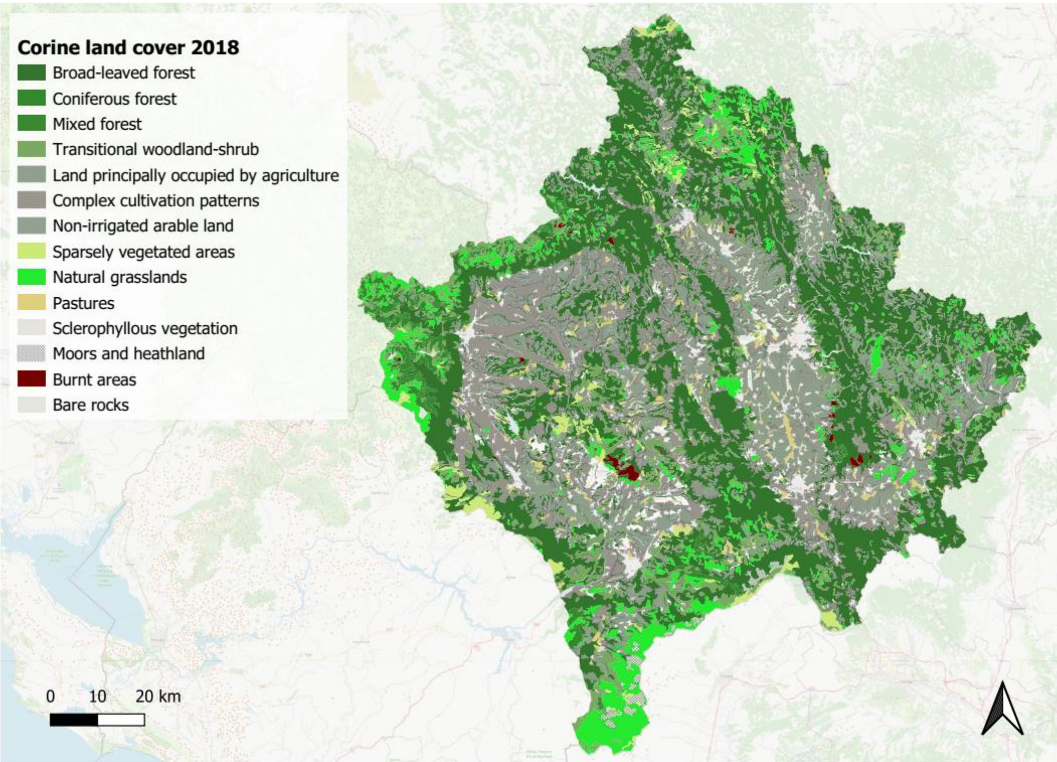


Figure 2-15 Corine land cover for Kosovo

The appropriate area (in km²), distributed into specific parts depending on the wind speed and land cover, is presented in Table 2-7.

Table 2-7 Distribution area (km^2) based on wind speed and land cover; red colour refers to bigger areas and green to smaller areas

Wind speed → / Land cover ↓	5 – 6 m/s	6 – 7 m/s	7 – 8 m/s	8 – 9 m/s	9 – 10 m/s	10 - 11 m/s	All (km^2)
Broad-leaved forest	866	418	76	13	1	0	1,374
Coniferous forest	10	7	2	0	0	0	19
Mixed forest	12	5	1	0	0	0	18
Transitional woodland-shrub	187	76	18	3	1	0	285
Complex cultivation patterns	263	54	0	0	0	0	317
Land principally occupied by agriculture, with significant areas of natural vegetation	323	109	12	0	0	0	444
Non-irrigated arable land	350	19	0	0	0	0	370
Bare rocks	0	0	0	0	0	0	0
Burnt areas	7	2	0	0	0	0	9
Moors and heathland	0	0	0	0	0	0	1
Natural grasslands	83	66	24	11	4	1	189
Pastures	39	7	1	0	0	0	46
Sparsely vegetated areas	42	13	4	3	1	0	63
All (km^2)	2182	776	138	30	7	1	3,134

If there were no limits and probabilities regarding the land cover, wind speed or any other condition, the distributed areas would have the total installed capacity presented in Table 2-8.

Table 2-8 Ideal wind power theoretical potential (MW) based on wind speed and land cover; red colour refers to the higher installed capacity and the green to the lower installed capacity

Wind speed → / Land cover ↓	5 – 6 m/s	6 – 7 m/s	7 – 8 m/s	8 – 9 m/s	9 – 10 m/s	10 - 11 m/s	All (MW)
Broad-leaved forest	1,731	836	152	25	2	1	2,747
Coniferous forest	19	15	3	0	0	0	37
Mixed forest	25	10	1	0	0	0	35
Transitional woodland-shrub	375	152	36	7	1	0	570
Complex cultivation patterns	525	108	1	0	0	0	634
Land principally occupied by agriculture,	646	217	23	1	0	0	887

Wind speed → Land cover ↓	5 – 6 m/s	6 – 7 m/s	7 – 8 m/s	8 – 9 m/s	9 – 10 m/s	10 - 11 m/s	All (MW)
with significant areas of natural vegetation							
Non-irrigated arable land	701	39	0	0	0	0	739
Bare rocks	0	0	0	0	0	0	0
Burnt areas	14	4	1	0	0	0	18
Moors and heathland	1	1	1	0	0	0	2
Natural grasslands	166	132	49	21	9	2	379
Pastures	77	14	1	0	0	0	92
Sparsely vegetated areas	84	26	8	6	2	0	127
All (MW)	4,363	1,552	276	60	15	3	6,268

Ideal wind power potential is still mostly in the 5-6 m/s range (70%), and 95% is in the range 5 – 7 m/s.

However, theoretical potential is not likely to be realized. In order to get a better perspective of the realizable wind potential, the values from Table 2-8 are multiplied with probabilities defined in Tables 2-5 and 2-6. **The results in Table 2-9 present the most probable overall wind energy technical potential of 1,781 MW,.**

Table 2-9 Most probable theoretical wind power potential (MW) based on wind speed and land cover; red colour refers to the higher installed capacity and the green to the lower installed capacity

	Wind speed	5 – 6 m/s	6 – 7 m/s	7 – 8 m/s	8 – 9 m/s	9 – 10 m/s	10 - 11 m/s	All
Land cover	probability	40%	70%	100%	100%	100%	100%	MW
Broad-leaved forest	25%	173	146	38	6	1	0	364
Coniferous forest	25%	2	3	1	0	0	0	5
Mixed forest	25%	2	2	0	0	0	0	4
Transitional woodland-shrub	50%	75	53	18	3	1	0	150
Complex cultivation patterns	80%	168	60	1	0	0	0	229
Land principally occupied by agriculture, with significant areas of natural vegetation	90%	233	137	21	1	0	0	391
Non-irrigated arable land	90%	252	24	0	0	0	0	277

Bare rocks	100%	0	0	0	0	0	0	0
Burnt areas	100%	6	3	1	0	0	0	9
Moors and heathland	100%	0	0	1	0	0	0	1
Natural grasslands	100%	66	93	49	21	9	2	239
Pastures	100%	31	10	1	0	0	0	42
Sparsely vegetated areas	100%	34	18	8	6	2	0	69
All	**MW**	1,042	549	138	37	12	2	1,781

After applying probabilities, most of the wind power potential is still in the 5-6 m/s range (60%), and 90% is in the 5–7 m/s range.

The most probable technical wind power potential of 1,781 MW could be further reduced in the project realisation due to already mentioned potential barriers (distance from grid connection point, distance from existing roads, restrictions due to environmental protection (e.g. birds and bats), protection of cultural or heritage areas, etc.). Such reduction may result in an actual potential of around **1,200 MW** for Kosovo.

Figure 2-13 shows electricity distribution areas in Kosovo with wind speed range between 5 and 11 m/s, outside of exclusion zones.

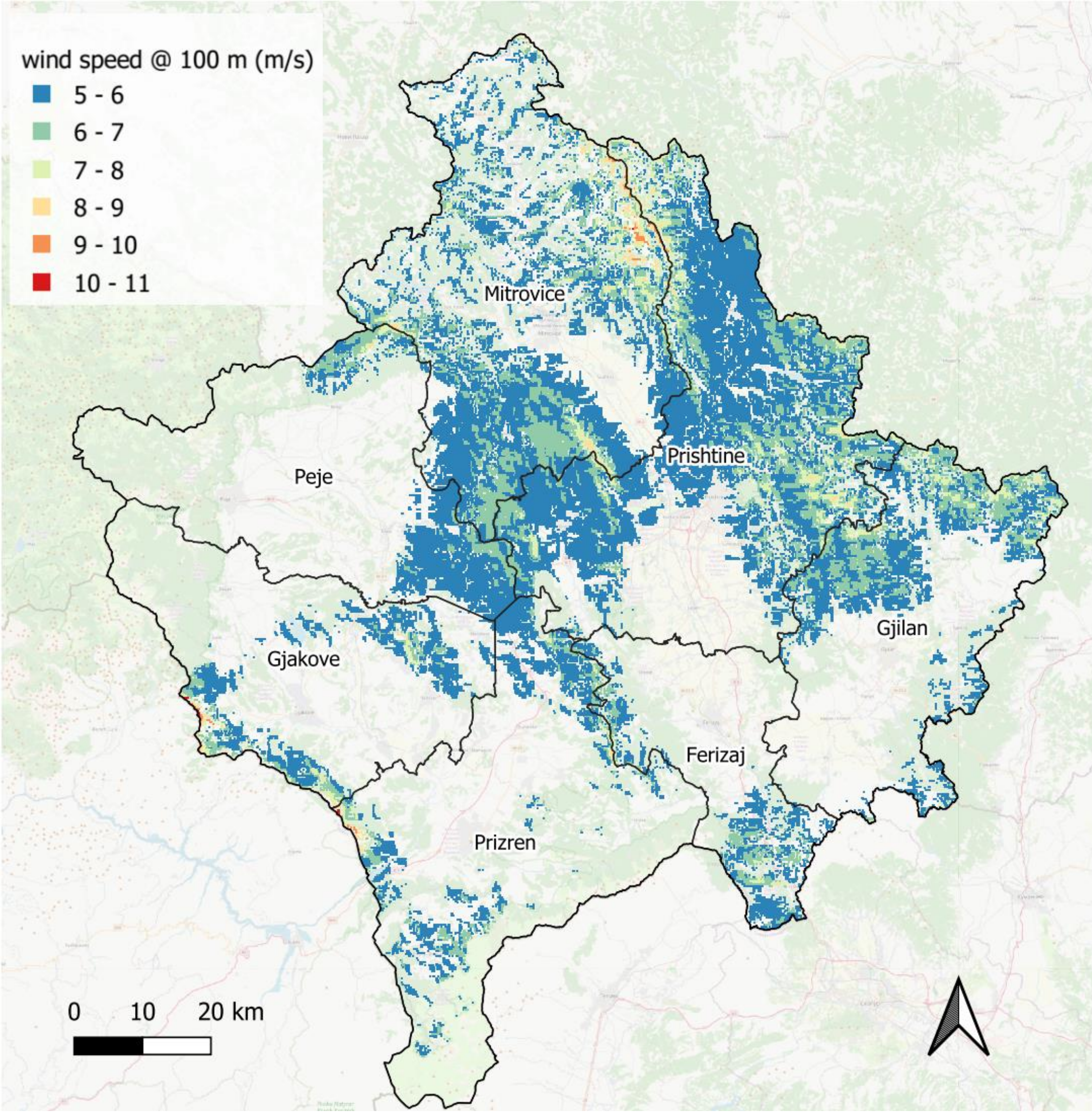


Figure 2-16 Wind speed in the range from 5 m/s to 11 m/s outside of exclusion zones

Table 2-10 presents ideal technical wind potential per distribution areas in Kosovo, and Table 2-11 shows the most probable technical potential per distribution areas after applying wind speed and land cover limitations.

Table 2-10 Ideal technical wind power potential (MW) based on wind speed and land cover – shares of potential over Kosovo electricity distribution areas

Wind speed range (m/s)	Gjakove	Peje	Prizren	Mitrovice	Prishtine	Ferizaj	Gjilan	All (MW)
5 to 6	261	360	326	1,086	1,655	194	482	**4,363**
6 to 7	61	85	84	458	526	73	265	**1,552**
7 to 8	20	9	13	73	108	8	46	**276**
8 to 9	8	1	4	30	15	1	1	**60**
9 to 10	3	0	2	8	1	0	0	**15**

Wind speed range (m/s)	Gjakove	Peje	Prizren	Mitrovice	Prishtine	Ferizaj	Gjilan	All (MW)
10 to 11	2	0	1	0	0	0	0	3
All (MW)	**354**	**454**	**429**	**1,656**	**2,306**	**275**	**794**	**6,268**

Table 2-11 Most probable technical wind power potential (MW) based on wind speed and land cover and applied probabilities – shares of potential over Kosovo electricity distribution areas

Wind speed range (m/s)	Gjakove	Peje	Prizren	Mitrovice	Prishtine	Ferizaj	Gjilan	all (MW)
5 to 6	58	89	76	257	424	39	98	1,042
6 to 7	22	27	35	175	168	22	99	549
7 to 8	11	4	6	40	49	2	24	138
8 to 9	5	1	2	20	9	0	0	37
9 to 10	3	0	1	8	1	0	0	12
10 to 11	1	0	1	0	0	0	0	2
All (MW)	**99**	**121**	**122**	**501**	**651**	**64**	**222**	**1,781**

As already mentioned, the results in Table 2-11 could be further reduced regarding potential barriers - distance from grid connection point, distance from existing roads, restrictions due to environmental protection (e.g. birds and bats), protection of cultural or heritage areas, etc.; giving an approximate overall result of **1,200 MW of realizable wind energy potential in Kosovo.**

Most of the Kosovo's area has wind speed below 7 m/s and the windiest parts are often in protected areas and high forests, meaning that areas with high wind power potential are excluded from the possible project development sites.

The most probable **technical energy potential is around 1,800 MW**, with 1,050 MW in Mitrovice and Prishtine distribution areas. In general, around 60% of most probable technical energy potential is in the wind speed range of 5 – 6 m/s and 90% in the range of 5 – 7 m/s.

Since the estimation of wind energy potential is based on a number of assumptions, the most accurate indicator for wind energy potential is actually areas outside exclusion zones presented in Table 2-7, showing the distribution of areas appropriate for windfarms depending on wind speed and land cover.

2.3 Hydro energy

The hydropower potential was assessed based on available data and documents provided by the Beneficiaries as well as publicly available documents. Required data such as the historical inflows (for minimum of last 20 years), gross (or net) head for every potential location, topographic maps of the terrain, data about watermills and river dams, spatial plans, GPS coordinates of locations, etc., were not provided.

Hydro energy is the main renewable energy source in Kosovo, amounting to an installed capacity of 108.24 MW. Kosovo unfortunately does not have plentiful water resources like other Balkan countries and in 2019 HPPs production amounted to around 10% of total power generation in Kosovo. The wider deployment of small hydropower plants is delayed since the most promising sites are located in protected areas.

The main rivers within the border of Kosovo are presented in Table 2-12 and Figure 2-17. The hydrology of water sources consists of four main rivers: Drini i Bardhë (White Drin), Ibri (Ibar), Morava e Binçës (Binačka Morava) and Lepenci (Lepenac). The hydropower potential of these rivers is estimated to approximately 700 GWh/year. Table 2-12 shows the hydropower potential of Kosovo's main rivers.

Table 2-12 Hydropower potential of main Kosovo rivers

No.	River	Hydropower potential [GWh/year]
1.	Drini i Bardhë	554.0
2.	Ibri	103.3
3.	Morava e Binçës	8.7
4.	Lepenci	23.8
	TOTAL	**689.8**

Figure 2-17 shows river basins of the main Kosovo rivers with hydro meteorological stations.

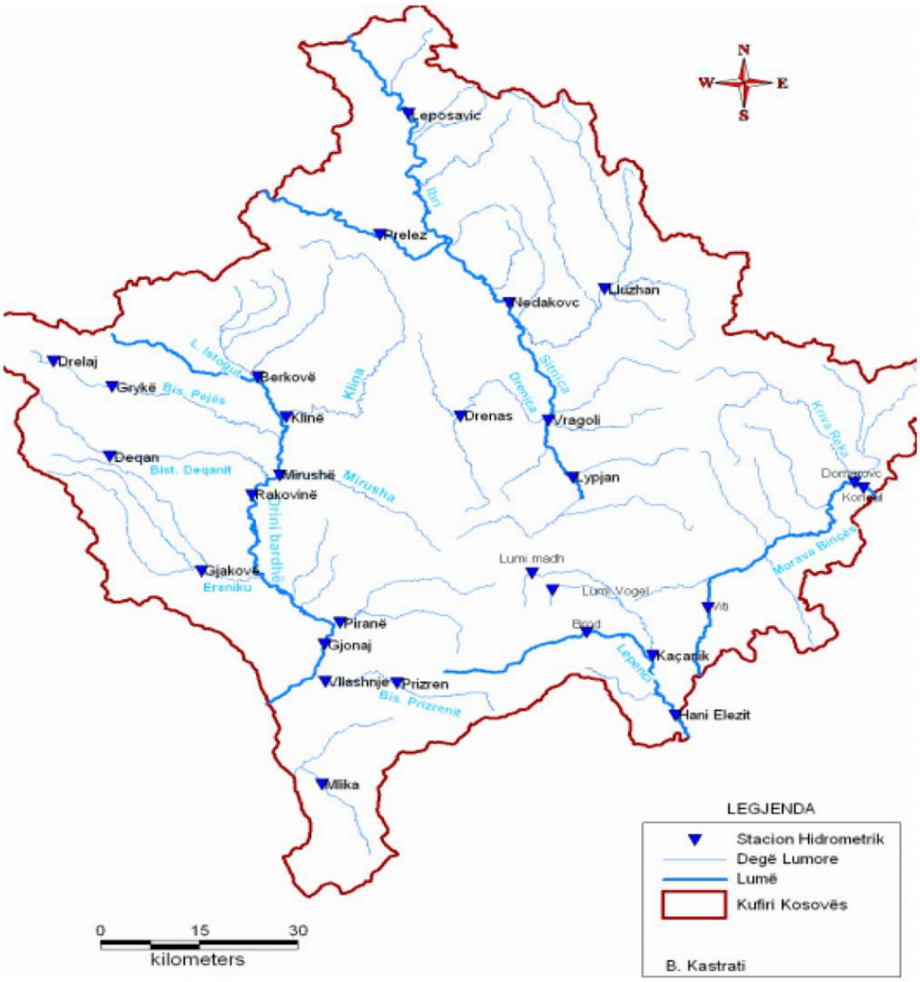


Figure 2-17 River basins (with hydro meteorological stations)

Source: Ministria e Mjedisit dhe Planifikimit Hapësinor Agjencia për Mbrojtjen e Mjedisit të Kosovës. Raport: Gjendja e Ujërave në Kosovë, 2010.

Based on the detailed research of small HPPs conducted by the Government of the Republic of Kosovo in 2006[7], 2009[8] and 2010[9], the north-western part of Kosovo has the highest potential, i.e. the area between Peja and Junik (the rivers of Lumbardhi of Peja, Lumbardhi of Decan, Lumbardhi of Llocan, and Erenik). The south-east part has smaller hydropower potential, i.e. the area between Dragash and Prizren (the rivers of Plava, Lumbardhi i Prizrenit, and Lepenci). The area of northern Mitrovica (the Bajska and Bistrica rivers) has even smaller potential, and the area of east of Llap (Kacandoll river) has the smallest hydropower potential.

Table 2-13 shows the list of possible locations for the construction of small hydropower plants.

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[7] Studimi i arafisibilitetit për identifikimin e burimeve ujore për hidrocentrale të vegjël në Kosovë, May 2006.
[8] Vlerësim i mëtejmë i potencialeve për hidrocentrale të vogla në Kosovë, December 2009.
[9] Vlërësim i mëtjmë i potencialeve për hidrocentrale të vegjëlnë Kosovë, July 2010.

Table 2-13 List of possible locations for the construction of SHPPs

No.	SHPP Name	River	Power Capacity (MW)	Electricity Generation (GWh)
1.	Kuqishtë	Lumëbardhi i Pejës	3.9	17
2.	Drelaj		6.2	27
3.	Shtupeç		7.6	35
4.	Bellaje	Lumëbardhi i Deçanit	5.2	25
5.	Deçan		8.3	39
6.	Lloçan	Lumëbardhi i Lloçanit	3.1	14
7.	Mal	Erenik	4.0	18
8.	Erenik		2.0	9
9.	Jasiq		1.9	9.7
10.	Dragash	Plava	2.2	10
11.	Orcush		5.6	25.6
12.	Reçan	Lumëbardhi i Prizrenit	1.5	6.7
13.	Brezovicë	Lepenc	2.1	10
14.	Lepenci		3.5	16
15.	Bajskë	Banjskë	0.3	1.4
16.	Batare	Bistrica (Batare)	1.1	5.8
17.	Majanc	Kaçandoll	0.6	2.9
18.	Mirusha	Drini i Bardhë & Deçanit	4.6	22
19.	Radesha 1	Radesha	0.75	3.66
20.	Radesha 2		1.49	7.37
21.	Restelica 1	Restelica	0.53	2.51
22.	Restelica 2		1.40	6.74
23.	Restelica 3		1.09	5.35
24.	Restelica 4		0.32	1.56
25.	Restelica 5		1.50	7.37
26.	Brodi 1	Brodi	0.81	3.90
27.	Brodi 2		1.11	5.37
28.	Brodi 3		1.06	5.13
29.	Brodi 4		1.44	6.97
30.	Lepenci 1	Lepencë	0.37	1.79
31.	Lepenci 2		0.55	2.61
32.	Lepenci 3		0.80	3.96
33.	Lepenci 4		1.72	8.40
34.	Lepenci 5		2.80	13.64
35.	Lepenci 6		2.77	13.34
36.	Lepenci 7		0.44	2.14
37.	Lepenci 8		0.53	2.45
38.	Lepenci 9		1.19	5.73
39.	Iber 1	Iber	0.24	1.22
40.	Iber 2		0.56	2.84
41.	Iber 3		0.63	3.25

No.	SHPP Name	River	Power Capacity (MW)	Electricity Generation (GWh)
42.	Iber 4		0.39	1.96
43.	Llapi 1	Llapi	0.53	2.93
44.	Klina 1	Klina	0.47	2.20
45.	Klina 2		0.47	2.44
46.	Morava e Binçës 1	Morava e Binçës	0.11	0.49
47.	Morava e Binçës 2		0.17	0.80
48.	Istogu 1	Istog	0.45	2.23
49.	Nerodime 1	Nerodime	0.17	0.84
50.	Nerodime 2		0.13	0.62
51.	Nerodime 3		0.12	0.60
52.	Çajlana 1	Çajlana	0.39	2.00
53.	Drenica 1	Drenica	0.11	0.55
54.	Reka e Aliagës 1	Reka e Aliagë	1.20	6.22
55.	Reka e Aliagës 2		0.76	3.98
56.	Drini i Bardhë 1	Drini i Bardhë	2.03	11.88
57.	Jabllanica		1.01	5.16
58.	Lepenci II-1	Lepenci	3.58	17.54
59.	Lepenci II-2		2.81	15.05
60.	Lepenci II-3		6.07	30.36
61.	Prizreni 1	Lumëbardhi i Perizrenit	1.15	5.79
62.	Prizreni 2		2.99	15.17
63.	Prizreni 4		2.53	13.04
64.	Prizreni 5		2.84	14.74
65.	Prizreni 6		1.19	5.99
66.	Prizreni 7		1.66	8.09
67.	Prizreni 8		1.76	8.86
68.	Prizreni 9		1.68	8.41
69.	Peja 4	Lumëbardhi i Pejës	0.77	3.89
70.	Peja 5		1.33	6.64
71.	Peja 6		1.20	6.00
72.	Peja 7		1.05	5.14
73.	Peja 8		0.93	4.52
74.	Peja 9		0.36	1.84
75.	Peja 10		1.72	8.54
76.	Peja 11		0.85	4.30
77.	Lloçani 1	Lumëbardhi i Lloçani	0.67	3.61
78.	Lloçani 2		1.50	7.92
79.	Lloçani 4		1.06	5.66
Total		-	**136.01**	**657.40**

Source: https://mzhe-ks.net/ repository/docs/Potencialet_e_Kosoves_per_Gjenerim_te_Energjise_Ujore.pdf

The main (big) hydropower potential in Kosovo is the pump storage hydropower plant project Zhur with an estimated installed power of 250 MW. The plant should be located in the south-western part of Prizren, in the stream of Drini i Bardhë (White Drin). The plant is supposed to be used as a storage facility, and its generated electricity will be utilized for peak demand. Based on Kosovo's "*Energy Strategy 2009-2018*"[10], for the project to result profitable, the estimated price of electricity would be 87.2 EUR/MWh during the first 15 years and drop to 39.5 EUR /MWh for the next 34 years (plant lifetime is 50 years according to the document). The "*Energy Strategy 2017-2026*"[11], hereafter the Energy Strategy, defined up to 200 MW of new flexible HPP (without specifying project names) to be commissioned in 2023. The latest relevant document "*Generation Adequacy Plan 2019-2028*" stated that KOSTT has received an application for connection of the HC REV ZHUR with a capacity of 4 x 62.5 = 250 MW, and the power plant will provide auxiliary services such as: black start, fast and substitute secondary and tertiary regulation. It is agreed with the Beneficiaries that PS HPP (Zhur) will be considered only as part of the sensitivity analysis in one of the scenarios within chapter 5 .

To encourage the use of RES, in 2016 Kosovo has set up a legal framework as well as a support scheme through feed-in tariffs for small hydropower, wind energy, photovoltaic energy and biomass. As a result of private investors' interest in SHPPs, a 97.23 MW of new SHPPs has been commissioned, ERO issued the final permits of authorization for 10.32 MW and preliminary permits of authorization for 16.71 MW of new capacities. Before implementation of the support scheme, there were 48.17 MW installed capacity. Table 2-14 shows commissioned hydropower plants and the current status of SHPP projects.

Table 2-14 Current status of hydropower plants/projects

No.	Hydropower plant	Status	Power Capacity [MW]
1.	Radavci		
2.	Burimi		
3.	Dikanci		
4.	Ujmani		
5.	Lumbardhi 1		
Total*			

[10] Republic of Kosovo, Ministry of Energy and Mining, Energy Strategy of the Republic of Kosovo 2009-2018, Prishtina 2009

[11] Republic of Kosovo, Ministry of Economic Development, Energy Strategy of the Republic of Kosovo 2017-2026, March 2017

Total**			
28.			
Total Applications			
TOTAL HPP			

* HPP commissioned before the adoption of the feed-in support scheme.

** HPP commissioned in course of the feed-in support scheme (after 2016).

Table 2-14 clearly shows that significant construction of small hydropower plants occurred after the adoption of the feed-in tariffs. This is the current status of commissioned SHPPs according to the latest ERO's report "*Electricity and Thermal Energy Annual Balance 2020*" (published in December 2019).

By comparing Table 2-14 and 2-13 it can be seen that another 110 MW (or 66 locations) of new small hydropower plants can be developed. It is important to emphasize that this comparison was made only by location names, so certain deviations are possible (for example in installed power). Development of some SHPP projects on the same river can have influence on neighboring SHPP projects, i.e. it can significantly reduce potential of installed power or even eliminate the whole project. Also, more and more stringent environmental regulations (e.g. higher natural inflow limits) significantly reduce the potential installed power of SHPPs. In order to make an accurate assessment which remaining locations are feasible, a detailed set of input data for each location was required, but not provided. Such analyses come down to the individual prefeasibility studies, which usually includes site visits. However, it was agreed with the Beneficiaries that only the currently planned projects (total of 63.3 MW, Table 2-14) will be commissioned until 2030.

Except listed locations, some new locations for small hydropower plants may appear in the future especially in the form of reconstruction of old mills into small hydropower plants.

Also, new small hydropower plants can be built in the water supply system if there is a surplus of pressure.

KOSTT's "*Transmission Development Plan 2018-2027*" (published in November 2017) identified 205 MW of new SHPP in the next 10 years. Furthermore, KOSTT's latest relevant document "*Generation Adequacy Plan 2019-2028*" (published in October 2018) defined 101 MW of small HPP in all three scenarios (low, referent and high scenario).

The Energy Strategy (published in March 2017) has defined 160 MW for new SHPP untill 2026. However, the Government of Kosovo has recently put a moratorium on new applications, due to potential environmental concerns and the lack of feasible potential to reach the hydro quota.

According to the *NREAP* (Update for 2018-2020; published in May 2020) in the electricity sector, RES generation increases are based on the development of small and medium hydro power plants of 124.1 MW, among the other RES.

All figures listed above are based on the aforementioned detailed research of small HPP in 2006, 2009 and 2010. The figures differ from report to report because some SHPPs were commissioned in the meantime.

3 ASSESSMENT OF THE COSTS

The decline of the investment costs caused by technological development of renewable energy technologies in recent years leads also to increased penetration of renewable energy sources in power systems of many countries. In a long-term generation expansion planning, it is important to make reasonable assumptions on the future variations in investment cost of different technologies.

The levelized cost of electricity (LCOE) is a useful tool for comparing the unit costs of different technologies over their operating life. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime, divided by the total energy output of the asset over that lifetime.

For the purposes of this study, LCOE is determined for each 5-year step during the planning horizon (2025/2030). Using related costs such as investments, FOM, VOM, fuel, environmental taxes, expected connection charges/costs etc., LCOE is calculated for:

- hydro, wind, solar and biomass generation units,
- PS HPP Zhur (250MW),
- TPP Kosova e Re (450MW) and
- WPP Selaci (103.4 MW).

Build cost of 1,400 EUR/kW for SHPP candidates is determined as an average build cost for the existing list of planned projects which is provided in ANNEX 2.

Build cost of 785 EUR/kW for small and 680 EUR/kW for large scale PV candidates is determined in cooperation with the WB. This cost is the sum of capital investment (680 EUR/kW for small and 600 EUR/kW for large scale PV candidates) increased by land purchase cost (50 EUR/kW[12]) and grid connection cost (55 EUR/kW for small and 30 EUR/kW for large scale PV candidates). This value refers to the first modelling year (2020), while in the later years a reduction rate presented in Table 3-1 is applied to the capital investment, based on data from the study "Levelized Cost of Electricity- Renewable Energy Technologies[13]".

Table 3-1 Yearly cost reduction for PV candidates

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduction rate (%)	2.20	2.15	2.10	2.05	2.00	1.95	1.90	1.85	1.80	1.75	1.70

[12] Based on the proposed value of 2.5 EUR/m^2 by the WB

[13] Levelized Cost of Electricity- Renewable Energy Technologies, Fraunhofer Institute for Solar Energy Systems ISE, March 2018

Build costs for small and large PV candidates up to 2030 are presented in Table 3-2 and Table 3-3.

Table 3-2 Build cost for small scale PV candidates

Small scale PV	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Equipment cost	680	665	651	637	624	612	600	588	577	567	557
Land	50	50	50	50	50	50	50	50	50	50	50
Grid connection	55	55	55	55	55	55	55	55	55	55	55
Total	**785**	**770**	**756**	**742**	**729**	**717**	**705**	**693**	**682**	**672**	**662**

Table 3-3 Build cost for large scale PV candidates

Large scale PV	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Equipment cost	600	587	574	562	551	540	529	519	509	500	491
Land	50	50	50	50	50	50	50	50	50	50	50
Grid connection	30	30	30	30	30	30	30	30	30	30	30
Total	**680**	**667**	**654**	**642**	**631**	**620**	**609**	**599**	**589**	**580**	**571**

Wind candidates are assumed to be large scale and connected to the transmission network. Build cost of 1,205 EUR/kW for wind candidates includes all costs (investment, grid connection cost etc.) and remains the same in all years over the planning horizon.

For biomass candidates build cost of 3500 EUR/kW is determined in cooperation with the WB and remains the same throughout the planning horizon.

Build costs for PS HPP Zhur, TPP Kosova e Re and WPP Selaci are agreed with the WB and presented in Table 3-4.

Table 3-4 Build costs for committed projects

	HPP Zhur	TPP Kosova e Re	WPP Selaci
Commissioning year	2027	2026	2022
Installed capacity (MW)	250	450	103.4
Build cost (EUR/kW)	1,800	2,200	1,280

Assumptions of power generation options for LCOE calculation for 2025 and 2030 are presented in Table 3-5 and Table 3-6. LCOE analysis of power generation candidates for the years 2025 and 2030 is presented in Figure 3-1 and Figure 3-2. LCOE components such as investment, fixed operation and maintenance (FOM), variable operation and maintenance (including fuel costs) and surcharge cost for CO2 emission units are expressed in EUR/MWh and presented separately in Table 3-5 and Table 3-6. Values for capacity factors (CF) are assumed values used to estimate LCOE (i.e. final CF will follow from the simulation and optimisation model). Discount rate used in the calculation is 8%.

Table 3-5 Assumptions of power generation options for LCOE calculation for 2025

Option	Investment	Efficiency	Fuel costs	Fixed costs	Variable costs	Lifetime	Expected annual CF for LCOE estimates
	EUR/kW	%	EUR/GJ	EUR/kW/year	EUR/MWh	years	%
HPP Small	1,400.0	100.0	0.0	10.0	5.0	40.0	35.0
Solar PV Large	619.6	100.0	0.0	10.8	0.0	30.0	19.3
Solar PV Small	716.5	100.0	0.0	10.8	0.0	30.0	18.1
Wind (onshore)	1,205.0	100.0	0.0	38.6	0.0	30.0	26.8
Biomass	3,500.0	35.0	5.0	20.0	2.3	30.0	70.0
WPP Selaci	1,280.0	100.0	0.0	38.6	0.0	30.0	32.5
Prices and costs in table are given for 2025							

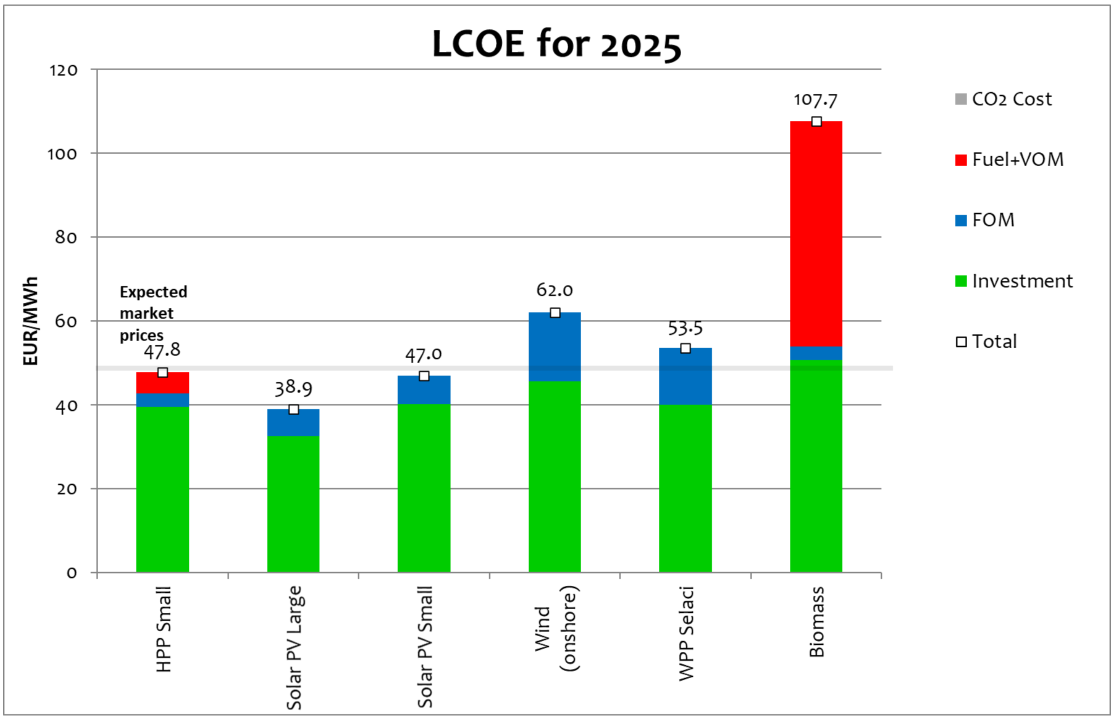

Figure 3-1 Estimated LCOE of power generation options in 2025

Table 3-6 Assumptions of power generation options for LCOE calculation for 2030

Option	Investment	Efficiency	Fuel costs	Fixed costs	Variable costs	Lifetime	Expected annual CF for LCOE estimates
	EUR/kW	%	EUR/GJ	EUR/kW/year	EUR/MWh	years	%
HPP Small	1,400.0	100.0	0.0	10.0	5.0	40.0	35.0
Solar PV Large	571.5	100.0	0.0	10.8	0.0	30.0	19.3
Solar PV Small	662.0	100.0	0.0	10.8	0.0	30.0	18.1
Wind (onshore)	1,205.0	100.0	0.0	38.6	0.0	30.0	26.8
Biomass	3,500.0	35.0	5.0	20.0	2.3	30.0	70.0
TPP Kosova e Re	2200.0	39.6	1.4	36.0	3.3	40.0	70.0
PSPP Zhur	1,800.0	100.0	0.0	10.0	5.0	40.0	29.0
WPP Selaci	1,280.00	100.0	0.0	38.6	0.0	30.0	32.5
Prices and costs in table are given for 2030							

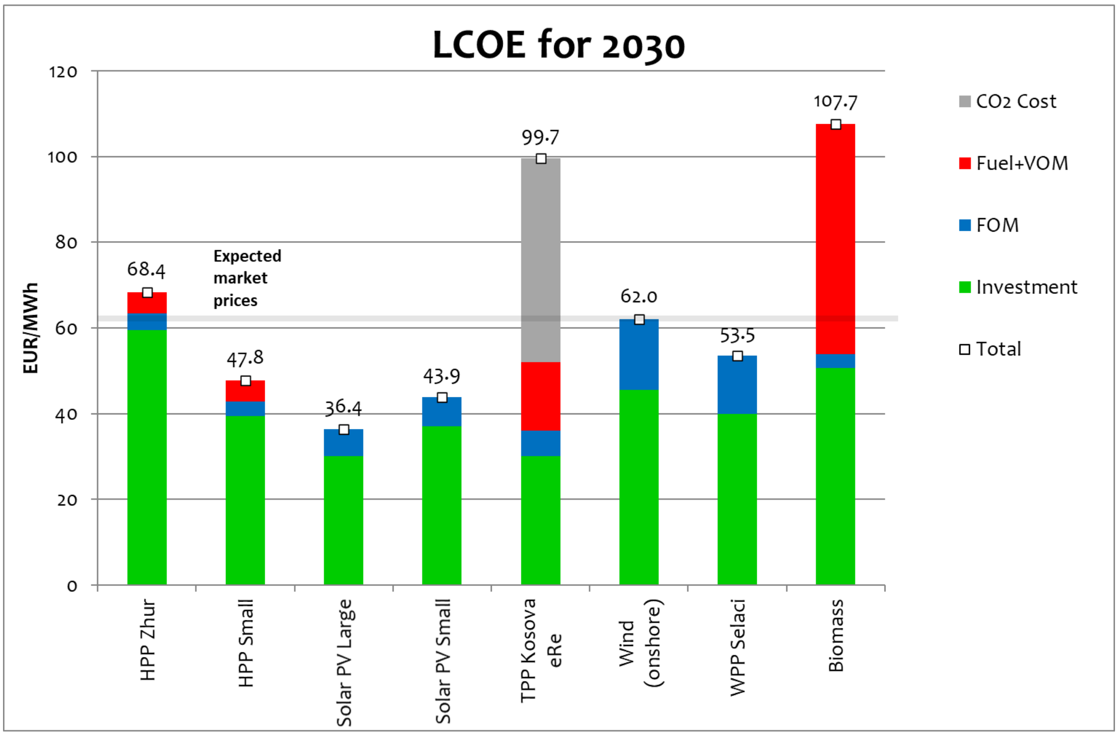

Figure 3-2 Estimated LCOE of power generation options in 2030

It should be noted that LCOE analysis is a simplistic approach used for an initial screening of generation options and competitiveness comparison. Comparison is static, i.e. it looks into technology at a certain point in time with an assumed set of related costs (investment, FOM, VOM and fuel, CO_2 cost, assumed capacity factor). The estimated LCOE of power generation options for 2025 and 2030 is presented in additionally shown in Table 3-7.

Table 3-7 Estimated LCOE of power generation options in 2025 and 2030

LCOE (EUR/MWh)	HPP Zhur	HPP small	Solar PV large	Solar PV small	TPP Kosova e RE	Wind (onshore)	WPP Selaci	Biomass
2025	0.0	47.8	38.9	47.0	0.0	62.0	53.5	107.7
2030	68.4	47.8	36.4	43.9	99.7	62.0	53.5	107.7

The following conclusions can be made for LCOEs over the study period:

- Market prices in neighbouring markets are creating a positive environment and can attract project developers.
- Solar PVs are expected to see further technological development and cost reductions. Still, development of wind and solar depends on future support schemes.
- Large scale and small hydro are not expected to show further cost reductions. More strict environmental regulation can make these projects more expensive, postpone development and discourage investors due to regulatory risks. Moreover, it was agreed with ERO that just currently planned projects (total of 63.3 MW, Annex 2) will be commissioned until 2030.
- Competitiveness of Kosova e Re is significantly affected by internalisation of external costs through CO_2 emission units surcharge.
- Finally, by 2030 the situation will become more favourable for variable renewables like wind and solar, while fuel and CO_2 prices significantly aggravate market position for TPP Kosova e Re.

Based on the above calculations, screening curves presented in Figure 3-3 were developed to compare LCOE for power generation candidates depending on their capacity factors.

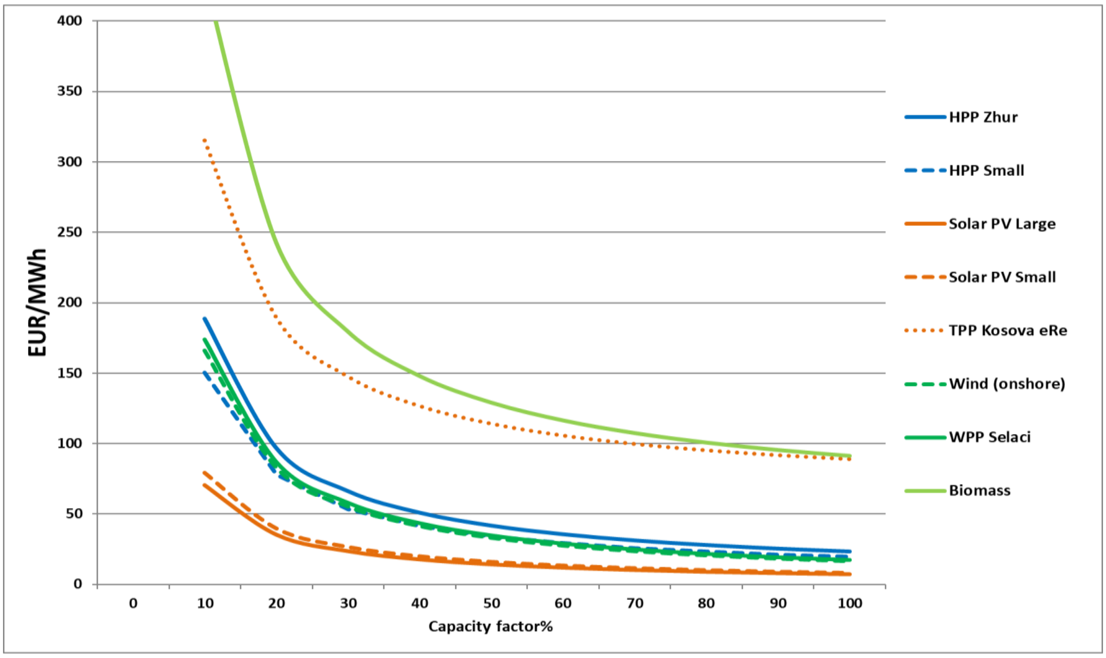

Figure 3-3 LCOE depending on capacity factor

The RE supply curve analysis is intended to provide high-level indicative cost information to policy makers about various renewable energy resources. As such, the supply curve analysis does not provide cost data that could support decisions with respect to specific projects, for several reasons. The analyses on small scale hydro, wind and solar projects are based on generic candidates, not on specific cost information about identified projects. However, committed projects (WPP Selaci, PS HPP Zhur and large-scale PV park) obtain exact cost data provided by the Beneficiaries and the WB and these data are used in development of RE supply curves for this project. But more important, the analyses developed in this chapter do not include constraints used in the optimization process described in chapter 5 . Optimization process observes RE candidates on much deeper level such as contribution to the firm capacity (10% for wind power plants and 0% for solar power plants) and capacity factor (between 26% and 32% for wind power plants and around 19% for solar power plants). This implies that the most favorable option for future RES development in this analysis doesn't necessary comply with the results of the optimization process. Although the solar projects have been selected as the most favorable option due to their low investment costs, the optimization process provides more indicative RE mix to meet the growing demand and given RES-E targets by 2030.

RE supply curves for 2025 and 2030 are presented in figures 3-4 and 3-5. It is important to emphasize that the cumulative generation per year (GWh/y) is presented in relation to LCOE (EUR/MWh), e.g. around 850 GWh of the electricity can be generated from solar power plants for the cost of 36 EUR/MWh and additional 200 MW can be obtained with the price of 44 EUR/MWh. On the other hand, to develop the same amount electricity from the wind power plants can be obtained with higher cost between 53 and 62 EUR/MWh.

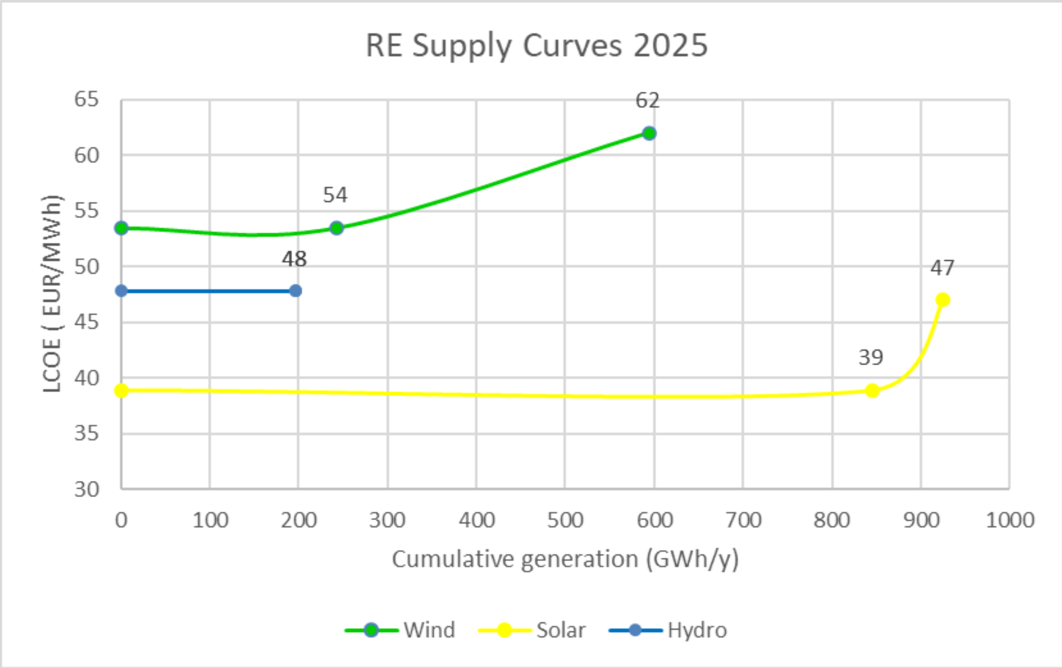

Figure 3-4 RE supply curves for 2025

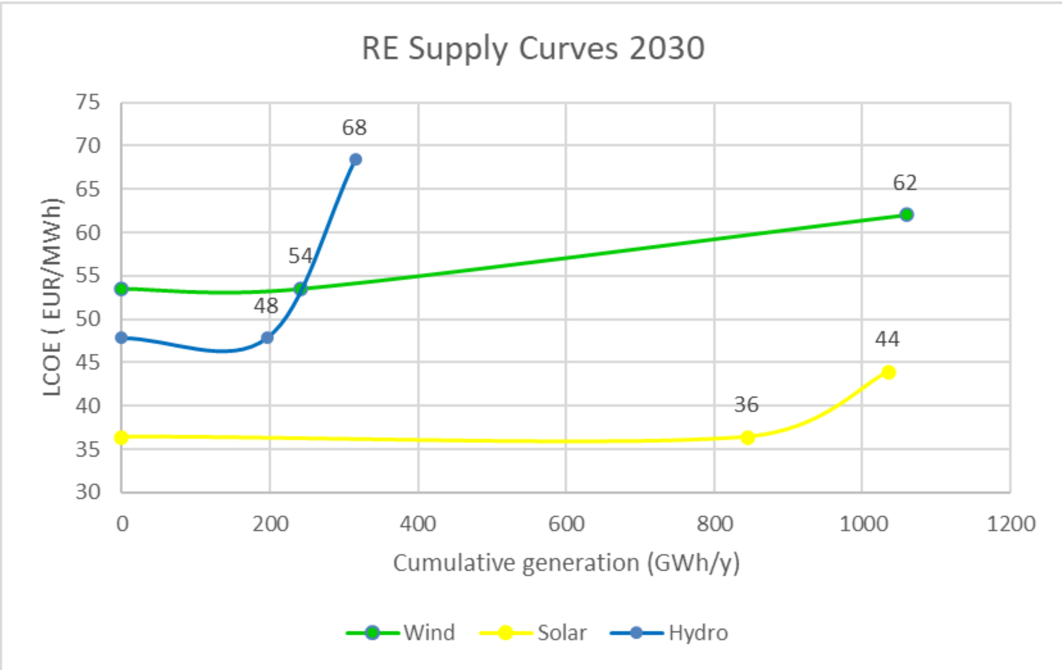

Figure 3-5 RE supply curves for 2030

4 ELECTRICITY DEMAND FORECASTS

4.1 Assessment of existing demand forecasts

4.1.1 Energy Strategy 2017-2026

Four scenarios of electricity demand for the period up to 2026 are analyzed in Kosovo's Energy Strategy (Low, Base, High and High1) based on variables including economic growth, the gradual reduction of technical and commercial losses, industrial development, foreseen measures of energy efficiency, and the diversification of energy sources for meeting demand. All four scenarios are presented in Table 4-1.

Table 4-1 Electricity demand scenarios 2017-2026 according to the Energy Strategy

Electricity Demand (GWh)	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Scenario 1 (LOW)	5,694	5,700	5,706	5,715	5,741	5,751	5,776	5,809	5,849	5,897
Scenario 2 (BASE)	5,784	5,826	5,902	5,955	6,024	6,084	6,156	6,238	6,330	6,455
Scenario 3 (HIGH)	5,942	6,041	6,164	6,253	6,361	6,461	6,577	6,706	6,848	7,010
Scenario 4 (HIGH 1)	5,990	6,120	6,280	6,410	6,610	6,870	7,080	7,319	7,522	7,731

These scenarios were compared with the actual developments since 2016 and the results served as the main inputs for the new demand scenarios definition.

4.1.2 Long-Term Energy Balance of the Republic of Kosovo 2017-2026

The Long-Term Energy Balance for the period 2017-2026 is based on data of realized energy balances and existing strategic documents of Kosovo. In calculating energy consumption forecasts, three basic factors are considered: economic growth, number of households and consumption of the three last years. Electricity demand forecast, under four different scenarios, is presented in Table 4-2.

Table 4-2 Electricity demand scenarios 2017-2026 according to the Long-Term Energy Balance

Peak load, GWh	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Low Scenario	5,250	5,580	5,706	5,715	5,741	5,751	5,776	5,809	5,849	5,897

Peak load, GWh	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Base Scenario	5,463	5,700	5,902	5,955	6,024	6,084	6,156	6,238	6,330	6,423
High Scenario	5,574	5,890	6,164	6,253	6,361	6,461	6,577	6,706	6,848	7,010
Development Scenario	5,990	6,120	6,280	6,410	6,610	6,870	7,080	7,319	7,522	7,731

4.1.3 Transmission Development Plan 2018-2027

Electricity demand forecast presented in Transmission development plan 2018-2027[14] is based on the forecast described in the Long-Term Energy Balance 2017-2026, in accordance with the provisions made in the Energy Strategy, adding the year 2027. Electricity demand forecast development for the period 2018-2027 under three different growth scenarios is shown in Table 3-3. The baseline scenario of load development is characterized by an annual average growth of around 1.38%. This load development scenario is the key input in evaluating the operating performance of the transmission network.

Table 4-3 Low, base and high growth scenarios for the peak load according to the Transmission Plan

Peak load, MW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Low Peak	1,137	1,152	1,184	1,186	1,192	1,194	1,199	1,206	1,214	1,224	1,237
Base Peak	1,162	1,188	1,225	1,236	1,250	1,263	1,278	1,295	1,314	1,333	1,348
High Peak	1,199	1,222	1,279	1,298	1,320	1,341	1,365	1,392	1,421	1,455	1,471

4.1.4 Generation Adequacy Plan 2019-2028

The forecast of electricity and power demand, taken into consideration in the assessment of Generation adequacy plan 2019-2028[15], was based on the document Long Term Energy Balance 2019- 2028. The forecast of electricity demand development for 2019-2028 according to three different growth scenarios is presented in Table 4-3. The baseline scenario of load development presents the key input in assessing the generation adequacy.

Table 4-4 Low, base and high growth scenarios for the peak load according to the Generation Adequacy Plan

Peak load, MW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Low Peak	1,161	1,115	1,126	1,145	1,154	1,151	1,158	1,159	1,161	1,160	1,165	1,167

[14] Transmission development plan 2018-2027, KOSTT, November 2017
[15] Generation Adequacy Plan 2019-2028, KOSTT, Prishtina, October 2018

Peak load, MW	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Base Peak	1,161	1,160	1,177	1,210	1,221	1,231	1,237	1,246	1,251	1,257	1,267	1,270
High Peak	1,161	1,213	1,276	1,276	1,294	1,311	1,324	13,40	1,351	1,364	1,381	1,390

4.2 Projections of the future electricity demand

Available demand forecasts for Kosovo were analyzed and reviewed to determine demand scenarios for analysis in the long-term optimization model.

In Kosovo's Energy Strategy scenarios of electricity demand for the period up to 2026 are analyzed. Those projections were compared with the actual energy balance for 2019 and the projection of electricity demand for 2020 according to the Electricity and Thermal Energy Balance 2020[16] provided by ERO.

Thus, based on the analysis of available demand forecasts and in line with the discussion with ERO, the following demand scenarios were determined:

- Base scenario and
- High scenario.

Demand projections in **Base scenario** are based on Scenario S3 from the Energy Strategy. However, in the forecast given in the Electricity and Thermal Energy Balance, demand for 2020[3] is 2.4% higher compared to the respective projections of S3 scenario. Thus, the Base Scenario for the electricity demand resulted by increasing the electricity demand in each year of S3 Scenario by 2.4%. As values under S3 were not available for the period after 2026, an extrapolation was used which resulted in electricity demand for Base scenario until 2030. The demand evolution and the respective yearly growth rate in the Base scenario is presented in Table 4-5. The average annual growth rate for the period up to 2030 is 1.83%.

Table 4-5 Demand projections in Base scenario until 2030

Unit	Level	Case	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GWh	Total	Base	6,403	6,514	6,616	6,735	6,867	7,012	7,178	7,304	7,429	7,554	7,680
Growth Rate			-	**1.73%**	**1.57%**	**1.80%**	**1.96%**	**2.11%**	**2.37%**	**1.76%**	**1.71%**	**1.68%**	**1.67%**

Demand projections in **High scenario** assume a fixed annual growth rate (2.3%) starting from the currently available forecast given in the Electricity and Thermal Energy Balance for 2020:

[16] Electricity and Thermal Energy Balance 2020, Energy Regulatory Office, December 2019

Table 4-6 Demand projections in High scenario by 2030

Unit	Level	Case	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GWh	Total	High	6,404	6,551	6,702	6,856	7,014	7,175	7,340	7,509	7,682	7,858	8,039
Growth Rate			-	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**	**2.30%**

Projections of electricity demand for both scenarios are presented in following picture along with Scenarios S1-S4 from the Energy Strategy up to 2026.

To summarise, the Consultant determined the projections of electricity demand until 2030 necessary for the execution of activities under Task 1 based on the values in Table 4-7 and Figure 4-2 for Base and High case scenarios.

The Consultant also received hourly load data for seven distribution areas in Kosovo for the year 2019. Hourly demand patters will be scaled according to peak load and total consumption projections in Base and High case to develop hourly profiles for the whole planning horizon. i.e. until 2030.

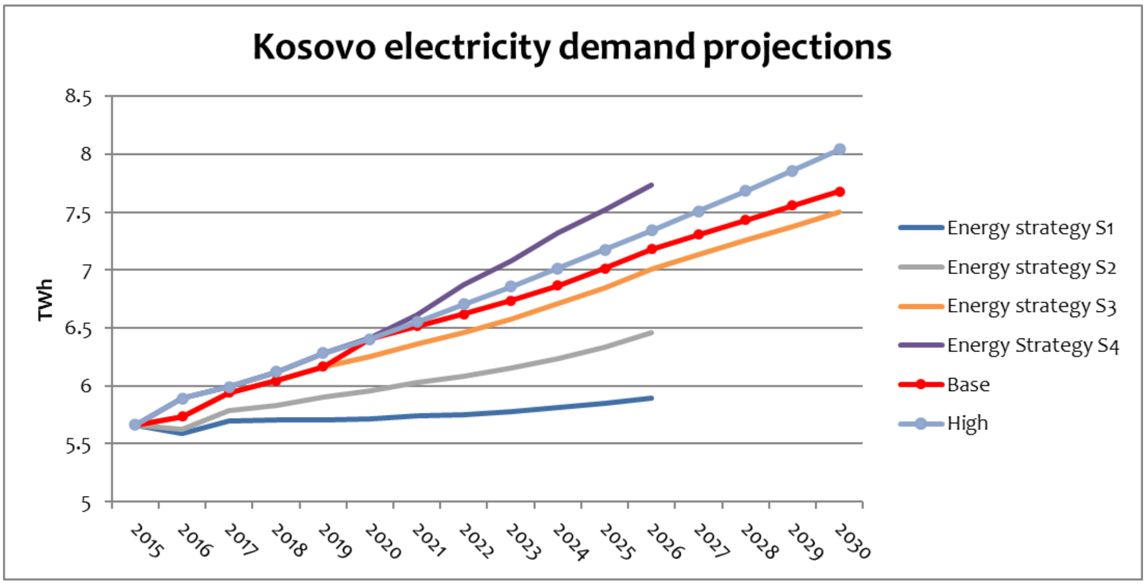

Figure 4-1 Different electricity demand projections for Kosovo by 2030

Table 4-7 Electricity demand projections for Kosovo by 2030

Unit	Case	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GWh	Base	6,403	6,514	6,616	6,735	6,867	7,012	7,178	7,304	7,429	7,554	7,680
GWh	High	6,404	6,551	6,702	6,856	7,014	7,175	7,340	7,509	7,682	7,858	8,039

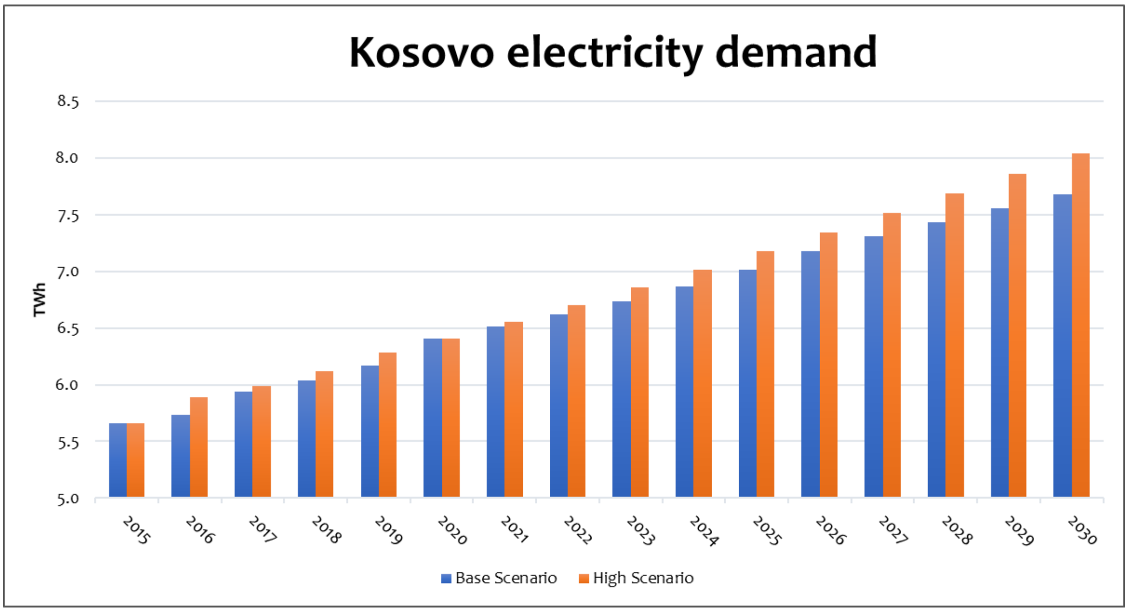

Figure 4-2 Final electricity demand projections for Kosovo up to 2030

5 POWER SYSTEM PLANNING TO DETERMINE THE OPTIMAL RENEWABLE ENERGY PENETRATION FOR KOSOVO'S POWER SYSTEM

5.1 Methodological approach

Long-term planning of the generation expansion for Kosovo's power system takes into consideration all relevant and feasible technology options in the near future, with the emphasis on **increasing the share of renewable generation in the system** to meet the given RES-E targets by 2030. The long-term planning process has the following main phases:

- Preparation of Kosovo's power system model;
- Definition of development scenarios to analyse;
- Executing the simulations;
- Analysing results and determining the least cost RE option.

To solve the problem of capacity expansion, an optimal combination of generation new builds needs to be found, considering planned retirements and demand projections. Some of the largest power generators in Kosovo are planned to be decommissioned by 2030 and need to be replaced with the new capacities. To determine optimal renewable energy penetration, Kosovo's power system model is prepared in the **PLEXOS® Market Simulation Software** tool (further in text: PLEXOS)[17], which allows detailed long-term generation expansion optimization and use of hourly resolution for medium and short-term simulations. PLEXOS is a simulation software that uses state-of-the-art mathematical optimization, to provide a high-performance, robust simulation system for electric power. Main advantage of this approach is that it allows identification of the least-cost generation expansion plan among various generation options and simulation of selected power supply options. The model allows detailed hourly simulation of all different options.

The objective of the optimization problem is **to minimize the net present value (NPV) of the total costs of the system over a long-term planning horizon**. The costs included in the objective function consist of annualized build cost for new generating capacities, fuel costs, variable O&M costs, CO_2 emission costs, value of unserved energy and cost of capacity shortage if the required capacity margin is defined. The optimal expansion plan represents therefore the least-cost investment plan that meets the system demand and obeys technical and regulatory constraints with a given set of candidate projects.

[17] More information on PLEXOS Market Simulation Software available on Energy Exemplar's website: https://energyexemplar.com/

The power system of Kosovo is represented by seven nodes in PLEXOS, based on the seven existing distribution areas in Kosovo (Pristina, Peja, Prizren, Ferizaj, Mitrovica, Gjakova and Gjilan). Each node aggregates all the electricity demand and generation of a given distribution area. In that way the constraints on new RE developments and associated costs are modelled on the level of each distribution area.

High voltage transmission network is modelled with given limits on transmission capacity. The representing power lines in the model connect distribution areas and neighbouring power systems. Neighbouring power systems of Albania, North Macedonia, Montenegro and Serbia are modelled as external electricity market nodes with predefined input time series of electricity prices. Generation capacities and load demand are not modelled for these nodes.

Detailed chart flow of the optimization process with input and output data included in the PLEXOS model is provided in Figure 5-1. Input data were provided by the Beneficiaries and the WB or proposed by the Consultant and verified by the Beneficiaries and the WB.

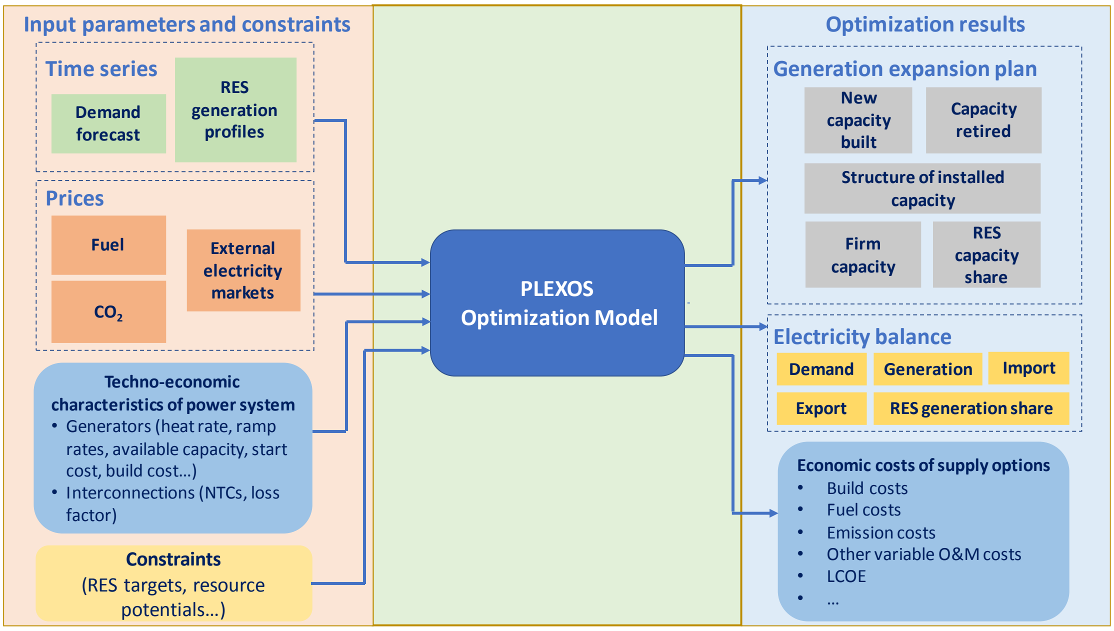

Figure 5-1 Chart flow of the long-term optimization process/model

Once the input data were collected and Kosovo's power system model was prepared in PLEXOS, different development scenarios were discussed and incorporated in the model based on the following parameters:

- electricity demand projections,
- RE generation share in projected electricity demand by 2030, i.e. RES-E target,
- commissioning of TPP Kosova e Re.

Optimization results are used to determine the optimal investment plan in new generating capacities to meet the RES-E targets, under different scenario assumptions. The results are examined regarding needed investments, firm capacity, RE mix, energy import and export and other important parameters, to determine the feasible and robust least cost investment plan. Electricity balance (load, generation, imports, exports) is also provided with emphasis on the share of RE generation compared to the total demand in Kosovo. Economic costs, including build costs, CO_2 emission costs, net import costs, etc. of each analysed scenario are compared.

5.2 Input data and assumptions

This section gives a detailed overview of input data and related modelling assumptions used in the PLEXOS model of Kosovo's power system.

5.2.1 General assumptions

Considering the goal to meet the 2030 RES-E target, the **planning horizon** includes the period up to 2030, starting from 2020, i.e. a total of 11 years.

Discount rate is assumed to be **8%** following the WB guidance based on real per capita GDP growth rate of Kosovo and income sensitivity of consumption. All the costs and revenues occurring over the planning horizon are discounted to the base year in the model with the assumed 8% discount rate.

5.2.2 RES-E target

RES electricity target refers to the share of electricity generation from renewable energy sources in the gross electricity demand of Kosovo.

The Inception Report delivered in April 2020 presented a methodology that considers two RES-E targets for 2030, Base and High, but in agreement with the WB, the Consultant will use only one.

The WB has identified a 2019 study[18] performed by the Technical University of Wien and financed by the Energy Community, as the only available reference on which the Consultant could base assumptions for acceptable target values to use in the model.

The Consultant suggested to assume 34% as the overall RES target (i.e. the % of RES in gross final energy demand) as determined in the study. Regarding the **RES-electricity** target the Consultant, ERO and the WB agreed to use **33%** in the PLEXOS model. This results from extrapolating the values of the scenario "RE target fulfilment - without RE cooperation" in the above-mentioned study of TU Wien as seen in Figure 5-2. An overall RES share of 37% corresponds to a RES electricity share of 36%. When extrapolated (linearly) the overall RES target of 34% would correspond to 33,08% RES electricity share. Rounded up this gives 33% which is in line with the share of other countries in the Energy Community.

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[18] Study on 2030 overall targets for the Energy Community - Energy efficiency, RES, GHG emissions reduction, TU Wien, EEG, REKK, June 2019

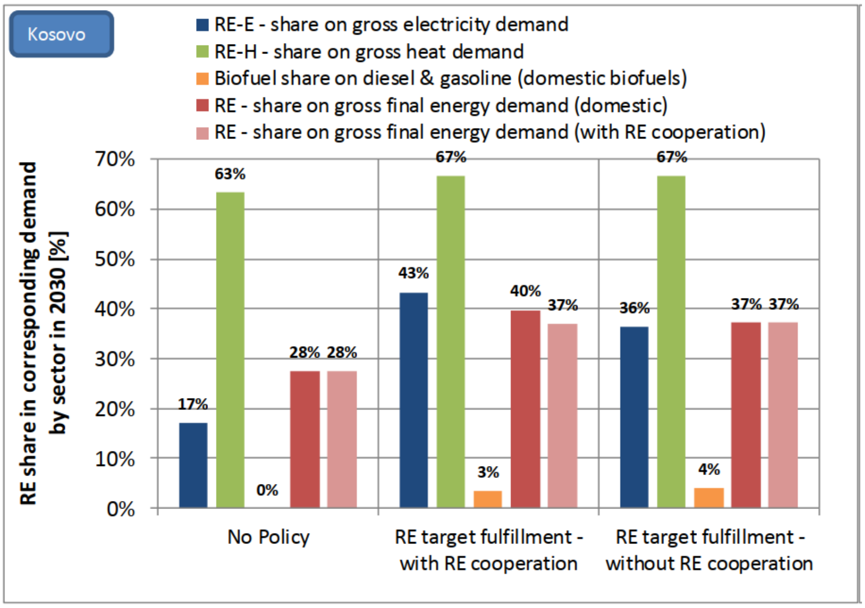

Figure 5-2 Expected future RE development in Kosovo according to the Study on 2030 overall targets for the Energy Community - Energy efficiency, RES, GHG emissions reduction (TU Wien, EEG, REKK, June 2019)

5.2.3 Electricity demand

Two scenarios of total electricity demand in Kosovo are determined based on the analysis available in the Energy Strategy and in cooperation with the Beneficiaries, as described in section 4.2 and depicted in the figure below.

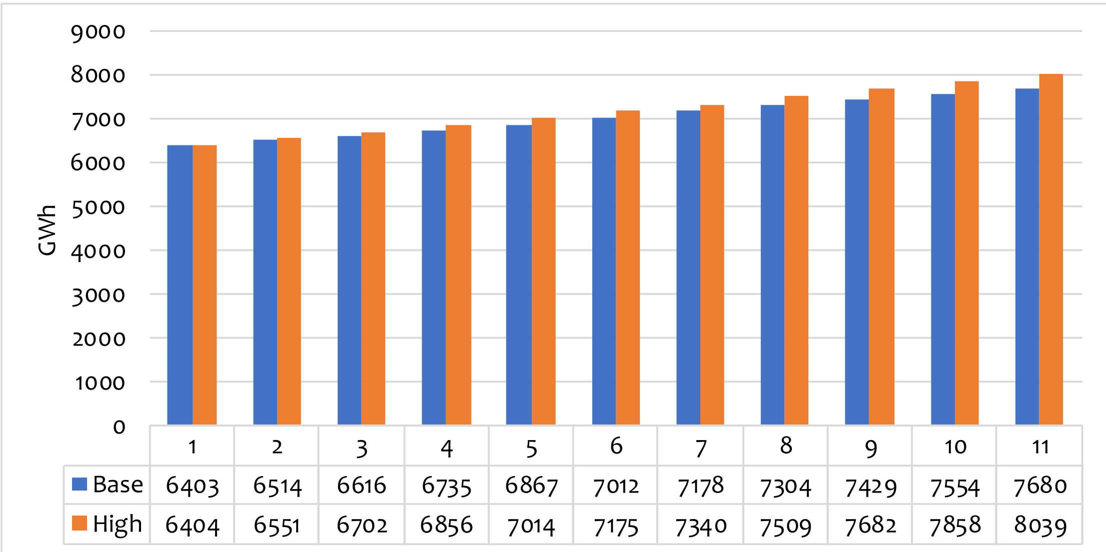

Figure 5-3 Projections of the total electricity demand in Kosovo in two scenarios

Given that the power system of Kosovo is represented in PLEXOS with seven nodes, demand data for each of the seven distribution areas was also necessary. During the inception period, the Consultant received data on hourly load in each distribution area for the year 2019 (Figure 5-4). Based on the received data, hourly load profiles were determined for each distribution area. Hourly load profiles and projections of total annual demand in Kosovo are used to determine hourly demand data for each distribution area until 2030. Average transmission losses which range from 1.76% to 2% are also taken into account in the model.

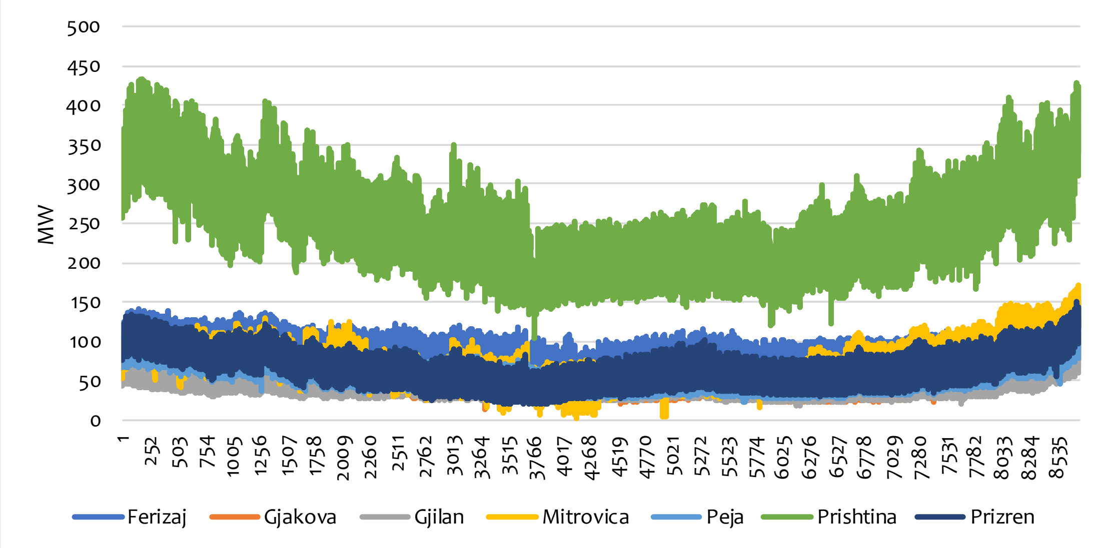

Figure 5-4 Hourly load data in 2019 for seven distribution areas in Kosovo

Based on the described methodology, the structure of the projected annual electricity demand until 2030 in Base and High scenarios for the seven distribution areas is shown in Figure 5-5 and Figure 5-6, respectively.

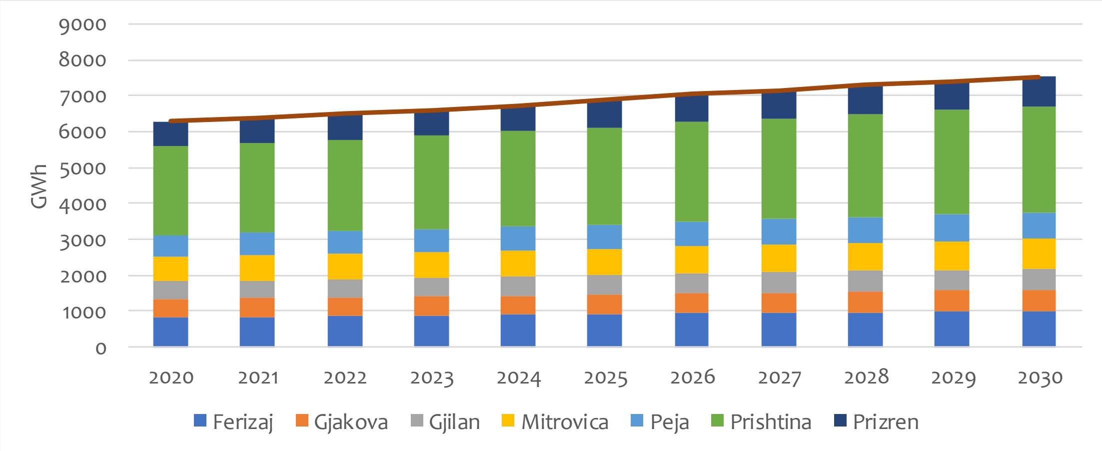

Figure 5-5 Annual electricity demand in Base scenario by distribution areas

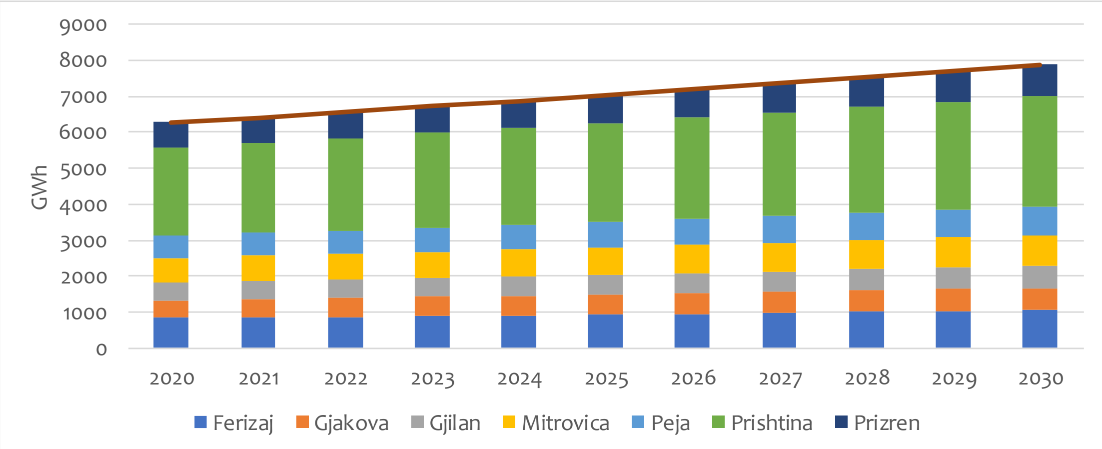

Figure 5-6 Annual electricity demand in High scenario by distribution areas

The greatest share of the total annual demand is concentrated in distribution area Prishtina, around 39%, followed by distribution area Ferizaj with 13% and Mitrovica and Prizren with 11% each. Distribution area Peja has a share of 10% in the total annual demand, while Gjilan and Gjakova account for 8% each.

5.2.4 Generation capacities

PLEXOS model of Kosovo power system consists of:

- existing generation units,
- committed generation units (units with predefined commissioning date), and
- candidate generation projects.

Existing generation units are listed in Table 1-1, according to which the total installed capacity in Kosovo is 1,440 MW. The majority of this capacity refers to thermal generation units, more specifically TPP Kosovo A and TPP Kosovo B. TPP Kosovo A has three units, with total installed capacity of 610 MW. Available capacity of these units is lower than the installed capacity and it amounts to 130 MW (TPP Kosovo A3), 130 MW (TPP Kosovo A4) and 135 MW (TPP Kosovo A5). According to the available data at KEK's website and the electricity balance for 2019, two units are in operation, while one unit is in reserve. Thus, it is assumed in the model that two of the three units are available for operation until the end of 2025. From 2026 onwards, all three units of TPP Kosovo A will be decommissioned. TPP Kosovo B has two units, with installed capacity of 339 MW each, but the available capacity of each unit is currently 251 MW. TPP Kosovo B1 will be under renewal in 2023, and TPP Kosovo B2 in 2024. After the renewal, available capacity of both units will increase to 268 MW.

Thermal units are modelled in PLEXOS based on the following techno-economic parameters:

- general data (plant name, number of units, fuel type),
- operational status – current state and target year per unit,
- maximum net output power per unit,
- minimum net output power per unit,
- heat rates at maximum net output power per unit,
- heat rates at minimum net output power per unit,
- fixed O&M costs per unit,
- variable O&M costs per unit,
- outage rates (forced outage rate – FOR, maintenance outage rate – MOR) and maintenance periods per unit,
- CO_2 emission factor per unit,
- operational constraints (ramping limits, minimum up/down time) per unit,
- must-run constraints per unit.

Other available capacities for electricity generation in Kosovo are renewable energy sources. Currently, there are around 109 MW of **hydro power plants**, out of which around 67 MW is connected to the transmission network and around 42 MW is connected to the distribution network. The largest hydro power plant is HPP Ujmani (35 MW). Detailed list of all existing hydro power plants is provided in Annex 1.

Hydro units are modelled in PLEXOS based on the following techno-economic parameters:

- general data (plant name, number of units),
- operational status – current state and target year,
- plant type (run of river, storage, pump storage plant),
- maximum net output power per unit,
- minimum net output power per unit,
- reservoir size,
- maximum net output power in pumping mode per unit in case of PS power plants,
- minimum net output power in pumping mode per unit in case of PS power plants,
- average monthly inflows for storage plants,
- average monthly generation for run of river plants,
- yearly electricity production.

Currently, there are 33.75 MW of **wind power plants** in operation (WPP Kitka 32.4 MW and WPP in Golesh 1.35 MW) and 10 MW of **PV plants** in operation (six PV plants). Wind and solar power plants are modelled based on the following parameters:

- installed capacities (solar),
- installed capacities (wind),
- hourly capacity factor for target year (solar),
- hourly capacity factor for target year (wind).

The Beneficiaries provided data on installed capacities and average annual capacity factor for existing wind and PV plants which are used as inputs in PLEXOS. The total wind and solar power production are the result of the resource limits embedded in the input time series.

Committed generation units, i.e. units with pre-defined commissioning date in the model are the following:

- TPP Kosova e Re (450 MW) – the planned year of commissioning is 2026,
- WPP Selaci (103.4 MW) – the planned year of commissioning is 2022,
- PS HPP Zhur (250 MW) – the planned year of commissioning is 2027.

Commissioning of TPP Kosova e Re is not envisaged in all analysed scenarios. Namely, one of the parameters for scenario definition is the commissioning of this power plant (as described in section 5.2.7).

Regarding PS HPP Zhur, this power plant is only analysed under sensitivity analysis, as described in section 5.6.1.

Candidate generation projects are defined in coordination with the Beneficiaries. All candidate generation projects are renewable energy sources, meaning that there are no conventional generation candidates. While wind, solar and biomass are modelled as generic candidates, small hydro power plants are modelled based on the existing list of planned projects (total of 63.3 MW) which is provided in Annex 2. It is assumed in the model that all small hydro projects will be commissioned by 2030, but the model chooses the exact year of commissioning for each project.

In addition to the techno-economic parameters that are usually used to model existing units, for candidate generation projects the following parameters need to be defined:

- maximum capacity of a unit,
- build cost,
- the earliest commissioning date,
- technical life,
- economic life.

Input data for generic candidate projects are provided in Table 5-1.

Table 5-1 Input parameters for generic candidate projects

Candidate	Max capacity (MW)	Build cost (EUR/kW)	The earliest COD (yr)	Technical life (yr)	Economic life (yr)	Connection (dist./trans.)
PV	10	785	1.1.2021	30	25	Distribution
Wind	50	1,205	1.1.2023	30	25	Transmission
Biomass	5	3,500	1.1.2021	30	25	Distribution

PV candidates are assumed to be small scale (up to 10 MW) and connected to the distribution network. Average annual capacity factor is 18.1 % based on the hourly solar irradiation data extracted from SolarGIS and converted to capacity factor profile by the WB. Utility scale PV candidates are analysed under a sensitivity analysis, as described in section 5.6 .

Build cost of 785 EUR/kW for small scale PV candidates refers to the first modelling year (2020), while in the later years a reduction rate is applied as described in chapter 3 .

Wind candidates are assumed to be large scale and connected to the transmission network, with average annual capacity factor of 26.8%.

For biomass candidates it is assumed that maximum installed capacity of biomass power plants by 2030 can be 20 MW. Currently there is only one application for the construction with installed capacity of 1.2 MW.

5.2.5 Fuel and CO_2 prices

Price of domestic lignite is determined based on the data received from the Beneficiaries, according to which the current lignite price is 10.5 EUR/tonne and it is expected to increase to around 12-14 EUR/tonne by 2030. Average energy content of 9.5 GJ/tonne is used to calculate lignite prices in EUR/GJ (Table 5-2), which are used as inputs to PLEXOS.

Table 5-2 Projection of lignite prices in Kosovo by 2030

Year	Price (EUR/tonne)	Price (EUR/GJ)
2020	10.5	1.1
2021	10.7	1.1
2022	11.0	1.2
2023	11.2	1.2
2024	11.4	1.2
2025	11.7	1.2
2026	11.9	1.3
2027	12.2	1.3
2028	12.5	1.3
2029	12.7	1.3
2030	13.0	1.4

For biomass, fuel price of 5 EUR/GJ is set during the entire planning horizon, based on the analyses provided in the study Development of REFiT Scheme and Financial Model for Biomass[19].

Introduction of CO_2 price in Kosovo is implemented in the model from year 2025. CO_2 price is determined based on relevant price projections available in TYNDP 2020[20] scenarios. In 2025 the CO_2 price is 23 EUR/tCO_2, based on the Best Estimate (BE) scenario. In 2030 the CO_2 price is 53 EUR/tCO_2, as in Distributed Energy (DE) scenario. Distributed Energy (DE) is a scenario compliant with the 1.5°C target of the Paris Agreement also considering the EU's climate targets for 2030. It takes a de-centralised approach to the energy transition. The projection of CO_2 prices from 2025 to 2030, based on TYNDP 2020, which were used as inputs in the PLEXOS model are presented in Table 5-3.

Table 5-3 Projection of CO_2 prices from 2025 to 2030

	2025	2026	2027	2028	2029	2030
Price (EUR/tonne CO2)	**23.0**	27.2	32.1	38.0	44.9	**53.0**

5.2.6 Simplified network model

The network model of Kosovo power system is represented in PLEXOS in a simplified manner. Entire power system is dived into seven nodes, according to the existing seven distribution areas in Kosovo (Figure 5-7). Each node aggregates electricity demand and generation of a given distribution area. Electricity demand in each node is modelled according to the methodology described in section 5.2.3. Generation capacities are allocated to nodes according to the geographical location of existing power plants and planned geographical locations of committed projects. Generic candidates are modelled separately in each of the seven nodes, e.g. there are seven small scale PV candidates, one in each node.

[19] Regulatory Support for Renewable Energy Regulatory Framework and Grid Integration; Part: Development of REFiT Scheme and Financial Model for Biomass, Fichtner Management Consulting AG, September 2016

[20] TYNDP 2020 Scenario Report, ENTSO-E, ENTSO-G, October 2019

Figure 5-7 Seven distribution areas in Kosovo

The high voltage transmission network is modelled with given limits on transmission capacity which are determined based on the existing network configuration depicted in Figure 5-8 and typical line capacities (MW) at different voltage levels.

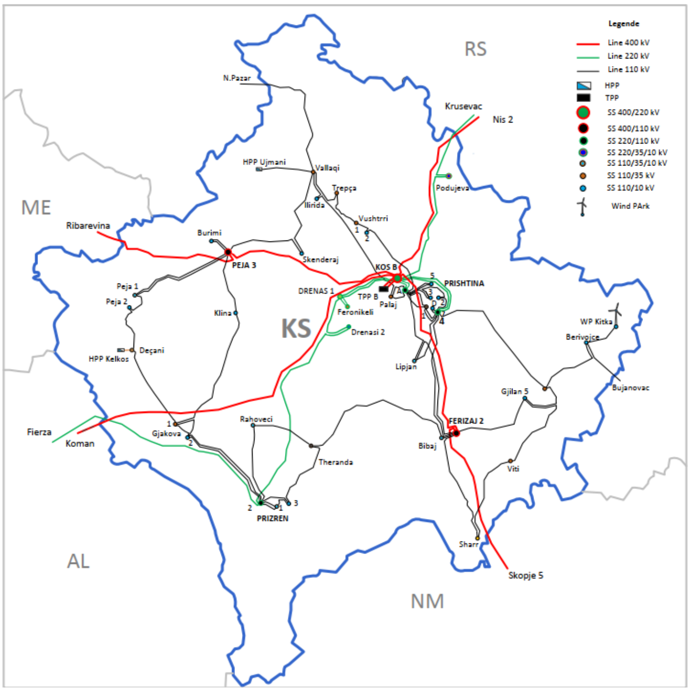

Figure 5-8 Transmission system of Kosovo in 2020

Source: KOSTT

The power lines in the model connect seven distribution areas, as illustrated in Figure 5-9.

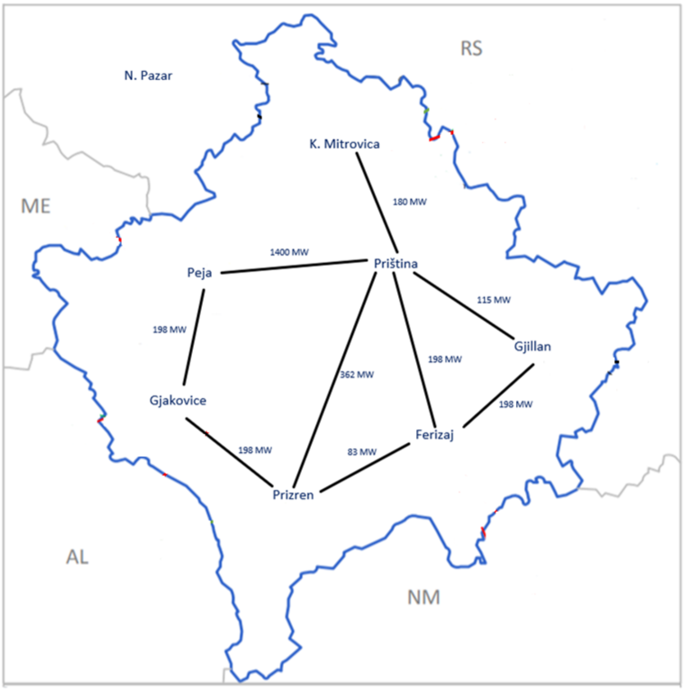

Figure 5-9 Simplified network model with corresponding line capacities in PLEXOS

Loss factors for each modelled line are determined to calculate transmission losses. Apart from power flows, limits and losses, other aspects of transmission network, like frequency and voltage variations are not analysed in the long-term model. Investments in the transmission grid are also not part of the least cost optimization planning process.

Regarding the line capacities with neighbouring countries, NTC values for both directions on each border are presented in Table 5-4. Annual net electricity import from neighbouring countries is limited to **15% of total annual electricity demand** in Kosovo, except in years 2023 and 2024 when units of TPP Kosovo B are under renewal.

Table 5-4 NTC values on borders between Kosovo and neighbouring countries (in MW)

Border	2025	2030
XK - MK	450	450
MK - XK	300	300
XK - AL	650	850
AL - XK	500	700
XK - ME	450	450
ME - XK	450	450
RS - XK	350	350
XK - RS	400	400

5.2.7 External electricity markets

Besides the power system of Kosovo, the model developed in PLEXOS includes the external electricity markets of Albania, North Macedonia, Montenegro and Serbia which are considered as spot markets. These markets are modelled as external nodes with predefined input time series of electricity prices. The prices are insensitive to fluctuations of prices in Kosovo and electricity exchange between external spot markets and Kosovo is constrained by the transmission capacities (shown in the Table 5-4). Generation capacities and load demand are not modelled for these nodes.

In order to determine average wholesale annual prices on the external electricity markets by 2030, marginal electricity prices from TYNDP 2020 were used. TYNDP 2020 contains marginal electricity price in 2025 in National Trends scenario and in three different analysed scenarios in 2030 (shown in Figure 5-10). In addition to the prices for the entire ENTSO-E area, marginal prices for each ENTSO-E country are available on the corresponding transparency platform[21].

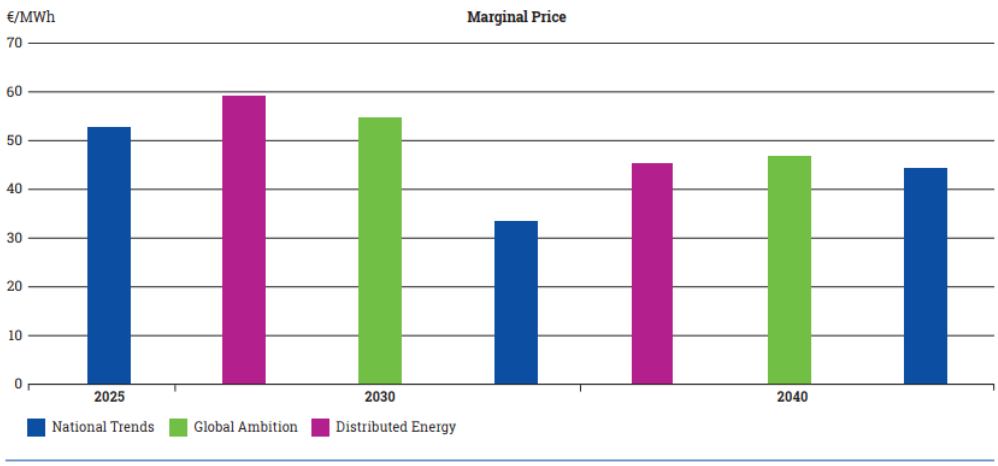

Figure 5-10 Marginal costs of electricity according to the TYNDP 2020 development scenarios

Source: TYNDP 2020 Scenario Report

The CO_2 price for the PLEXOS model under this study is determined based on the Distributed Energy scenario (as described in section 5.2.5), according to the proposal of the WB. Thus, the same scenario is used to determine annual wholesale electricity prices in neighbouring countries of Kosovo for 2030. For 2025, National Trends scenario is used, and for 2020 the prices are determined based on the TYNDP 2018 projections. Electricity prices for other years in the planning horizon were linearly interpolated.

Projections of average annual wholesale electricity prices in Albania, North Macedonia, Montenegro and Serbia used as inputs to PLEXOS model are shown in Table 5-5.

[21] https://www.entsos-tyndp2020-scenarios.eu/download-data/

Table 5-5 Wholesale electricity prices on external markets used as inputs to PLEXOS model

Year	AL	ME	MK	RS
2020	**40.5**	**38.3**	**40.5**	**38.1**
2021	42.0	39.7	42.0	39.5
2022	43.5	41.1	43.5	40.9
2023	45.1	42.6	45.1	42.4
2024	46.7	44.1	46.7	43.9
2025	**48.4**	**48.1**	**48.4**	**48.1**
2026	50.9	50.6	50.8	50.5
2027	53.4	53.1	53.4	53.1
2028	56.1	55.8	56.1	55.8
2029	59.0	58.6	58.9	58.6
2030	**61.9**	**61.3**	**61.9**	**61.9**

In addition to the projections of annual prices, hourly price time series are required to model spot markets in PLEXOS. Thus, hourly prices variation throughout the year is modelled according to the historical data on day-ahead market prices from regional power exchanges HUPX[22] and BSP Southpool[23] for the period 2017-2019. The model uses hourly profile of prices throughout the year and projected average annual prices to determine hourly prices per year during the planning horizon.

5.2.8 Battery energy storage system

In addition to the RE generation candidates, battery energy storage system (BESS) candidates are also modelled in PLEXOS. The following input data for batteries were received from the WB:

- technology: Lithium ion
- storage capacity (MWh): to be optimized through modelling
- peak power (MW): 1/3 of storage capacity
- capital cost: $300,000 /MWh
- grid connection cost: $5,000/MW
- annual O&M costs: 1.5% of total capex
- useful life: 20 years
- augmentation cost: 20% of storage capacity every five years at a cost of $150,000/MWh
- round-trip efficiency: 90%.

[22] Hungarian Power Exchange, https://hupx.hu/en/
[23] BSP Energy Exchange, https://www.bsp-southpool.com/home.html

Based on the received data, the input parameters for batteries available in PLEXOS are determined as follows:

- max power: 1 MW
- storage capacity (MWh): 3 MWh
- capital cost: 765 EUR/kW[24]
- grid connection cost: 4.25 EUR/kW[25]
- fixed annual O&M costs: 26.8 EUR/kW/yr[26]
- technical life: 20 years
- round-trip efficiency: 90%.

Battery candidates are implemented in all scenarios with the year 2023 as the earliest possible year in which they can be built. Each out of the seven nodes in the model has a generic BESS candidate.

5.2.9 Other constraints and assumptions

System reserve requirements

System reserve requirements are imposed on each individual system; firm domestic capacity should be available to cover peak load. Firm capacity represents the portion of the total installed capacity considered firm for the purposes of calculating capacity reserve margin. If a unit is out for renewal, then its installed capacity is not considered for firm capacity calculation. Firm capacity is set to:

- 100% for thermal power plants, storage hydro power plants and BESS
- 25% for run-off-river hydro power plants,
- 10% for wind power plants, and
- 0% for solar power plants.

Minimum system reserve margin is set to 15% from 2025 onwards.

RE potential

Technical wind and solar potential determined under Sub-task 1.3 is used in the PLEXOS model to constrain the maximum generation capacity that can be built in wind and solar power plants. A detailed analysis for realizable technical wind potential is provided in section 2.2 based on which the maximum installed capacity of wind power plants in each of the seven distribution areas is limited in PLEXOS as shown in Table 5-6.

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[24] Based on the data received from the WB (300,000 $/MWh and conversion factor 1 $ =0.85 €)
[25] Based on the data received from the WB (5,000 $/MW and conversion factor 1 $ =0.85 €)
[26] Based on the data received from the WB (1.5% of total CAPEX + augmentation cost)

Table 5-6 Maximum technical wind power potential – shares of potential over Kosovo electricity distributions

Distribution area	MW
Prishtina	651
Ferizaj	64
Mitrovica	501
Peja	121
Gjakova	99
Prizren	122
Gjilan	222
Total	**1,780**

Regarding the solar power plants, maximum installed capacity in Kosovo is constrained in PLEXOS to 3,600 MW, according to the analysis provided in section 2.1 . Constraints implemented per distribution area are determined based on the analysis done under Task 2, i.e. based on the **distribution area allocation factors** for solar technology presented in Table 5-7. These factors represent acceptable ranges of the total installed solar capacity in Kosovo for each distribution area, e.g. the distribution area of Prishtina can accommodate between 10-30% of the total country-level PV capacity [27].

Table 5-7 Distribution area allocation factors for solar capacity from Task 2 used as input constraints in PLEXOS

	PV Allocation Factor		
Distribution Area	Average	Min	Max
Prishtina	19.2%	9.6%	28.8%
Ferizaj	7.3%	5.0%	15.0%
Mitrovica	11.2%	5.6%	16.7%
Peja	20.9%	10.5%	31.4%
Gjakova	28.8%	14.4%	43.3%
Prizreni	5.2%	5.0%	15.0%
Gjilani	7.3%	5.0%	15.0%

Cost of local environmental pollution

During the inception phase of the project, it was agreed with the Beneficiaries and the WB to add the cost of local environmental pollution, shown in Table 5-8, to the total cost of

[27] Distribution area allocation factors are determined taking into account non-technical factors considered like land availability/suitability (e.g. excluding urban areas, forests, national parks etc.), expressed investor interest according to the existing applications and interdependencies between the different RES technologies (installation of large PV plants not favoured in areas with a high hydro potential, where small HPP will mostly occupy available network hosting capacity).

supply for each scenario analysed. The costs will be calculated based on generation per each unit of TPP Kosovo (from the PLEXOS results) and local environmental costs (EUR/kWh) in the table. This means that these costs will be calculated based on the results from PLEXOS, but not included in the optimization process in PLEXOS. The resulting total supply costs will be presented both inclusive and exclusive of local environmental cost.

Table 5-8 Estimated Local Environmental Costs for Kosovo A and Kosovo B[28]

Coal Power Plants	Environmental Cost (EUR/kWh)
Kosovo A	0.06712
Kosovo B pre-rehabilitation	0.06712
Kosovo B post-rehabilitation	0.02607
New 450 MW ultra-supercritical (USC) plant	0.00854

5.3 Scenarios definition

In the inception phase of the project a total of nine supply-demand scenarios were defined for analysis in PLEXOS (Table 5-9). The proposed scenarios differ in the following assumptions:

- commissioning of TPP Kosova e Re,
- targets on share of RE generation in Kosovo's electricity demand.

Table 5-9 Set of possible scenarios for analysis in PLEXOS defined in the inception phase of the project

Scenario name	Scenario parameters		
	Kosovo electricity demand	TPP Kosova e Re	RES-E target
BaU	Base	In operation	Without target
S1	Base	In operation	Base
S2	High	In operation	Base
S3	Base	Not in operation	Base
S4	High	Not in operation	Base
S5	Base	In operation	High
S6	High	In operation	High
S7	Base	Not in operation	High
S8	High	Not in operation	High

[28] Source: World Bank based on "External Costs of Power Production in South Eastern Europe," Antonis Papaemmanouil; and the World Bank Project Appraisal Document for Lignite Power Technical Assistance Project (2016)

According to the Energy Strategy, construction of TPP Kosova e Re is envisaged with 2023 as the target year for commissioning. It is stated in the Energy Strategy that the commissioning of TPP Kosova e Re will enable an intensive integration of RES generation and will encourage regional market integration. Until today, realization of this project still hasn't started, and it is unrealistic that the new unit in TPP Kosova will be in operation in 2023. Furthermore, in March 2020 company Contour Global announced that it has suspended plans for the realization of the project TPP Kosova e Re. However, this decision and complete suspension of TPP Kosova e Re project is not yet incorporated in Kosovo's strategic documents. Thus, considering the uncertainty in realization of this project, the Consultant proposed to analyse the following two supply scenarios:

- with TPP Kosova e Re in operation (not before 2026),
- without TPP Kosova e Re.

Regarding the RES electricity target, i.e. share of RE generation in the total electricity demand of Kosovo in 2030, it was initially proposed to analyse two possible targets, Base and High. However, based on later discussions with the WB and availability of references to determine possible targets, it was decided to analyse just one possible RES-E target, more specifically the High one of 33% (as described in section 5.2.7). The reduction of number of RES-E targets led to the reduction of the quantity of the proposed scenarios to be analysed from nine to five. Additionally, given the uncertainty of the TPP Kosova e Re project realization, it was determined to analyse one more scenario, i.e. the BaU scenario without TPP Kosova e Re in operation. The final set of scenarios to be analysed in PLEXOS is shown in the Table 5-10.

Table 5-10 Final set of scenarios for analysis in PLEXOS

Scenario name	Scenario parameters		
	Kosovo electricity demand	*TPP Kosova e Re*	*RES-E target*
BaU	Base	In operation	Without target
BaU without TPP Kosova e Re	Base	Not in operation	Without target
~~S1~~	~~Base~~	~~In operation~~	~~Base~~
~~S2~~	~~High~~	~~In operation~~	~~Base~~
~~S3~~	~~Base~~	~~Not in operation~~	~~Base~~
~~S4~~	~~High~~	~~Not in operation~~	~~Base~~
S5	Base	In operation	33%
S6	High	In operation	33%
S7	Base	Not in operation	33%
S8	High	Not in operation	33%

For easier differentiation of scenario assumptions, the scenarios are named as follows:

- 'BaU' scenario,
- 'BaU without TPP Kosova e Re' scenario,
- 'Base with TPP Kosova e Re' scenario (S5),

- 'High with TPP Kosova e Re' scenario (S6),
- 'Base without TPP Kosova e Re' scenario (S7),
- 'High without TPP Kosova e Re' scenario (S8).

Optimization results for each scenario are presented in the following section.

5.4 Optimization results

In the following sections, results for generation expansion of Kosovo's power system are analyzed based on the outputs of the **long-term system optimization** process performed using PLEXOS. The results of the optimization process give detailed outputs such as generation investment plan, total installed capacity and firm capacity in each scenario.

All scenarios are also optimized in PLEXOS on a **medium and short-term level** using hourly resolution for simulations. Short-term optimization provides hourly-level results for electricity generation and cross-border exchange, which give a more precise calculation of RES-E share in electricity demand.

In each scenario, **there is a cap in the model on annual level for new builds of solar and wind power plants (50 MW each), as well as for batteries (50 MW)**. Prior to setting this cap, several iterations were made without any cap, which resulted in unrealistic builds on annual level, e.g. more than 500 MW of wind power plants or solar power plants built in one year. It is common to put such limitation on annual level in the model to avoid unrealistic builds which could not be technically feasible over the short time horizon considering the existing trends, technical and administrative/procedural issues of the analyzed country. Thus, 50 MW for wind power plants is determined based on the size of the planned wind projects provided by the Beneficiaries. The same cap was set to solar power plants, considering current trends and the fact that PV candidates in the model are distribution level, with unit size of 10 MW.

Additionally, a cap on annual builds of biomass is set to 5 MW. In total, due to currently very low interest for investments in biomass/biogas projects, 20 MW is determined in the inception phase of the project as the maximum capacity of biomass power plants that can be built over the planning horizon.

5.4.1 'BaU' scenario

In **BaU scenario** the projected electricity demand in Kosovo is set according to the Base demand scenario. Commissioning of TPP Kosova e Re is envisaged in 2026 and there is no target for RES-E share, i.e. the electricity generation from RES compared to the projected demand is the result of optimization in PLEXOS.

Generation expansion

To meet the growing demand, a total of **1,936.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030) in BaU scenario. The sequence of newly installed capacities is shown in Table 5-11.

Table 5-11 Generation investment plan in BaU scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP		50	50	50	50	50	50	50	50	50	50	**500**
WPP			103.4	50	50	50	50	50	50	50	50	**503.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**81.1**	**168.4**	**171.7**	**155**	**150**	**600**	**150**	**150**	**150**	**150**	**1936.7**

In 2020, the model chooses to build 10.5 MW of small HPPs, followed by another 26.1 MW in 2021. By 2023, all small hydro candidates (63.3 MW) are commissioned. By 2024, 20 MW of biomass candidates are commissioned, which is the maximum that can be built over the planning horizon. From 2021, 50 MW of solar power plants are selected to enter into operation each year until the end of the planning horizon, resulting in 500 MW of new PV plants by 2030. In 2022 WPP Selaci (103.4 MW) is commissioned, followed by 50 MW of new wind power plants in each year from 2023 until the end of planning horizon. TPP Kosova e Re is commissioned in 2026. Model also chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Based on the generation investment plan, existing generation capacities in Kosovo and planned decommissioning of TPP Kosovo A, the total installed capacities per technology type are presented in Figure 5-11. Lower lignite capacity in 2023 and 2024 is due to renewal of the two units of TPP Kosovo B.

Total installed capacity in 2030 is 2,688.9 MW (including batteries), out of which 46% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in total capacity, 20% and 19% respectively, which corresponds to 537.2 MW of wind power plants and 510 MW of PV plants. Detailed data on installed capacity per technology type are provided in ANNEX 3.

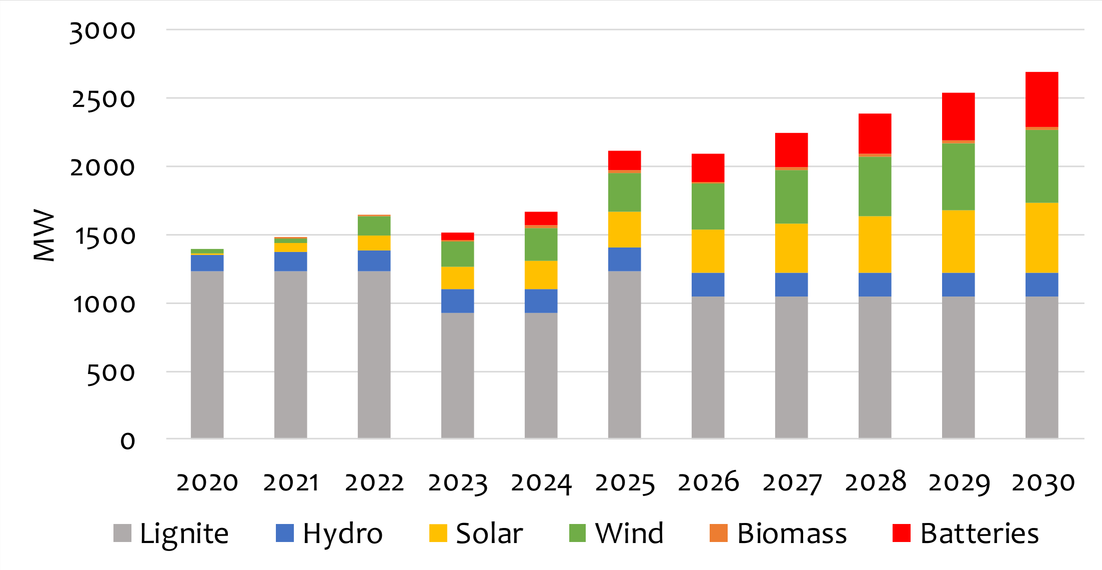

Figure 5-11 Total installed capacity per technology in BaU scenario

Figure 5-12 provides data about firm capacity in Kosovo over the planning horizon, together with peak load in each year. It can be seen that only in the year 2025 firm domestic capacity can cover the peak load. In all other years, capacity reserve margin is negative.

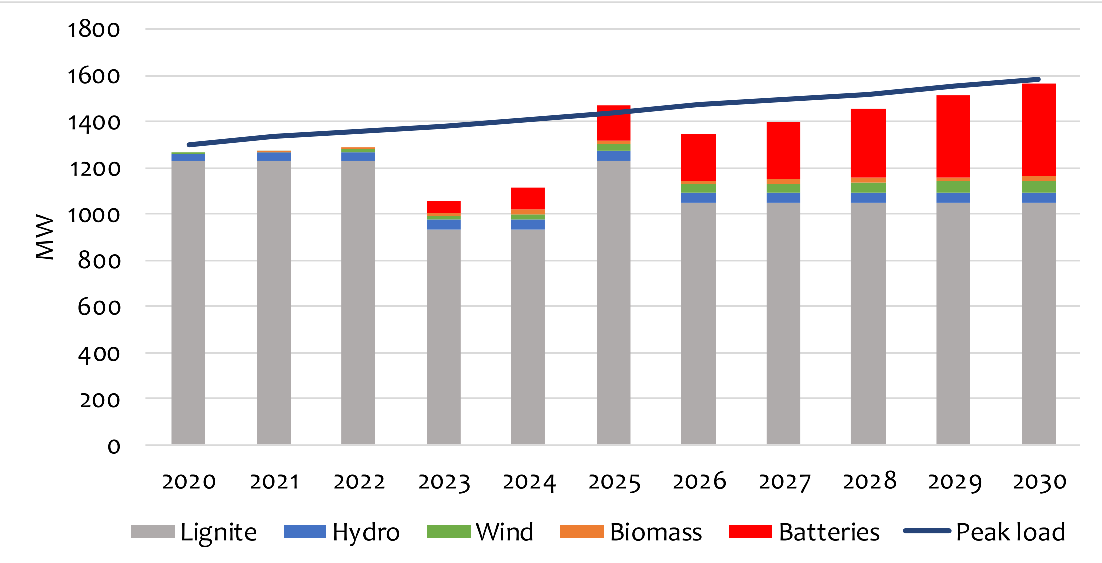

Figure 5-12 Firm capacity per technology in BaU scenario

Electricity balance and RES-E share

The previous section showed the optimal generation expansion plan in BaU scenario obtained by long-term optimization in PLEXOS. For more precise results on electricity generation and electricity imports and exports, simulations were also carried out on **medium and short-term level using hourly resolution**.

Electricity generation by technology type is shown in Figure 5-13, together with annual imports, exports and demand in BaU scenario.

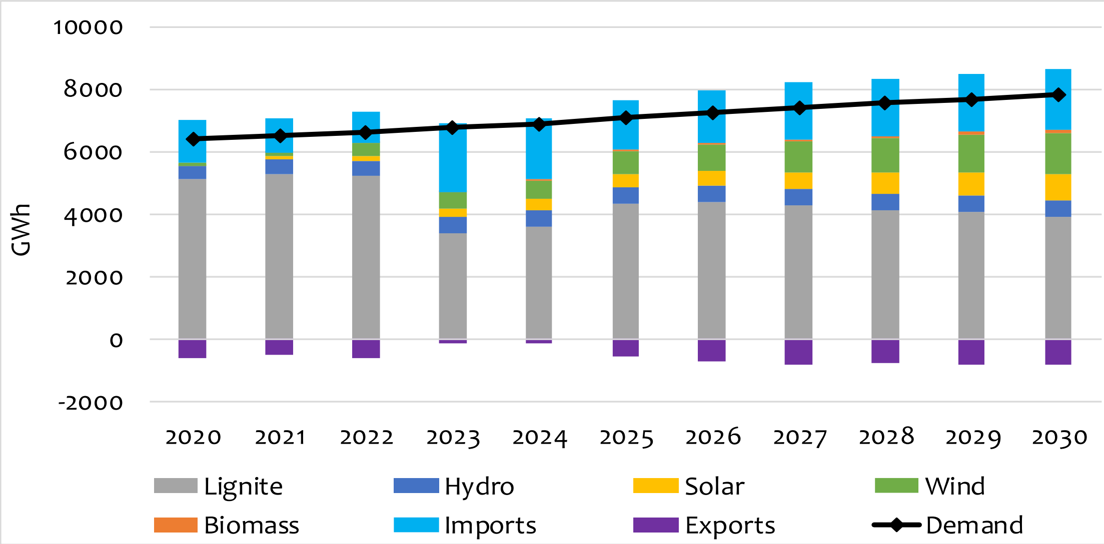

Figure 5-13 Electricity generation by technology in BaU scenario

It can be observed that the total electricity generation increases from 5.6 TWh in 2020 to around 6.7 TWh in 2030. In all years, except for 2023 and 2024, net interchange (imports-exports) is lower than 15% of total electricity demand, which is set as a constraint in the model. In the respective two years the two units of TPP Kosovo B are under renewal, so imports are significantly higher, amounting to about 30% of the total annual demand. Batteries balance the system operation from 2023 on and the net load of batteries is accounted for in the presented demand.

Generation shares per technology are depicted in the following figure. It can be observed that the initial high share of generation from lignite power plants is decreased due to increase of the share of RE plants. In 2030, total generation from wind and solar power plants amounts to 2.1 TWh.

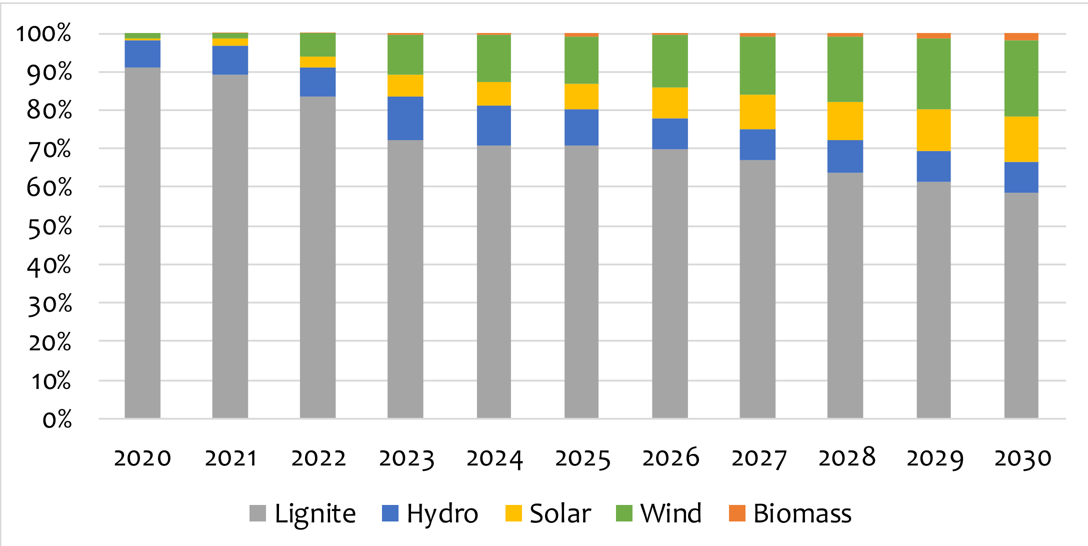

Figure 5-14 Generation shares per technology in BaU scenario

Renewable energy generation share in the total demand over the entire planning horizon is depicted in Figure 5-15. With TPP Kosova e Re in operation from 2026 and limited net electricity import to 15%, generation from the existing and newly built RE capacities amounts to **36.3%** of the projected electricity demand in Base scenario in 2030.

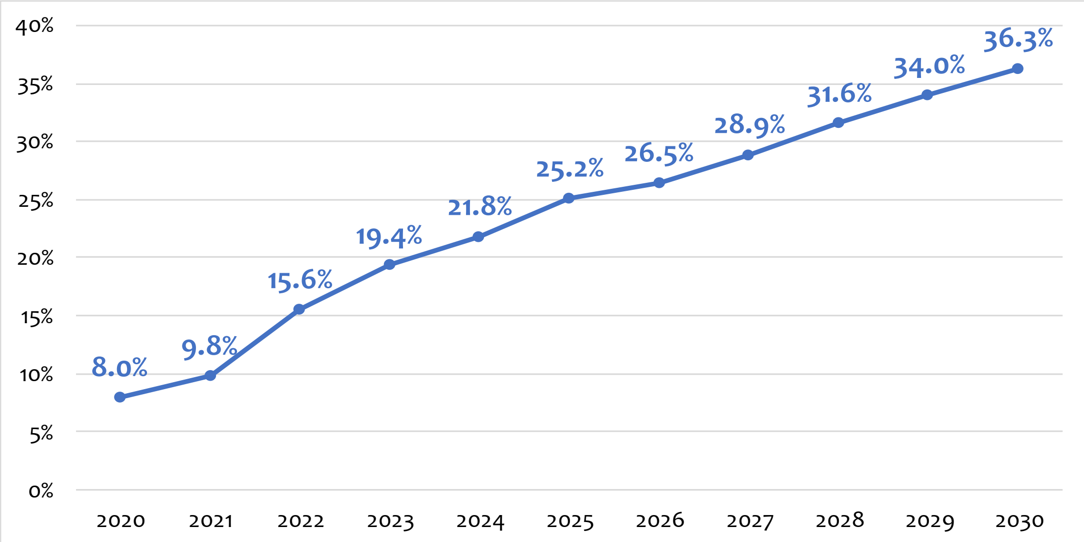

Figure 5-15 RES-E generation share in electricity demand in BaU scenario

The realized RES-E share in 2030 is the result of optimization, i.e. no constraint is set to this share in order to allow the model to completely optimize generation expansion, under all other model assumptions.

5.4.2 'BaU without TPP Kosova e Re' scenario

In **BaU without TPP Kosova e Re scenario,** the projected electricity demand in Kosovo is set according to the Base demand scenario, realization of TPP Kosova e Re project is not envisaged during the entire planning horizon and there is no target for RES-E share, i.e. the electricity generation from RE compared to the projected demand is the result of optimization in PLEXOS.

Generation expansion

To meet the growing demand, a total of **1,486.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030). The sequence of newly installed capacities is shown in Table 5-12.

Table 5-12 Generation investment plan in BaU without TPP Kosova e Re scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP		50	50	50	50	50	50	50	50	50	50	**500**
WPP			103.4	50	50	50	50	50	50	50	50	**503.4**
Batteries				50	50	50	50	50	50	50	50	**400**

TOTAL	**10.5**	**81.1**	**168.4**	**171.7**	**155**	**150**	**150**	**150**	**150**	**150**	**150**	**1486.7**

By 2026, generation investment plan is the same as in BaU scenario. In this scenario there is no TPP Kosova e Re so the new capacity in 2026 refers to solar and wind power plants, and also batteries. After 2026, investments are the same as in BaU scenario, resulting in 503.4 MW of new wind power plants and 500 MW of new solar power plants in 2030. The model chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Total installed capacities per technology type are presented in the following figure. Detailed data on installed capacity per technology type are provided in ANNEX 3.

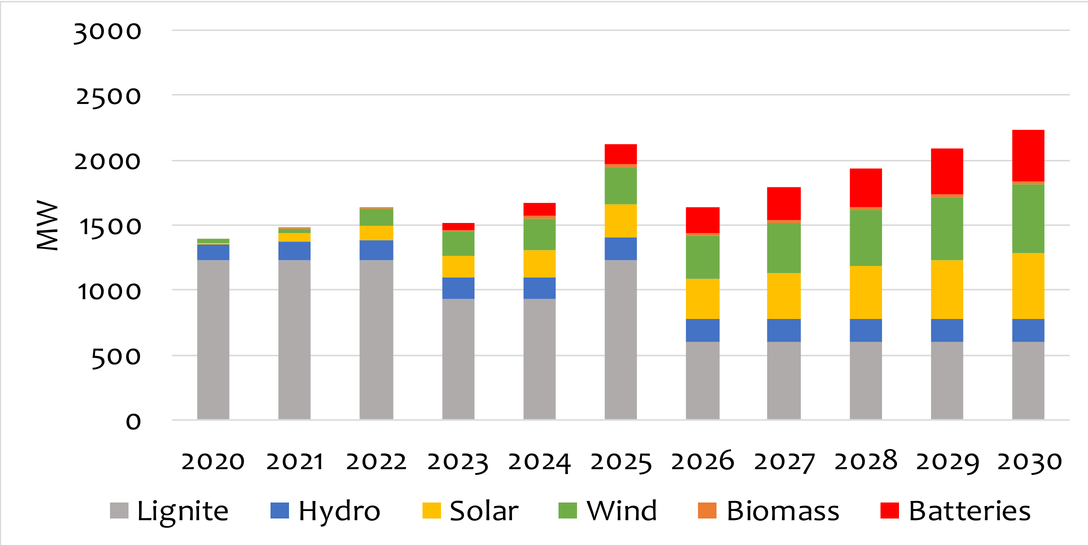

Figure 5-16 Total installed capacity per technology in BaU without TPP Kosova e Re scenario

Total installed capacity in 2030 is 2,238.9 MW (including batteries), out of which 55% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in the total capacity, 24% and 23% respectively, which corresponds to 537.2 MW of wind power plants and 510 MW of PV plants.

Firm capacity per technology is presented in Figure 5-17. From 2026 firm capacity is significantly lower compared to the BaU scenario, because there are no new thermal capacities built after decommissioning of TPP Kosovo A.

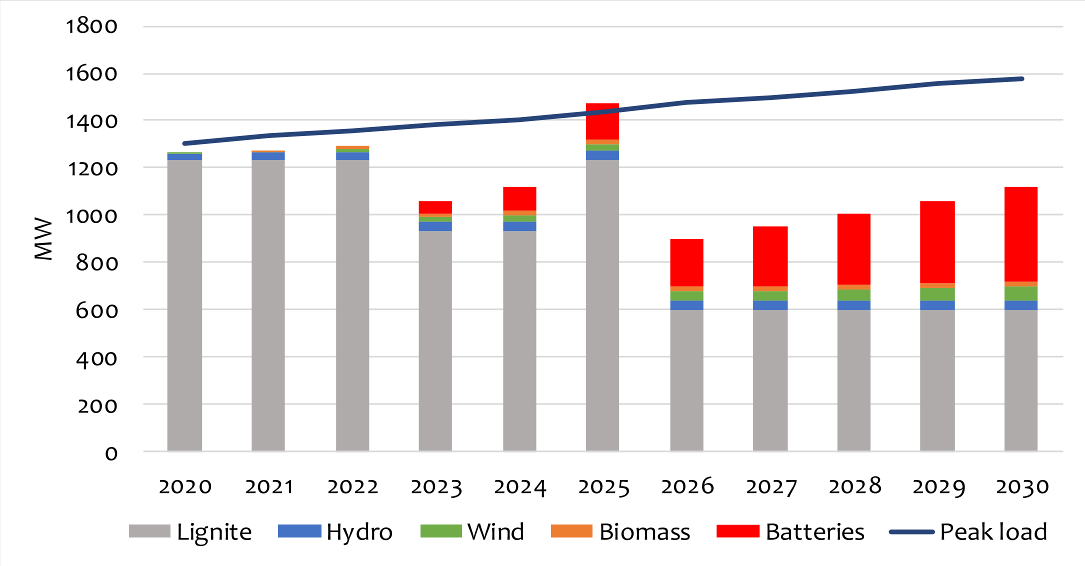

Figure 5-17 Firm capacity by technology in BaU without TPP Kosova e Re scenario

Electricity balance and RES-E share

As already described in section 5.4.1, the optimal generation expansion plan in all scenarios is obtained by long-term optimization in PLEXOS. Additionally, simulations were also carried out on a medium and short-term level using hourly resolution.

Unlike long-term optimization, medium and short-term optimization take into account planned and forced maintenances which are modeled for thermal units based on MOR and FOR, as described in section 5.2.4. Considering that, the total generation of thermal power plants is higher in long-term optimization compared to the short-term optimization. Thus, short-term optimization results for electricity generation, imports and exports in BaU without Kosovo e Re scenario showed lower total generation compared to the long-term optimization, due to the maintenances and unplanned outages of TPP Kosovo A and B. Given the constraint on 15% of net electricity import, from 2026 when TPP Kosovo A is decommissioned, certain amount of unserved energy appears in each year until 2030. In order to obtain short-term optimization results without unserved energy, annual net import constraint was relaxed starting from the year 2026 and it amounted to around 25%. The results are presented below.

Electricity generation per technology type is shown in Figure 5-18, together with annual imports, exports and total demand. Total electricity generation increases from 5.6 TWh in 2020 to around 5.9 TWh in 2030. From 2026 on, the two units of TPP Kosovo B are the only thermal units in operation, which affects the increase of net imports to around 25% compared to the projected annual demand. As in BaU scenario, batteries balance the system operation from 2023 and the net load of batteries is accounted for in the presented demand.

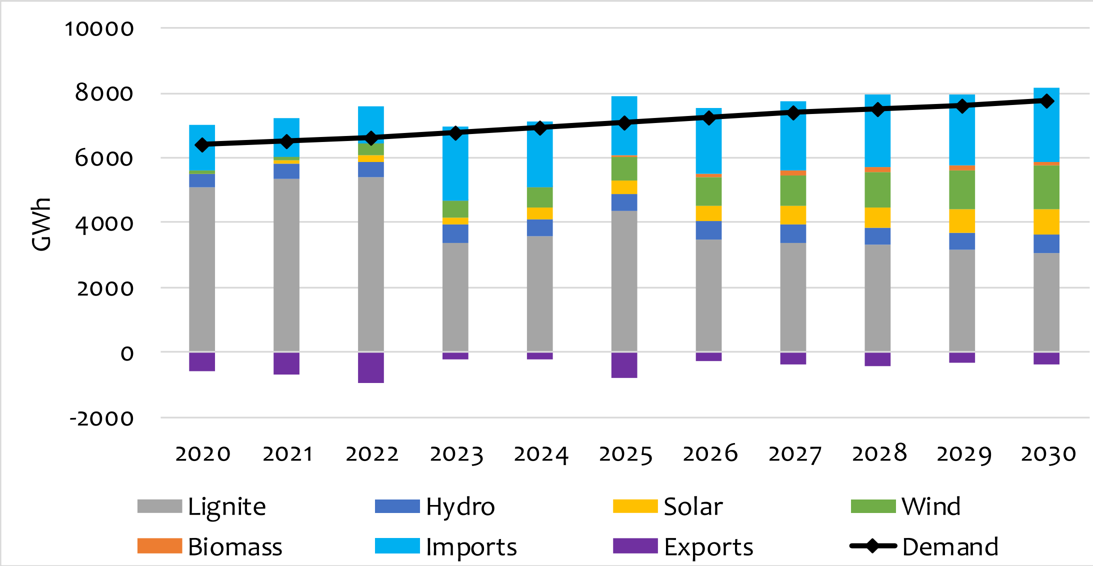

Figure 5-18 Electricity generation per technology in BaU without TPP Kosova e Re scenario

Generation shares per technology are depicted in the following figure. It can be observed how the initial high share of generation from lignite power plants (higher than 90%) in 2020 is decreased to 52% in 2030 due to the increase of the share of RE plants. Generation from existing and new wind power plants in 2030 amounts to 1.3 TWh, while generation from all solar power plants amounts to 807 GWh.

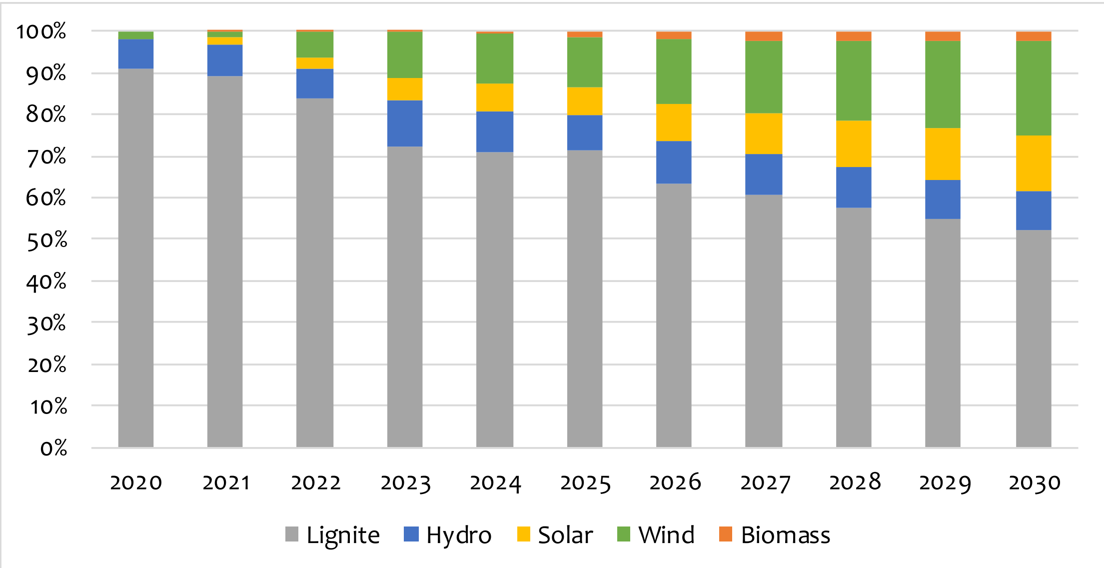

Figure 5-19 Generation shares per technology in BaU without TPP Kosova e Re scenario

Renewable energy generation share in the total demand over the entire planning horizon is depicted in Figure 5-20. Without TPP Kosova e Re project and with net electricity import limited to 15% before 2026 and 25% from 2026 onwards, generation from the existing and newly built RE capacities amounts to 36.6% of the projected electricity demand in Base scenario in 2030. It can be observed that RE generation share in total demand in 2030 in BaU without TPP Kosova e Re is somewhat higher compared to BaU scenario. In general, higher shares are realized earlier in the planning horizon of BaU without TPP Kosova e Re scenario.

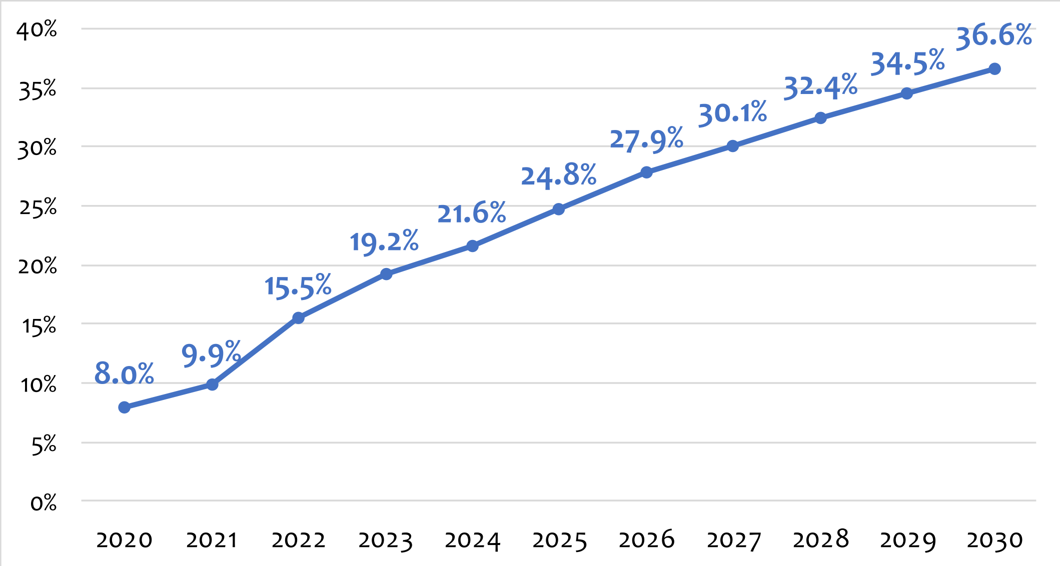

Figure 5-20 RES-E generation share in electricity demand in BaU without Kosovo e Re scenario

5.4.3 'Base with TPP Kosova e Re' scenario (S5)

In **Base with TPP Kosova e Re scenario** the projected electricity demand in Kosovo is set according to the Base demand scenario, commissioning of TPP Kosova e Re is envisaged in 2026 and **the RES-E target is set to 33% in 2030**.

Generation expansion

To meet the growing demand, a total of **1,826.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030) in Base with TPP Kosova e Re scenario. The sequence of newly installed capacities is shown in Table 5-13.

Table 5-13 Generation investment plan in Base with TPP Kosova e Re scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP			40	50	50	50	50	50	50	50	50	**440**
WPP			103.4	50	50	50	50	50	50	50		**453.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**31.1**	**158.4**	**171.7**	**155**	**150**	**600**	**150**	**150**	**150**	**100**	**1826.7**

In 2020 the model chooses to build 10.5 MW of small HPPs, followed by another 26.1 MW in 2021. By 2023 all small hydro candidates (63.3 MW) are commissioned, which is the same as in BaU scenario. All biomass candidates are commissioned by 2024. New solar power plants are built starting from 2022 and resulting with a total of 440 MW in new capacity by

2030. In 2022 WPP Selaci (103.4 MW) is commissioned, followed by 50 MW of new wind power plants in each year from 2023 until 2029, which gives a total of 453.4 MW of new wind power plants by 2030. TPP Kosova e Re is commissioned in 2026. The model also chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Based on the presented generation investment plan, existing generation capacities and planned decommissioning of TPP Kosovo A, total installed capacities by technology type are presented in Figure 5-21.

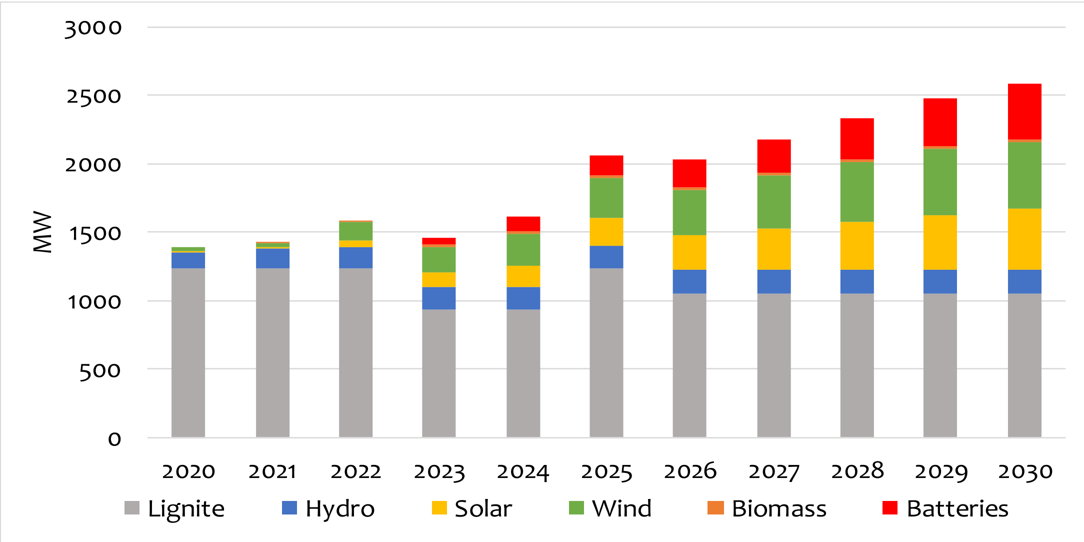

Figure 5-21 Total installed capacity by technology in Base with TPP Kosova e Re scenario

Total installed capacity in 2030 is 2,578.9 MW (including batteries), out of which 44% refers to renewable energy sources. Wind power plants capacity (487.2 MW) corresponds to the share of 19% in total capacity, which is higher compared to the share of solar power plants (17%).

The following figure provides data about firm capacity in Kosovo over the planning horizon together with peak load in each year in Base with TPP Kosova e Re scenario.

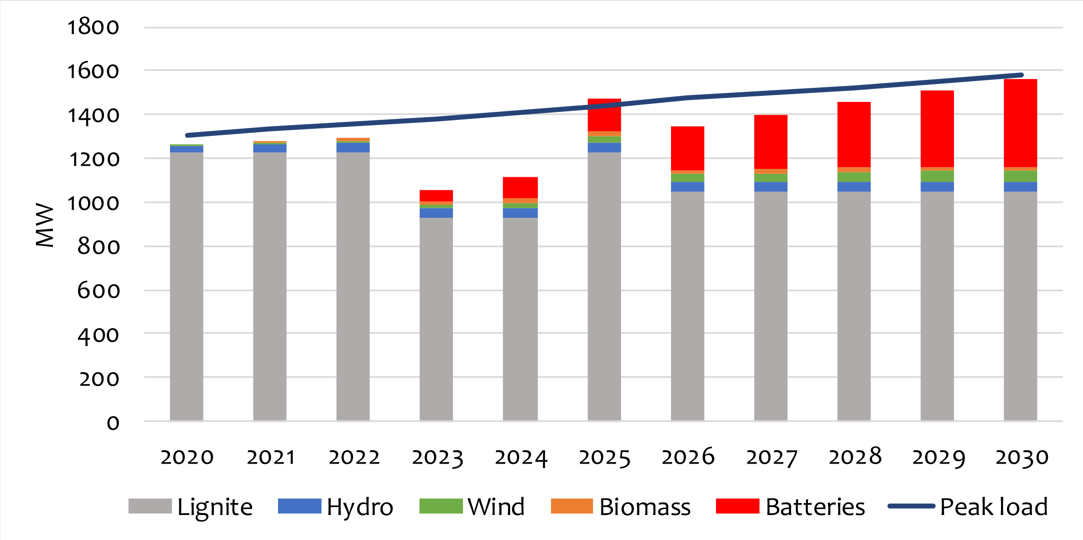

Figure 5-22 Firm capacity by technology in Base with TPP Kosova e Re scenario

Electricity balance and RES-E share

Electricity generation per technology type is shown in Figure 5-23, together with annual imports, exports and total demand in Base with TPP Kosova e Re scenario. Total electricity generation increases from 5.6 TWh in 2020 to around 6.7 TWh in 2030. In 2023 and 2024 net imports are 32% and 28% compared to the total annual demand. In other years the value of net interchange is lower or equal to 15%.

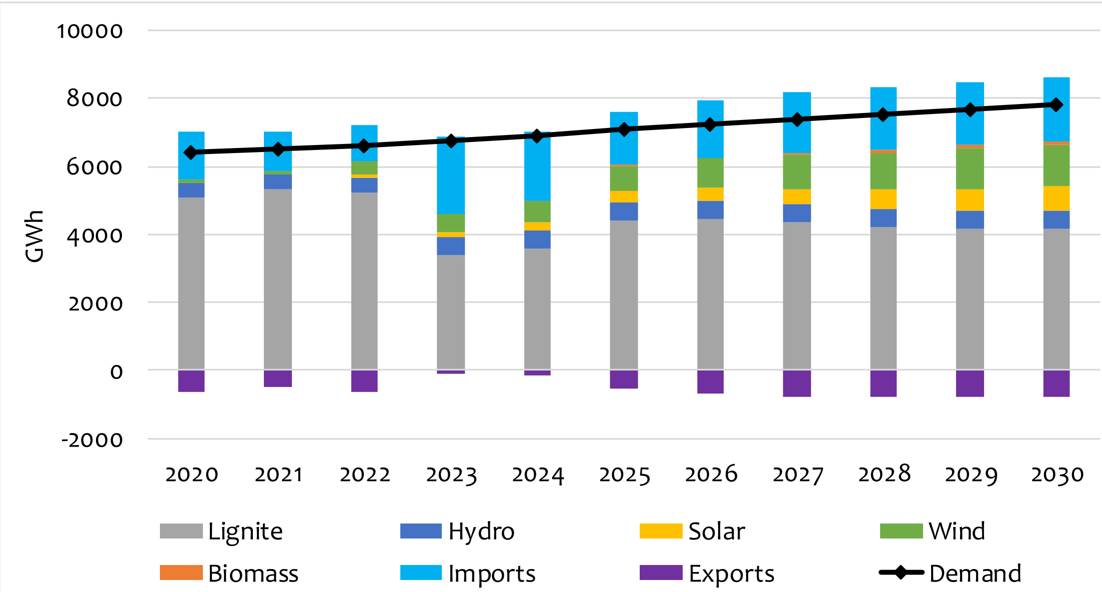

Figure 5-23 Electricity generation per technology in Base with TPP Kosova e Re scenario

Generation shares per technology are depicted in the following figure. As in the case of BaU scenario, initial high share of generation from lignite power plants is decreased due to increase of RES plants share. In 2030 wind power plants have a share of 18% in the total generation in Kosovo, solar power plants 11%.

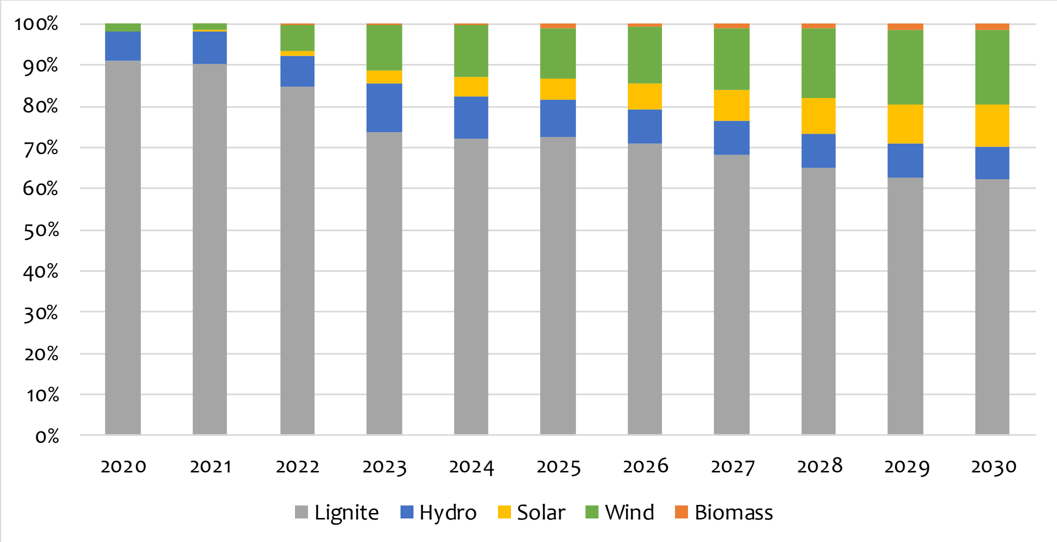

Figure 5-24 Generation shares per technology in Base with TPP Kosova e Re scenario

Renewable energy generation share in the total demand over the entire planning horizon is depicted in Figure 5-25. With TPP Kosova e Re in operation from 2026 and limited net electricity import to 15%, generation from the existing and newly built RE capacities amounts to 33% of the projected electricity demand in Base scenario in 2030. The realized RES-E share in 2030 is the result of optimization, with the imposed constraint on RES-E target in 2030, meaning that the model optimizes solution with the objective to achieve the set constraint/target at minimum system costs.

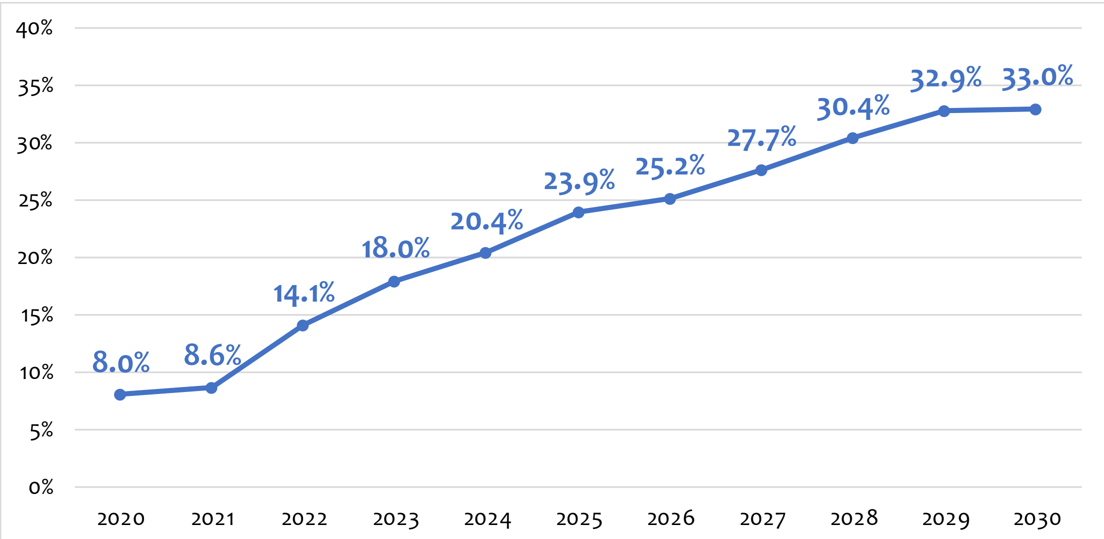

Figure 5-25 RES-E generation share in electricity demand in Base with TPP Kosova e Re scenario

5.4.4 'High with TPP Kosova e Re' scenario (S6)

In **High with TPP Kosova e Re scenario** the projected electricity demand in Kosovo is set according to the High demand scenario, commissioning of TPP Kosova e Re is envisaged in 2026 and the RES-E target is set **to 33% in 2030**.

Generation expansion

To meet the growing demand, a total of **1,866.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030) in High with TPP Kosova e Re scenario. The sequence of newly installed capacities is shown in Table 5-14.

Table 5-14 Generation investment plan in High with TPP Kosova e Re scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP			30	50	50	50	50	50	50	50	50	**430**
WPP			103.4	50	50	50	50	50	50	50	50	**503.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**31.1**	**148.4**	**171.7**	**155**	**150**	**600**	**150**	**150**	**150**	**150**	**1866.7**

As in all previously described scenarios, by the end of 2023 the model chooses to build all small hydro candidates (63.3 MW). All biomass candidates are commissioned by 2024. In 2022 30 MW of solar power plants are selected to enter into operation, followed by 50 MW in each of the following years in the planning horizon. From 2022 to 2030 a total of 430 MW of new solar power plants is built. In 2022 WPP Selaci (103.4 MW) is commissioned, followed by 50 MW of new wind power plants in each year from 2023 until the end of the planning horizon. TPP Kosova e Re is commissioned in 2026. Model chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Based on the presented generation investment plan, existing generation capacities and planned decommissioning of TPP Kosovo A, total installed capacities per technology type are presented in Figure 5-26.

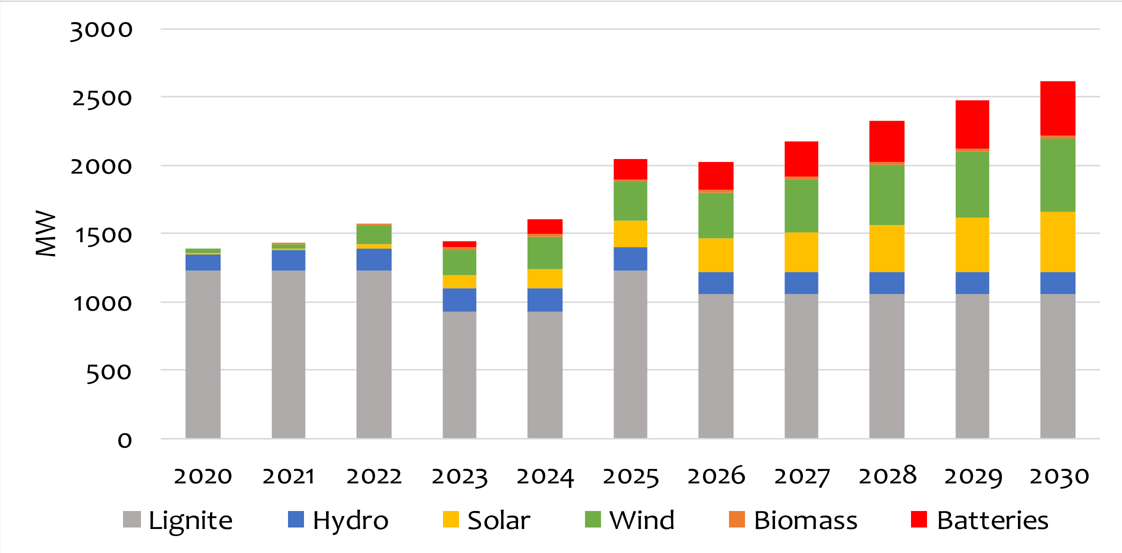

Figure 5-26 Total installed capacity per technology in High with TPP Kosova e Re scenario

Total installed capacity in 2030 is 2,618.9 MW (including batteries), out of which 45% refers to renewable energy sources. Wind power plants with total installed capacity of 537.2 MW have a share of 20% in total capacity, while 440 MW of solar power plants represent 17% of the total capacity in 2030.

The following figure provides data about firm capacity in Kosovo over the planning horizon together with peak load in each year.

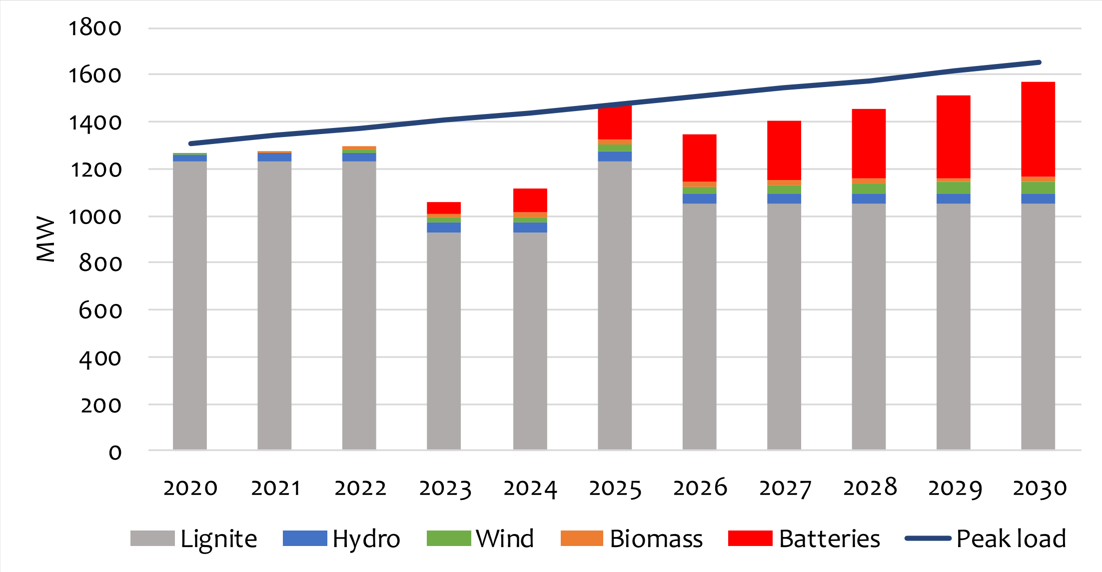

Figure 5-27 Firm capacity per technology in High with TPP Kosova e Re scenario

Electricity balance and RES-E share

Electricity generation per technology type is shown in Figure 5-28, together with annual imports, exports and total demand in High with TPP Kosova e Re scenario. Total electricity generation increases from 5.6 TWh in 2020 to around 7 TWh in 2030. In 2030 total electricity demand is slightly higher than 8 TWh, according to High demand scenario. Batteries are in operation form 2023 and net load of batteries is also included in presented demand in Figure 5-28. In 2023 and 2024 net interchange is 34% and 30% compared to the total demand, while in all other years of the planning horizon net interchange is lower or equal to 15% of demand.

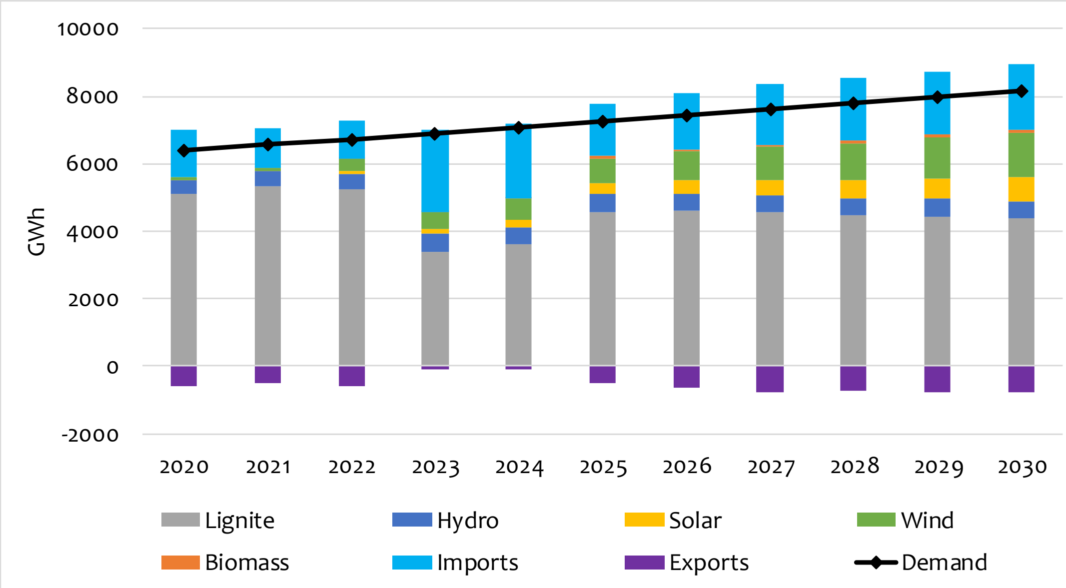

Figure 5-28 Electricity generation per technology in High with TPP Kosova e Re scenario

Generation shares per technologies are depicted in the following figure.

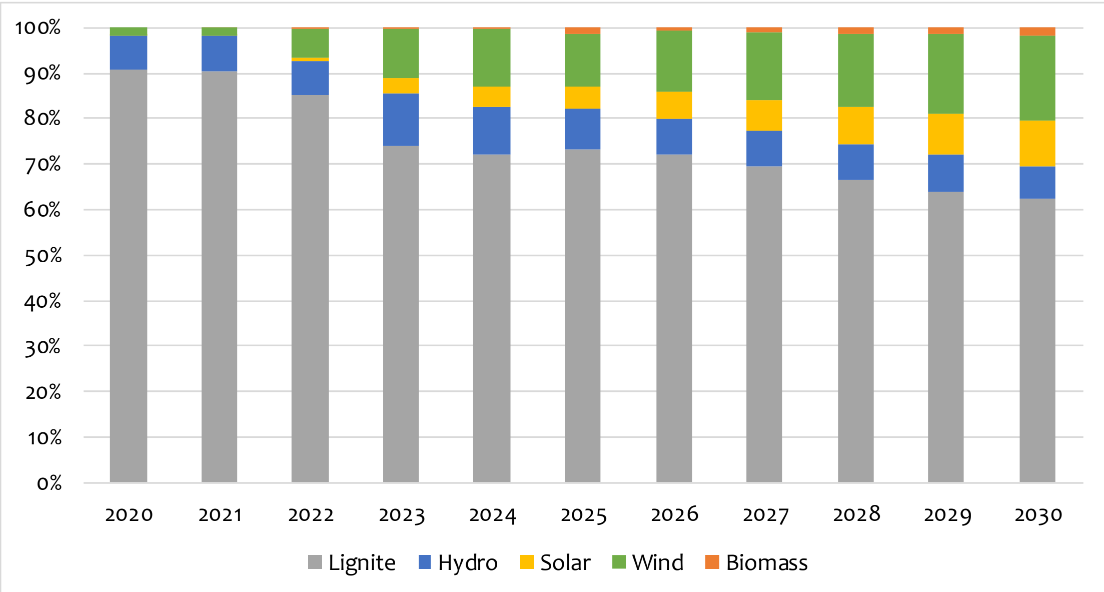

Figure 5-29 Generation shares per technology in High with TPP Kosova e Re scenario

Renewable energy generation share in the total demand over the entire planning horizon is depicted in Figure 5-30.

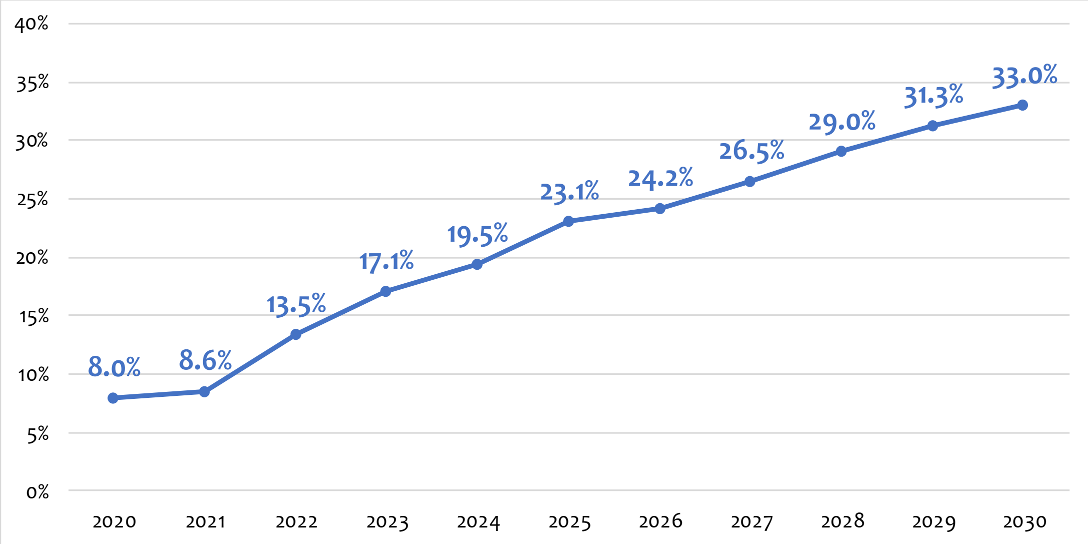

Figure 5-30 RES-E generation share in electricity demand in High with TPP Kosova e Re scenario

5.4.5 'Base without TPP Kosova e Re' scenario (S7)

In **Base without TPP Kosova e Re scenario** projected electricity demand in Kosovo is according to the Base demand scenario, realization of TPP Kosova e Re project is not envisaged during the entire planning horizon and the RES-E target is set **to 33% in 2030**.

Generation expansion

To meet the growing demand, a total of **1,406.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030) in Base without TPP Kosova e Re scenario. The sequence of newly installed capacities is shown in Table 5-15.

Table 5-15 Generation investment plan in Base without TPP Kosova e Re scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP		30	50	50	50	50	50	50	50	40	50	**470**
WPP			103.4	50	50	50	50	50	50	50		**453.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**61.1**	**168.4**	**171.7**	**155**	**150**	**150**	**150**	**150**	**140**	**100**	**1406.7**

As in all other scenarios, by 2023 all small hydro candidates (63.3 MW) are commissioned. By 2024 20 MW of biomass candidates are commissioned, which is the maximum that can be built over the planning horizon. In 2021 30 MW of solar power plants are selected to enter into operation, followed by 50 MW each year until 2028. In 2029 and 2030 a total of 90 MW enters into operation, resulting in 470 MW of new PV plants by 2030. In 2022 WPP Selaci (103.4 MW) is commissioned, followed by 50 MW of new wind power plants in each year from 2023 until 2029. In the last year of the planning horizon there are no new wind power plants built. The model also chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Total installed capacities by technology type are presented in Figure 5-31. Total installed capacity in 2030 is 2158.9 MW (including batteries), out of which 54% refers to renewable energy sources. Wind and solar power plants have approximately the same shares in total capacity, 23% and 22% respectively, which corresponds to 487.2 MW of wind power plants and 480 MW of PV plants.

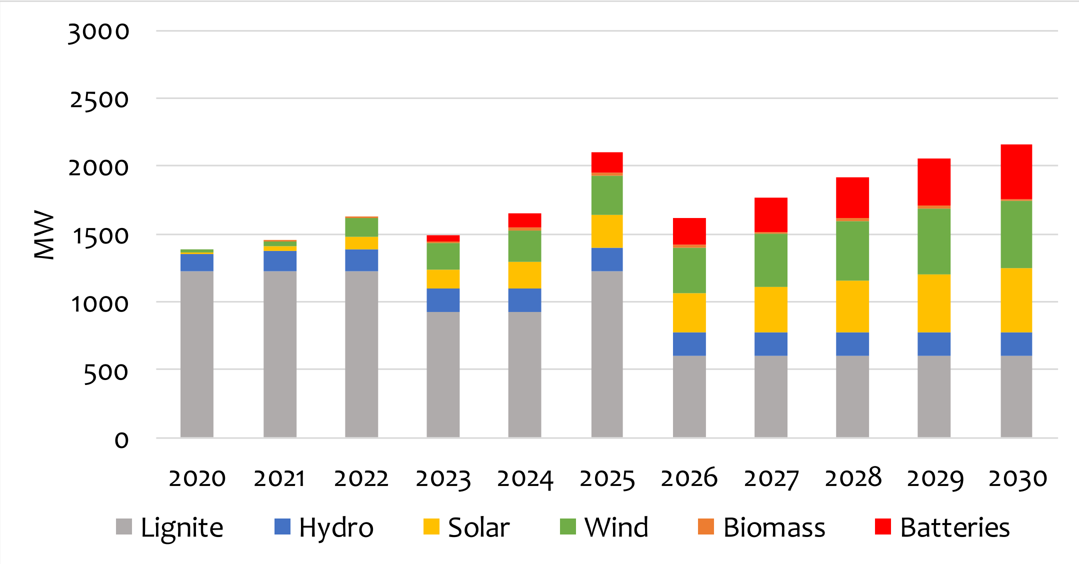

Figure 5-31 Total installed capacity by technology in Base without TPP Kosova e Re scenario

Figure 5-32 provides data about firm capacity in Kosovo over the planning horizon together with peak load in each year. Only in the year 2025 firm domestic capacity can cover peak load. In all other years, capacity reserve margin is negative.

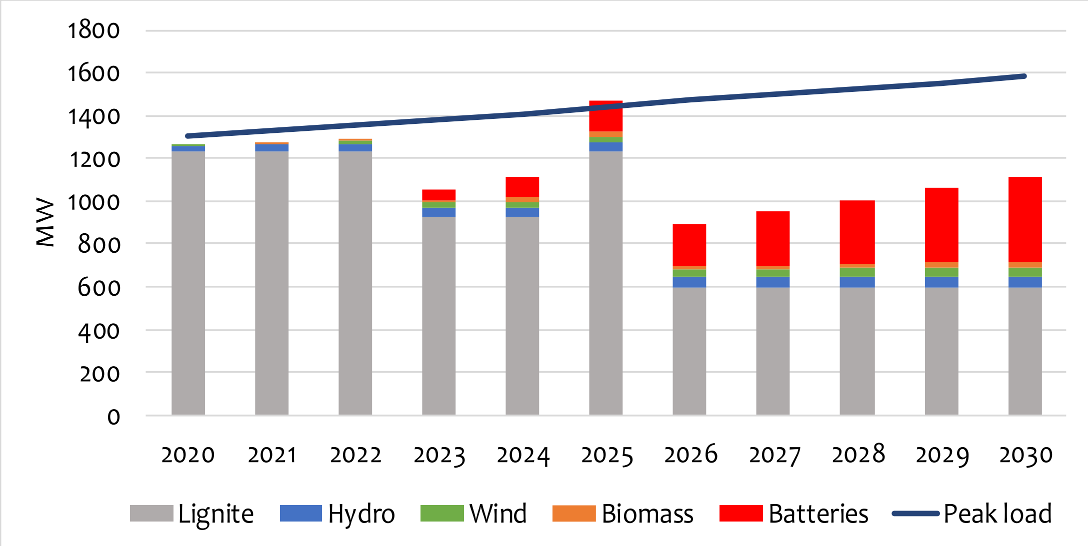

Figure 5-32 Firm capacity by technology in Base without TPP Kosova e Re scenario

Electricity balance and RES-E share

In the case of Base without TPP Kosova e Re scenario, short-term optimization results have showed the same trends regarding the unserved energy as in BaU without TPP Kosova e Re scenario. Unserved energy occurs in the period from 2026 when TPP Kosovo A is decommissioned and TPP Kosovo B is the only thermal power plant in operation. In order to obtain short-term optimization results without unserved energy, annual net import constraint was relaxed starting from year 2026 and it amounted around 25%. RES-E target is set to 33% in 2030 compared to the projected electricity demand in Base demand scenario.

Electricity generation per technology type is shown in Figure 5-33, together with annual imports, exports and total demand. Total electricity generation increases from 5.6 TWh in 2020 to around 5.9 TWh in 2030. Average annual net import amounts 25% compared to the projected annual demand from 2026 to 2030.

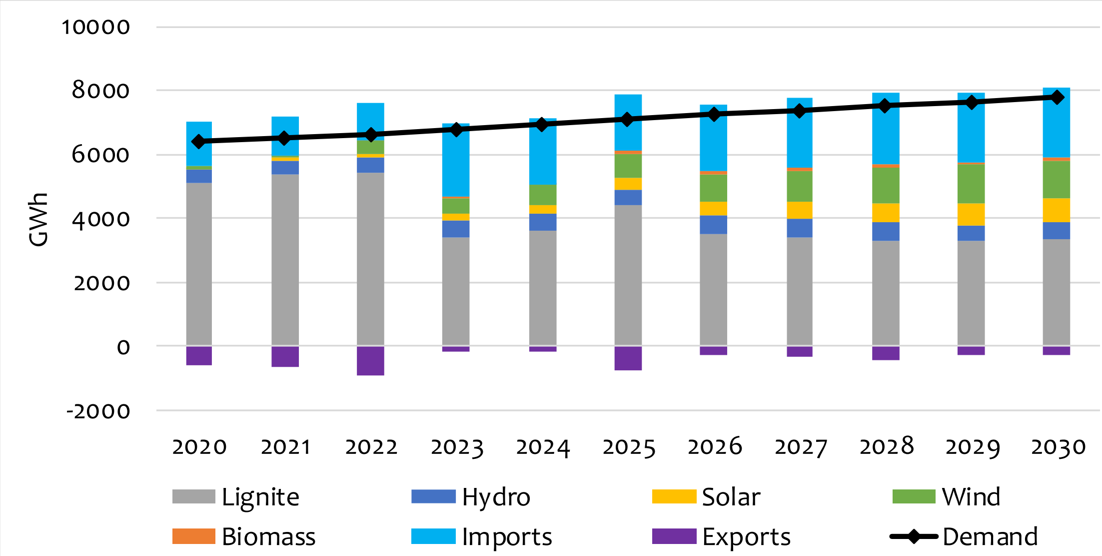

Figure 5-33 Electricity generation per technology in Base without TPP Kosova e Re scenario

Generation shares per technology are depicted in the following figure. As in all previously described scenarios, initial high share of generation from lignite power plants is decreased due to increase of share of RE plants. It can be observed that the share of RE in total generation in 2030 is equal as in 2029, around 43%.

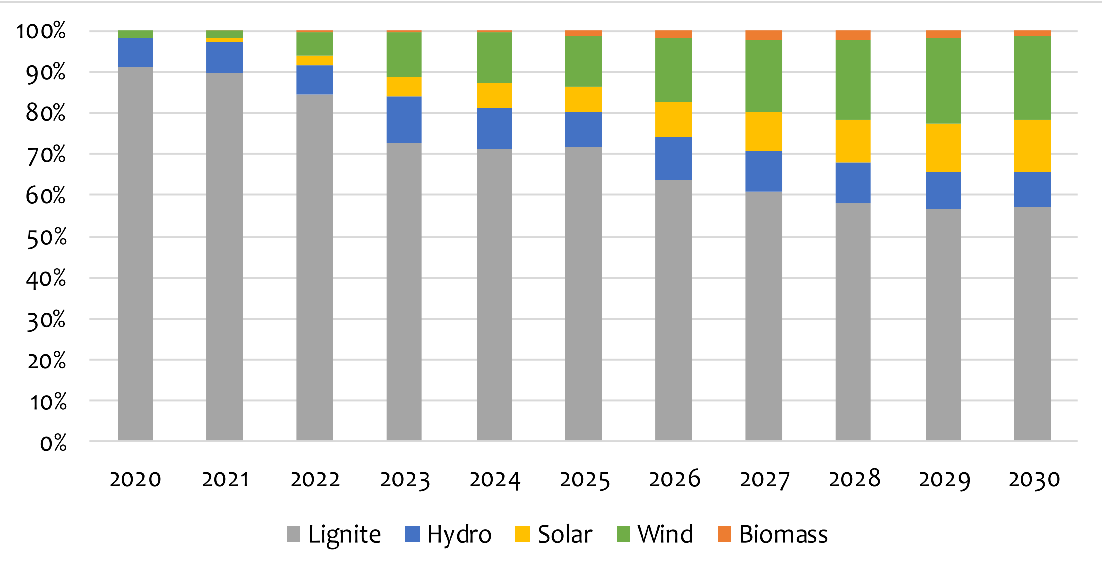

Figure 5-34 Generation shares per technology in Base without TPP Kosova e Re scenario

Figure 5-35 presents RE generation shares in the total demand over the entire planning horizon. Without TPP Kosova e Re project and with limited net electricity import to 15% until 2026 and 25% from 2026, generation from the existing and newly built RE capacities reaches 33% of the projected electricity demand in 2029. This share remains the same in 2030. In comparison to Base with TPP Kosova e Re scenario, higher RES-E shares are realized earlier in the planning horizon.

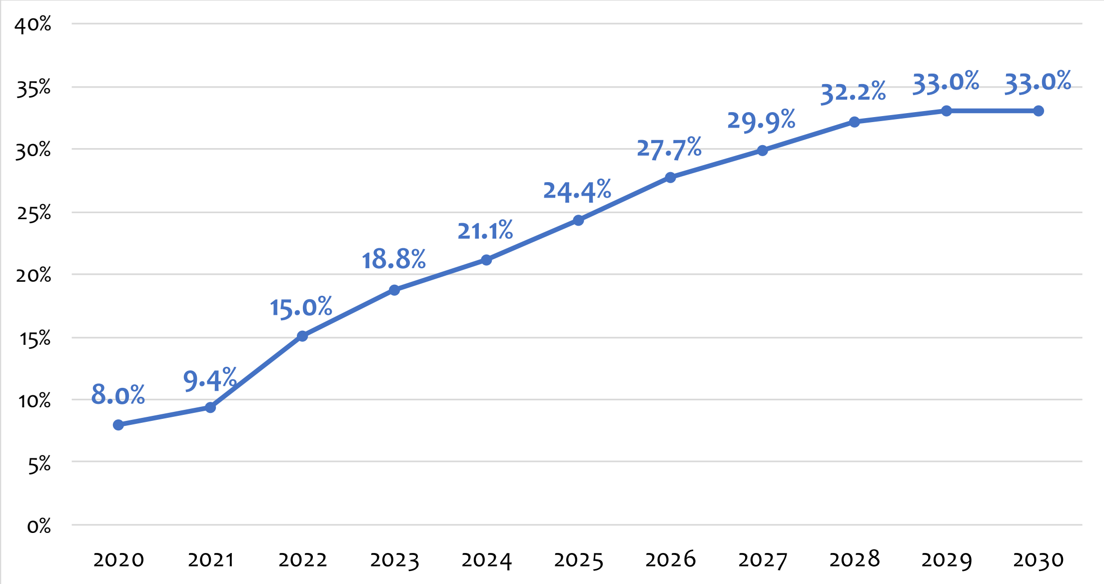

Figure 5-35 RES-E generation share in electricity demand in Base without Kosovo e Re scenario

5.4.6 'High without TPP Kosova e Re' scenario (S8)

In **High without TPP Kosova e Re scenario** projected electricity demand in Kosovo is set according to the High demand scenario, realization of TPP Kosova e Re project is not envisaged during the entire planning horizon and the RES-E target is set **to 33% in 2030**.

Generation expansion

To meet the growing demand, a total of **1,436.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030) in High without TPP Kosova e Re scenario. The sequence of newly installed capacities is shown in Table 5-16.

Table 5-16 Generation investment plan in High without TPP Kosova e Re scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP		40	50	50	50	50	50	50	50	30	30	**450**
WPP			103.4	50	50	50	50	50	50	50	50	**503.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**71.1**	**168.4**	**171.7**	**155**	**150**	**150**	**150**	**150**	**130**	**130**	**1436.7**

As in all other scenarios, by 2023 all small hydro candidates (63.3 MW) are commissioned and by 2024 20 MW of biomass candidates are commissioned. By 2030 a total of 450 MW of new PV plants are built. In addition to WPP Selaci (103.4 MW) which is commissioned in 2022, 400 MW of new wind power plants are built by 2030. The model also chooses to invest in 50 MW of battery candidates each year from 2023 to 2030.

Total installed capacities per technology type are presented in Figure 5-36. Total installed capacity in 2030 is 2,188.9 MW (including batteries), out of which 54% refers to renewable energy sources. Wind and solar power have shares of 25% and 21% in total capacity, which corresponds to 537.2 MW of wind power plants and 460 MW of PV plants.

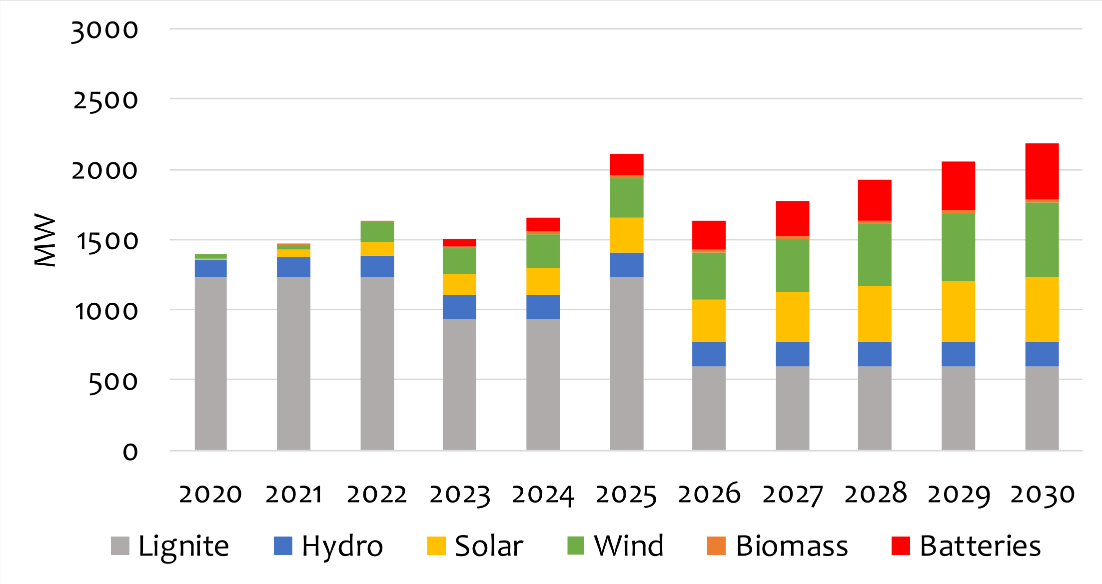

Figure 5-36 Total installed capacity per technology in High without TPP Kosova e Re scenario

Figure 5-37 provides data about firm capacity in Kosovo over the planning horizon together with peak load in each year.

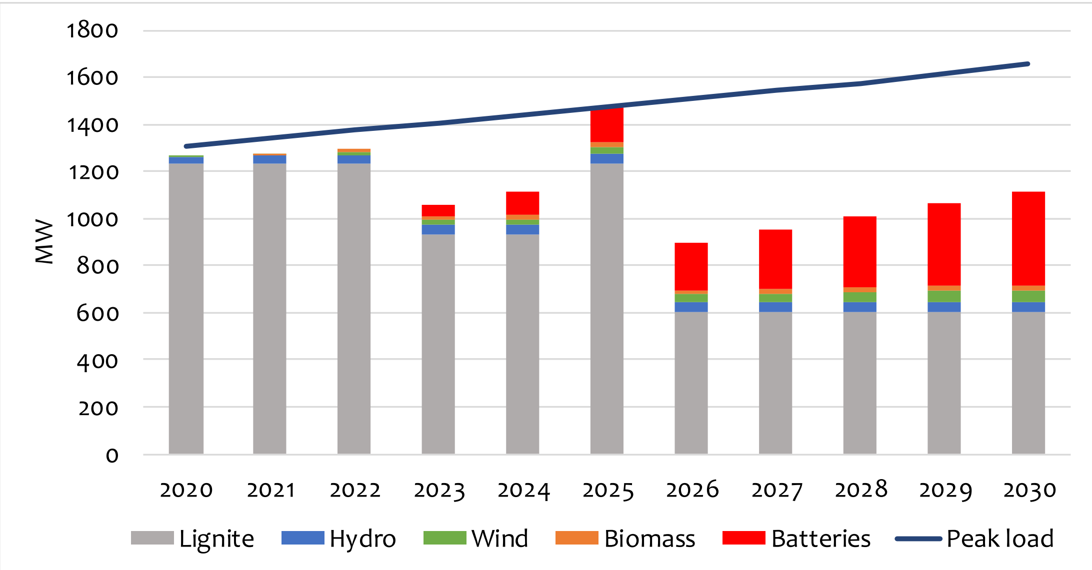

Figure 5-37 Firm capacity by technology in High without TPP Kosova e Re scenario

Electricity balance and RES-E share

In case of High without TPP Kosova e Re scenario, short-term optimization results have showed the same trends regarding the unserved energy as in other two scenarios without

TPP Kosova e Re project (BaU without TPP Kosova e Re scenario and Base without TPP Kosova e Re scenario). Unserved energy appears in the period from 2026 when TPP Kosovo A is decommissioned. The same modelling approach was used to obtain short-term optimization results without unserved energy, meaning that annual net import constraint was relaxed from the year 2026 and it amounted to around 25%. RES-E target is set to 33% in 2030 compared to the projected electricity demand in High demand scenario.

Electricity generation per technology type is depicted in Figure 5-38, together with annual imports, exports and total demand. Total electricity generation increases from 5.6 TWh in 2020 to around 6.1 TWh in 2030. Average annual net import amounts 25% from 2026 to 2030 compared to the projected annual demand.

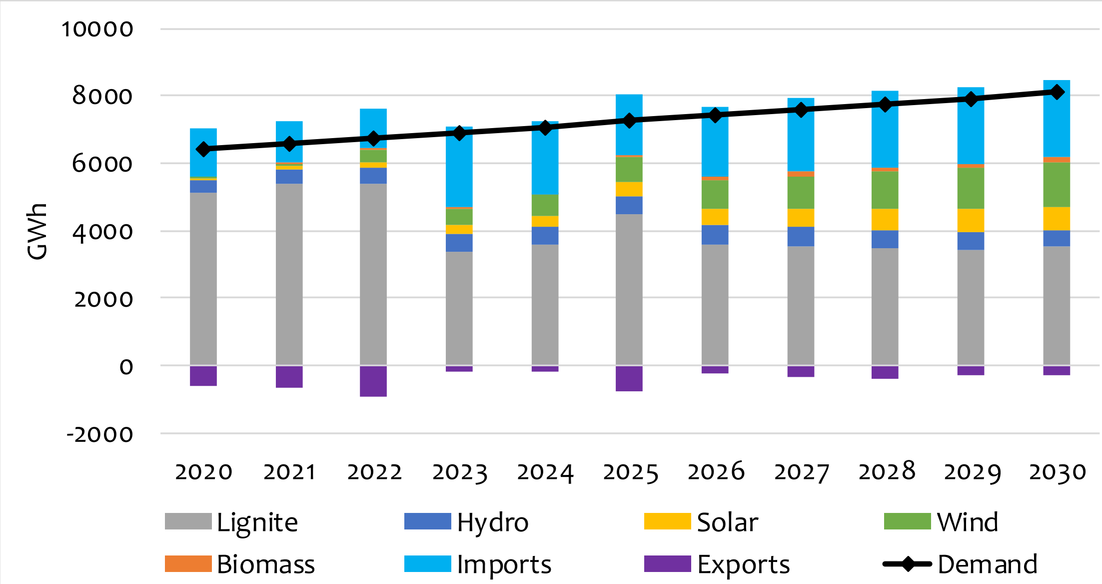

Figure 5-38 Electricity generation per technology in High without TPP Kosova e Re scenario

Generation shares per technologies are depicted in the following figure. As in all previously described scenarios, initial high share of generation from lignite power plants is decreased due to increase of share of RE plants.

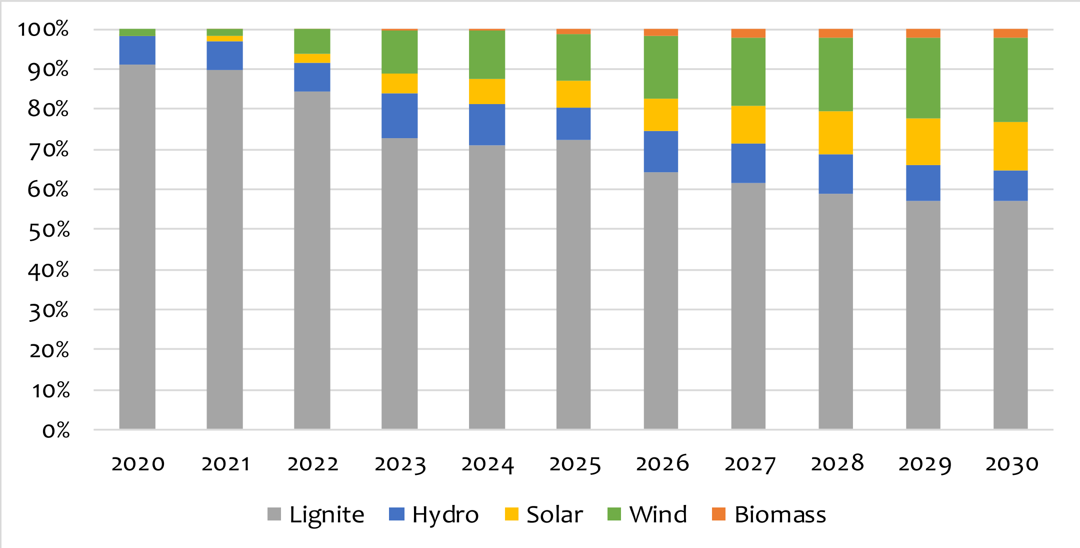

Figure 5-39 Generation shares per technology in High without TPP Kosova e Re scenario

Renewable energy generation share in the total demand over the entire planning horizon is depicted in Figure 5-40.

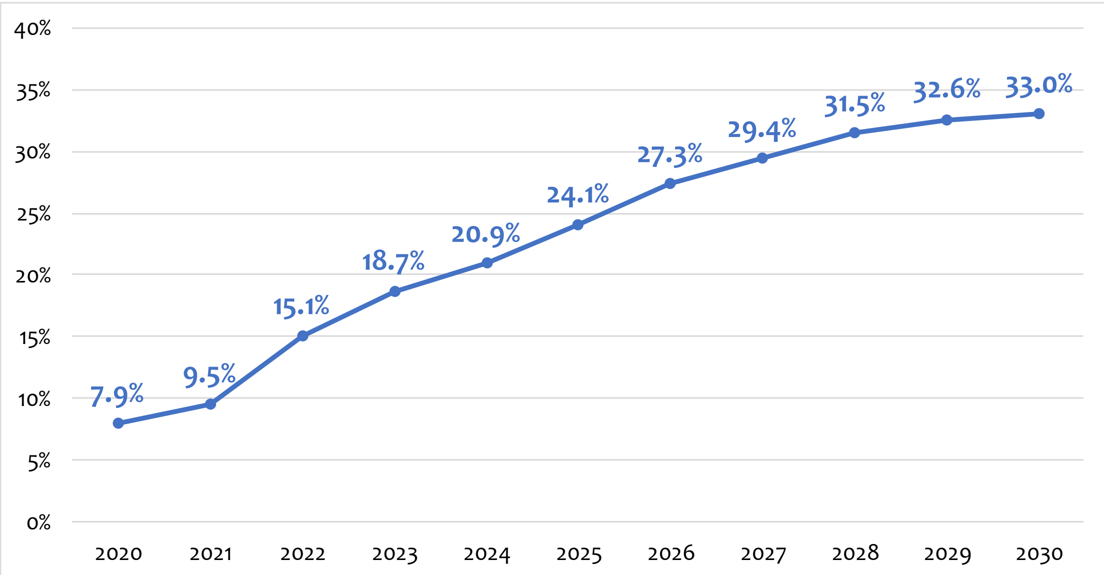

Figure 5-40 RES-E generation share in electricity demand in High without Kosovo e Re scenario

5.4.7 Common insights for all scenarios

In all scenarios biomass power plants (maximum of 20 MW) are built by 2024, and all small hydro power plants (63.3 MW) are built by 2023. Committed units have predefined year of commissioning, so **the main differences in generation expansion plans are in new builds of generic solar and wind power candidates** in different scenarios. In 'BaU' scenarios a total of 500 MW of new solar power plants is built by 2030, and 400 MW of wind power plants (without committed WPP Selaci). In these scenarios RES-E share in 2030 is higher than 36%.

If the RES-E share is predefined in 2030, model chooses to build less solar and wind capacity compared to 'BaU' scenarios. Annual sequence of builds is determined by growing demand and constraints on maximum builds on annual level which serve to prevent unrealistic annual builds of wind, distribution level PV and batteries. In general, between 1130 and 1209 MW of RE capacity (hydro, biomass, solar and wind) in 2030 will be necessary to fulfill 33% RES-E share in 2030, in Base or High demand scenario.

Constraints on distribution of the new wind and solar power plants per seven areas of Kosovo also affect annual sequence of builds (described in section 5.2.9.). While for wind constraints per area determine maximum capacity that can be built, constraints for solar determine **minimum and maximum capacity per area in relation to total capacity** in the country. Distribution of new solar power plants per seven areas of Kosovo in 2030 for analyzed scenarios is provided in Table 5-17. It can be seen that the highest share of total new solar capacity in 2030 should be in Gjakova area, from 22% to 30%, depending on the scenario.

Table 5-17 Distribution of new solar power plants between seven areas of Kosovo in 2030

	BaU	BaU without TPP Kosova e Re	Base with TPP Kosova e Re (S5)	High with TPP Kosova e Re (S6)	Base without TPP Kosova e Re (S7)	High without TPP Kosova e Re (S8)
Ferizaj	70	70	40	50	70	70
Gjakova	110	110	120	130	120	110
Gjilan	70	70	70	40	60	60
Mitrovica	60	50	30	30	40	30
Peja	70	80	60	50	60	60
Prishtina	50	50	50	50	50	50
Prizreni	70	70	70	80	70	70
Total	**500**	**500**	**440**	**430**	**470**	**450**

In all scenarios 400 MW of batteries is built, which is the maximum that can be built over the planning horizon considering the annual constraint of 50 MW. Size of candidate units is 1 MW, with capacity of 3 MWh, resulting in total storage capacity of 1200 MWh by 2030. The model chooses to build maximum possible number of BESS units due to their assumed low capital costs and high contribution to firm capacity (100%). Batteries also provide more balancing options in terms of variable renewable energy generation, especially of solar power plants. Example of hourly engagement of batteries is provided in the following figure, which presents hourly load diagram in two weeks in January 2030. In hours with low or no generation from solar power plants, batteries act like a generator in the system, while in hours with low demand batteries serve to absorb the energy surplus. If there is energy surplus in the system during peak hours, due to high wind and solar generation, then energy is exported and sold in external markets.

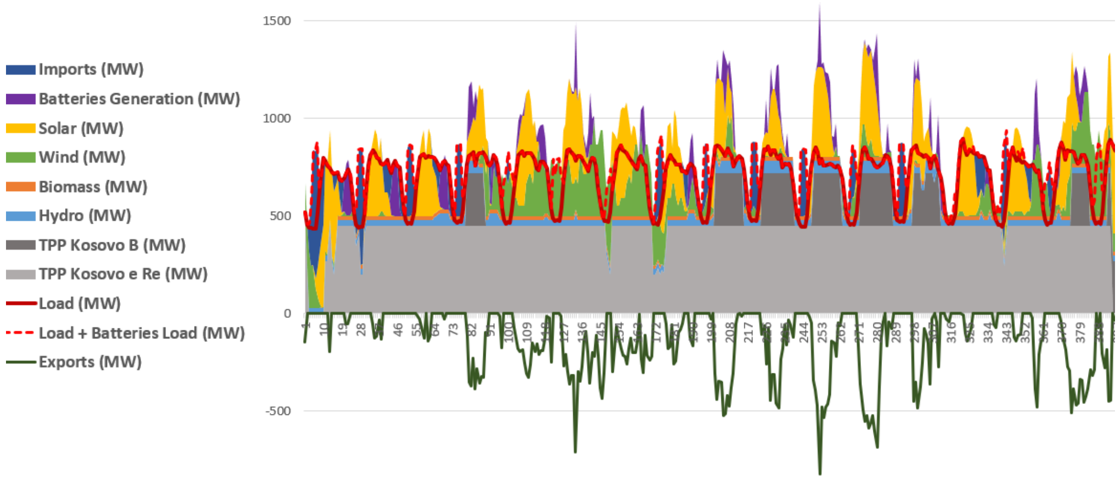

Figure 5-41 Example of hourly load diagram in January 2030

In addition to wind and solar which have predefined input generation time series, hourly load is covered by biomass, lignite and hydro. Biomass power plants are modelled as thermal units with their efficiencies and fuel prices and are dispatched as any other thermal unit, meaning that there is no priority in dispatch in terms of predefined generation/time series. Thus, different annual generation from biomass is possible in different scenarios, despite the same installed capacity.

Different generation of existing hydro power plants is also possible, due to the HPP Ujmani generation which has reservoir and thus its hydro generation can be optimized, unlike all other hydro power plants which are RoR and generation is based on the input time series. RES-E share set to 33% in 2030 also has impact on the generation, meaning that the model optimizes RES generation if possible (e.g. with hydro and biomass) to be in line with 33% in 2030.

5.5 Economic costs of analyzed scenarios

5.5.1 Kosovo power system costs

In this section all analyzed supply scenarios are compared based on their total costs that consist of the following components:

- generation build costs;
- fuel costs;
- other variable O&M costs;
- CO_2 emission costs;
- fixed O&M costs;
- net import costs; and
- costs of local environmental pollution.

Cumulative generation build costs for the six scenarios until 2030 are presented in Figure 5-42. These costs include build costs of new generation capacities and batteries. The scenarios in which TPP Kosova e Re is built in 2026 have higher cumulative investment costs, which range from EUR 2.32 billion in Base with TPP Kosova e Re scenario to EUR 2.43 billion in BaU scenario. In scenarios without TPP Kosova e Re these costs range from EUR 1.35 billion to EUR 1.44 billion, depending on the scenario.

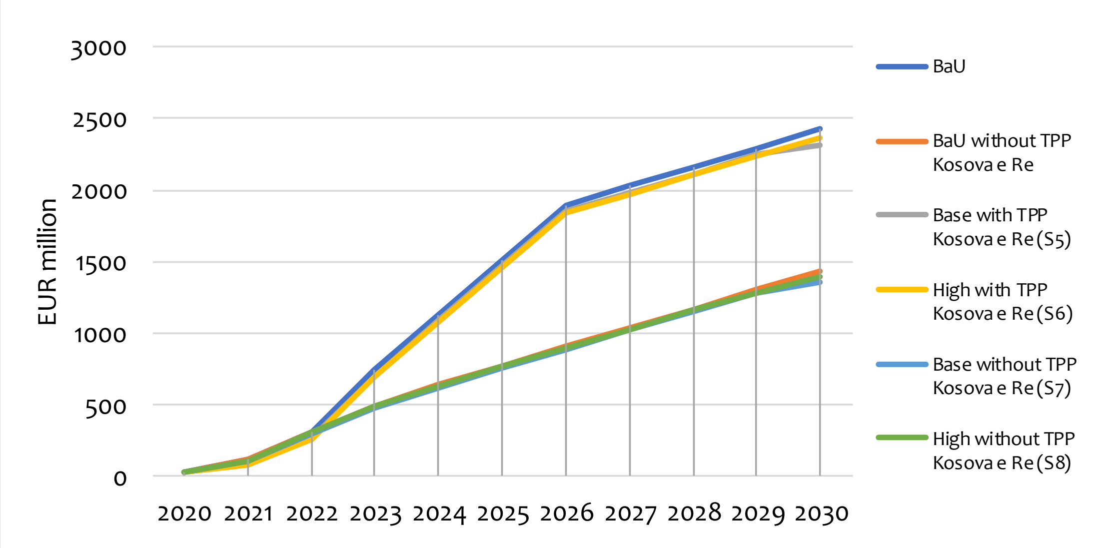

Figure 5-42 Cumulative build costs

Annual fuel costs in all scenarios are presented in the following figure. If entire planning horizon is observed, the highest total fuel costs are in High with TPP Kosova e Re scenario.

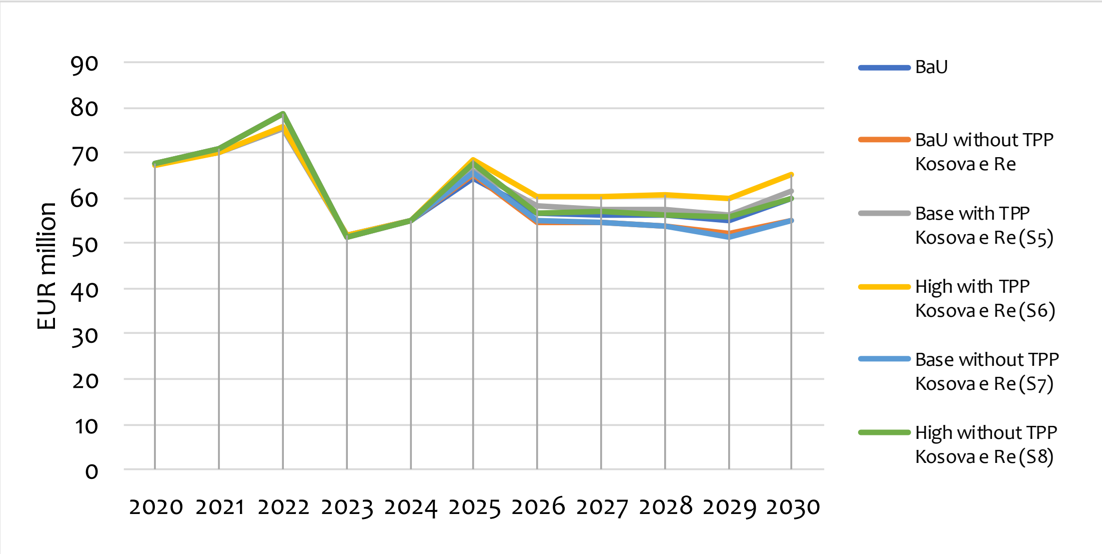

Figure 5-43 Total fuel costs

Significant decrease of the total fuel costs in 2023 and 2024 is due to the renewal of the two units of TPP Kosovo B. From 2026 there is no significant difference in the total fuel costs between the scenarios. However, in scenarios without TPP Kosova e Re, the highest share in fuel consumption and fuel costs have units of TPP Kosovo B, while in scenarios with TPP Kosova e Re the greatest shares of total annual fuel costs refer to this specific unit.

Other variable operation and maintenance costs are depicted in Figure 5-44. It can be observed that scenarios without TPP Kosova e Re in operation have lower VO&M costs.

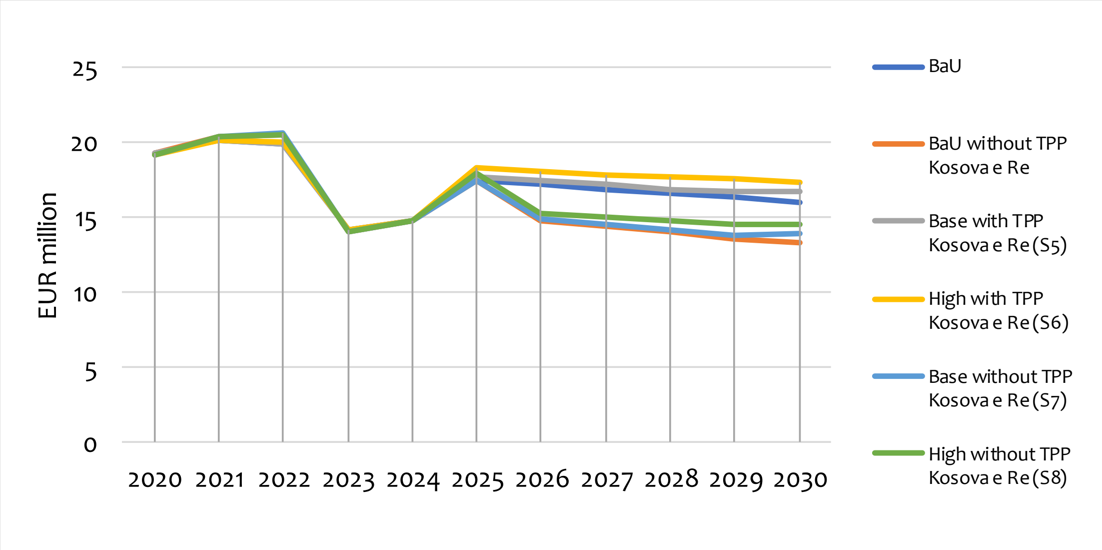

Figure 5-44 Variable O&M costs

CO_2 emission costs depicted in Figure 5-45 appear from 2025 due to the introduction of the Co_2 price in the PLEXOS model from 2025. CO_2 emission costs are in line with generation from lignite power plants and total emission costs are lowest in BaU without TPP Kosova e Re in which the total generation from lignite plants is the lowest.

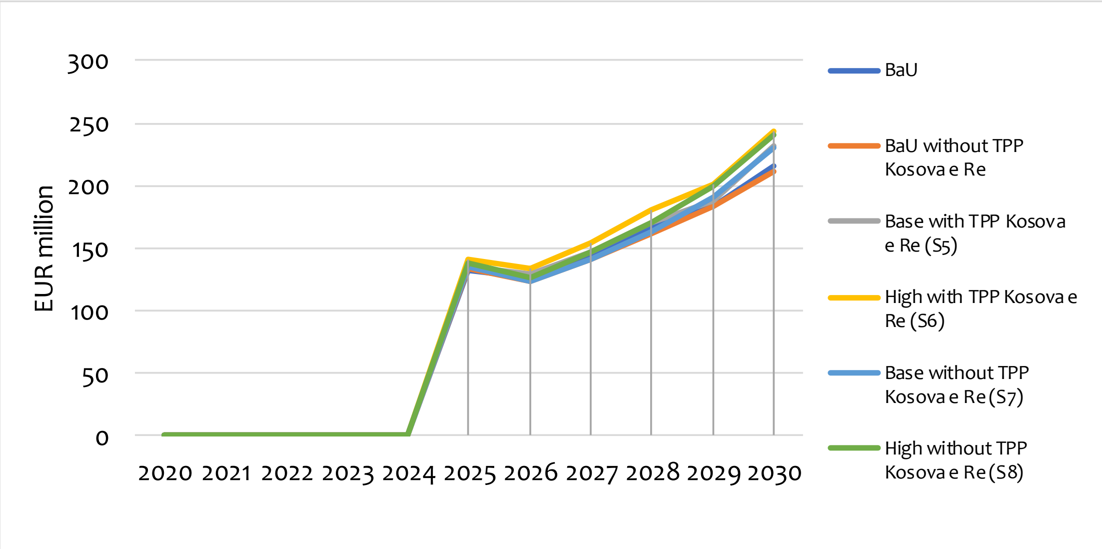

Figure 5-45 CO_2 emissions costs

Fixed operation and maintenance costs of generating capacities and batteries depend on the installed capacities in the system, regardless of their energy output. It can be observed in Figure 5-46 that these costs are higher in scenarios with TPP Kosova e Re in operation.

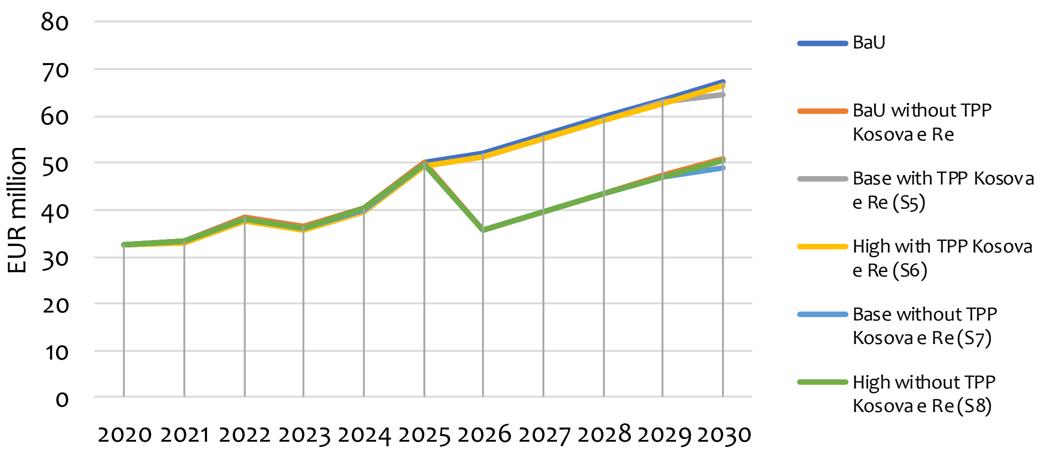

Figure 5-46 Generators and batteries fixed O&M costs

Net import costs are calculated as the difference between costs of electricity imports and revenue from electricity exports to neighboring markets. Positive values of net import costs in the entire planning horizon depicted in Figure 5-47 show that in all scenarios Kosovo is net electricity importer. Significant differences between the total net import costs can be observed between scenarios without TPP Kosova e Re in operation and with TPP Kosova e Re in operation, due to the higher imports in the respective scenarios. As described in section 5.4 , in these scenarios constraint on net imports is increased to 25% due to unserved energy with net imports limited to 15%. The highest cumulative net imports costs are in High without TPP Kosova e Re scenario (EUR 872 million).

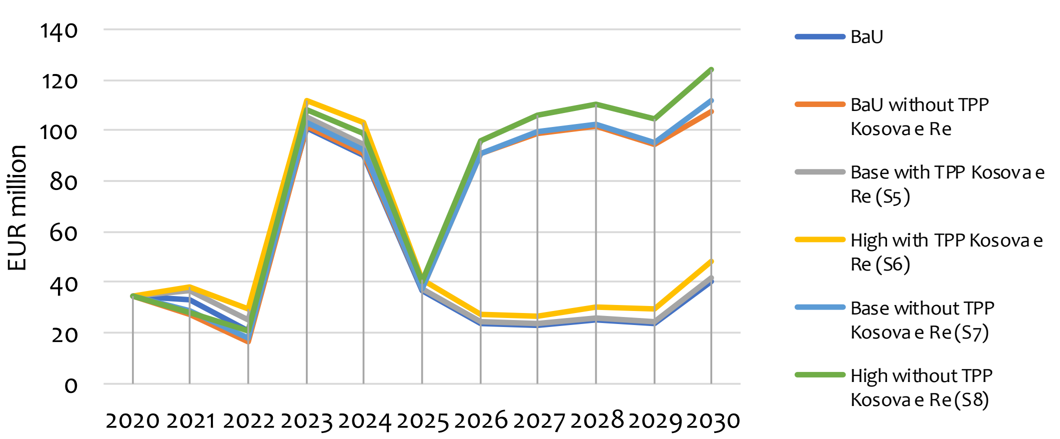

Figure 5-47 Net import costs

All presented costs are results of PLEXOS optimization. In addition to these costs, costs of local environmental pollution are calculated based on generation results from PLEXOS and specific costs provided by the WB (section 5.2.9) and presented in Figure 5-48. After decommissioning of TPP Kosovo A, these costs significantly decrease because TPP Kosovo A has the highest specific local environmental cost. Also, after the renewal in 2023 and 2024, TPP Kosovo B has lower specific local environmental cost which affects the decrease of total costs for local environmental pollution from 2025.

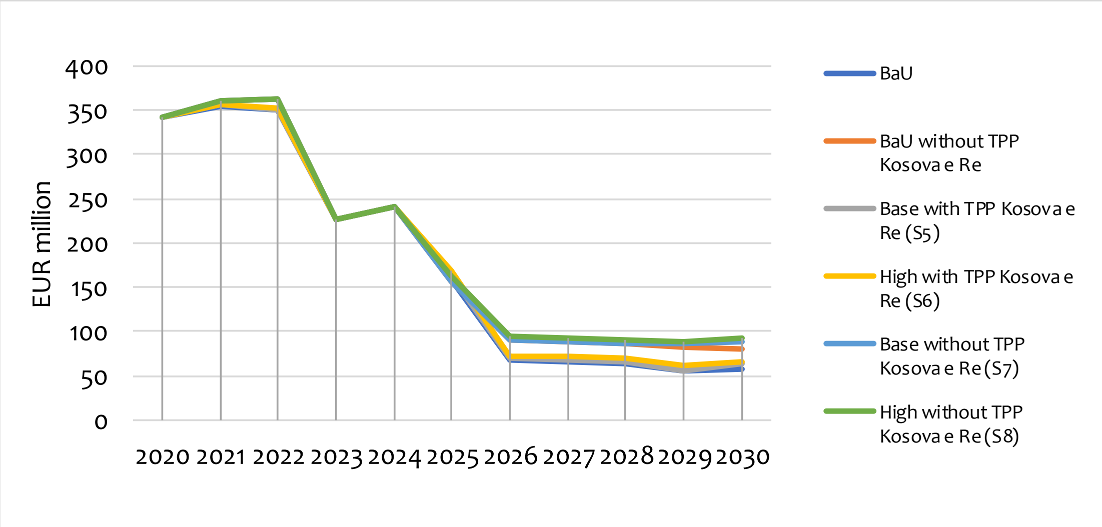

Figure 5-48 Local environmental costs

5.5.2 Net present value of costs

The costs in the previous section are presented in their real future values as they appear during the planning horizon. However, to enable comparison of scenarios, the time value of money has to be taken into consideration by discounting the values of future costs. All future costs are therefore discounted to their net present value in the year 2020 applying the reference discount rate of 8%. The structure **of total NPV of costs** is presented in the following table.

Table 5-18 Total net present value of costs (EUR million)

Scenario	Build cost	Fuel cost	Variable O&M cost	Emission cost	Fixed O&M cost	Net import cost	Total NPV of costs
BaU	1,682	476	134	536	350	326	**3,505**
BaU without TPP Kosova e Re	979	473	128	529	306	514	**2,928**
Base with TPP Kosova e Re (S5)	1,612	481	136	553	344	344	**3,470**
High with TPP Kosova e Re (S6)	1,633	491	138	581	345	373	**3,561**
Base without TPP Kosova e Re (S7)	934	473	129	542	303	522	**2,903**
High without TPP Kosova e Re (S8)	959	483	130	564	305	556	**2,997**

For the six analyzed scenarios the NPV value of build costs ranges from EUR 0.9 billion to EUR 1.68 billion. The differences between other components of costs, such as fuel costs or VO&M are lower. The lowest net present value of total cost has the Base without TPP Kosova e Re scenario, which has the lowest NPV of build costs, the lowest generation and consequently the lowest fuel costs and other O&M costs.

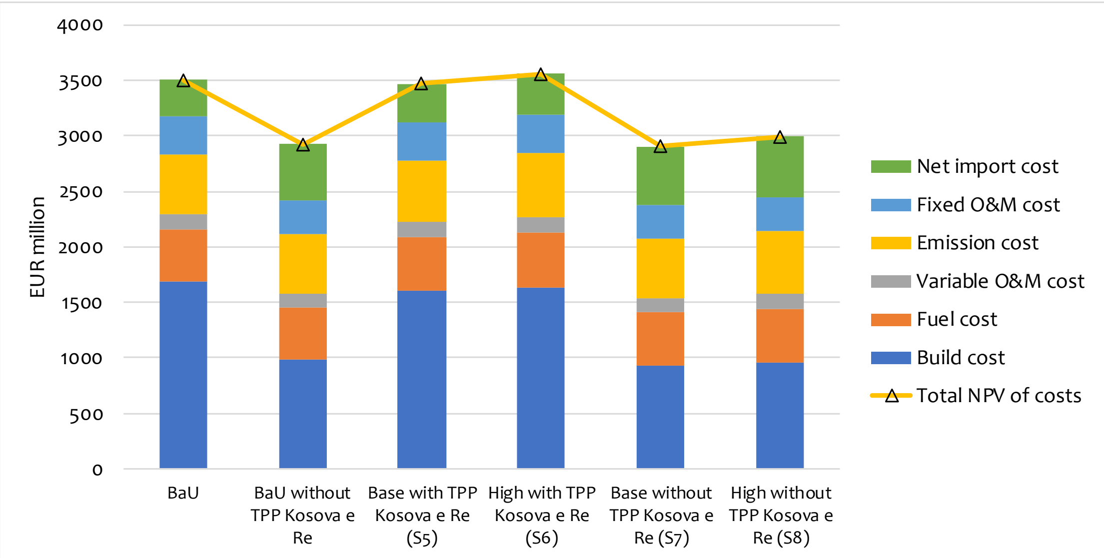

Figure 5-49 Net present value of costs

The structure of total NPV of costs when local environmental pollution costs are considered is presented in the following table.

Table 5-19 Total net present value of costs with included local cost of environmental pollution (EUR million)

Scenario	Build cost	Fuel cost	Variable O&M cost	Emission cost	Local environ. costs	Fixed O&M cost	Net import cost	Total NPV of costs
BaU	1,682	476	134	536	1,609	350	326	**5,114**
BaU without TPP Kosova e Re	979	473	128	529	1,686	306	514	**4,614**
Base with TPP Kosova e Re (S5)	1,612	481	136	553	1,619	344	344	**5,090**
High with TPP Kosova e Re (S6)	1,633	491	138	581	1,635	345	373	**5,196**
Base without TPP Kosova e Re (S7)	934	473	129	542	1,692	303	522	**4,595**
High without TPP Kosova e Re (S8)	959	483	130	564	1,706	305	556	**4,702**

The lowest net present value of total cost has Base without TPP Kosova e Re scenario when local environmental costs are included in the total costs.

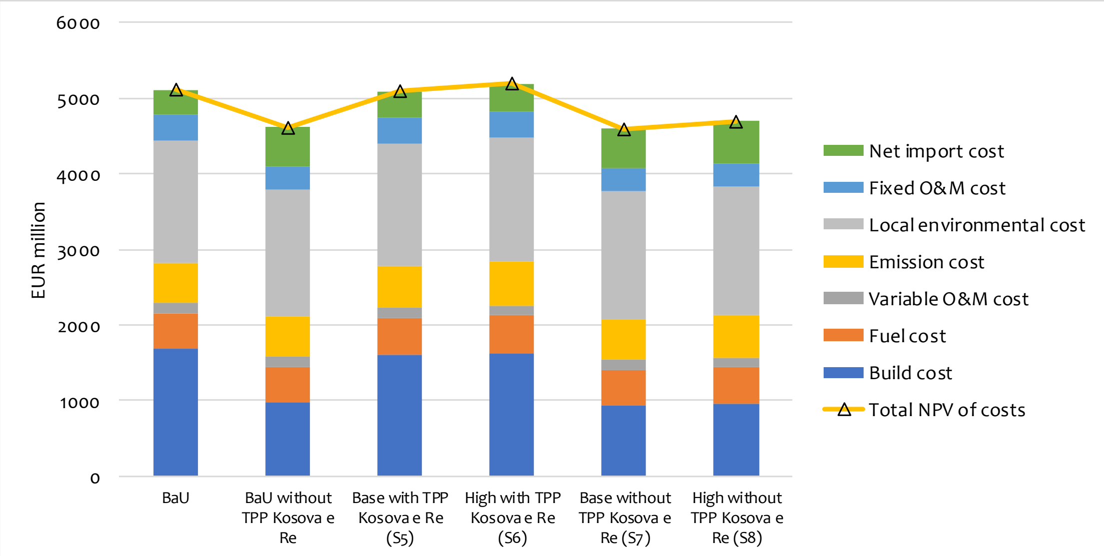

Figure 5-50 Net present value of costs with included local environmental costs

Cost breakdown

NPV of costs that can be presented per technology type, such as build costs, fuel costs, and O&M costs, are provided in the following tables.

Table 5-20 Total net present value of build costs per technology type (EUR million)

Scenario	Solar	Hydro	Biomass	Wind	Lignite	Batteries	Total NPV of build costs
BaU	242	77	60	410	703	189	**1,682**
BaU without TPP Kosova e Re	242	77	60	410	-	189	**979**
Base with TPP Kosova e Re (S5)	200	77	60	382	703	189	**1,612**
High with TPP Kosova e Re (S6)	193	77	60	410	703	189	**1,633**
Base without TPP Kosova e Re (S7)	224	77	60	382	-	189	**934**
High without TPP Kosova e Re (S8)	222	77	60	410	-	189	**959**

Table 5-21 Total net present value of fuel costs per technology type (EUR million)

Scenario	Biomass	Lignite	Total NPV of fuel costs
BaU	16	460	**476**
BaU without TPP Kosova e Re	25	448	**473**
Base with TPP Kosova e Re (S5)	16	465	**481**
High with TPP Kosova e Re (S6)	18	474	**491**
Base without TPP Kosova e Re (S7)	22	451	**473**
High without TPP Kosova e Re (S8)	25	457	**483**

Table 5-22 Total net present value of VO&M costs per technology type (EUR million)

Scenario	Hydro	Biomass	Lignite	Total NPV of VO&M costs
BaU	19	1	114	**134**
BaU without TPP Kosova e Re	19	1	108	**128**
Base with TPP Kosova e Re (S5)	19	1	116	**136**
High with TPP Kosova e Re (S6)	19	1	118	**138**
Base without TPP Kosova e Re (S7)	19	1	109	**129**
High without TPP Kosova e Re (S8)	19	1	110	**130**

Table 5-23 Total net present value of FO&M costs per technology type (EUR million)

Scenario	Solar	Hydro	Biomass	Wind	Lignite	Batteries	Total NPV of FVO&M costs
BaU	18	12	2	72	217	27	**350**
BaU without TPP Kosova e Re	18	12	2	72	173	27	**306**
Base with TPP Kosova e Re (S5)	14	12	2	71	217	27	**344**
High with TPP Kosova e Re (S6)	14	12	2	72	217	27	**345**
Base without TPP Kosova e Re (S7)	17	12	2	71	173	27	**303**
High without TPP Kosova e Re (S8)	17	12	2	72	173	27	**305**

5.6 Sensitivity analysis

In the inception phase of the project it was discussed if PS HPP Zhur of 250 MW should be included in the long-term PLEXOS analysis as a committed unit. Given that there is significant uncertainty in the realization of this project, it was decided to include this power plant as part of a sensitivity analysis in just one of the analyzed scenarios. The earliest commissioning year is 2027.

The same approach is adopted for a utility-scale PV park that should be located at the depleted coal mine of TPP Kosovo A where available area is enough to accommodate up to 600 MW. The park would be connected to transmission network via the existing substation for TPP Kosovo A and B. The earliest commissioning year is 2023.

The selected scenario for sensitivity analysis is Base without TPP Kosova e Re scenario, considering the lowest NPV of the total costs compared to the other scenarios, as well as low probability of TPP Kosova e Re project realization.

5.6.1 PS HPP Zhur

Input data

PS HPP Zhur project refers to the pumped storage hydro power plant of 250 MW that should be located in Kosovo near the village of Zhur, in distribution area Prizreni. The main characteristics of this project used as inputs to PLEXOS model, are listed in the following table.

Table 5-24 Input data for PS HPP Zhur used in PLEXOS model

	PS HPP Zhur
Build cost (EUR/kW)	1,800
The earliest COD (year)	2027
Installed capacity (MW)	250
Pump load (MW)	250
Storage size for upper reservoir (GWh)	2
Storage size for lower reservoir (GWh)	2
Overall pump cycle efficiency (%)	73

Optimization results

Long-term optimization results for Base without TPP Kosova e Re scenario with PS HPP Zhur committed in 2027 show that a total of **1,656.7 MW** of new generation capacity (including batteries) is built over the planning (2020-2030). The sequence of newly installed capacities is shown in Table 5-25.

Table 5-25 Generation investment plan in Base without TPP Kosova e Re scenario with PS HPP Zhur

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7	0							**63.3**
SPP (distr.)								250				**250**
Utility-scale PV		30	50	50	50	50	50	50	50	40	50	**470**
WPP			103.4	50	50	50	50	50	50	50		**453.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**61.1**	**168.4**	**171.7**	**155**	**150**	**150**	**400**	**150**	**140**	**100**	**1656.7**

Investment plan in all renewables is the same as in Base without TPP Kosova e Re scenario. Model also chooses to build 400 MW of batteries like in Base without TPP Kosova e Re scenario, but their distribution per areas in Kosovo is different compared to Base without TPP Kosova e Re scenario. In this case there are no batteries built in area of Prizreni, in which PS HPP Zhur is located. Total installed capacities per technology type are presented in the following figure.

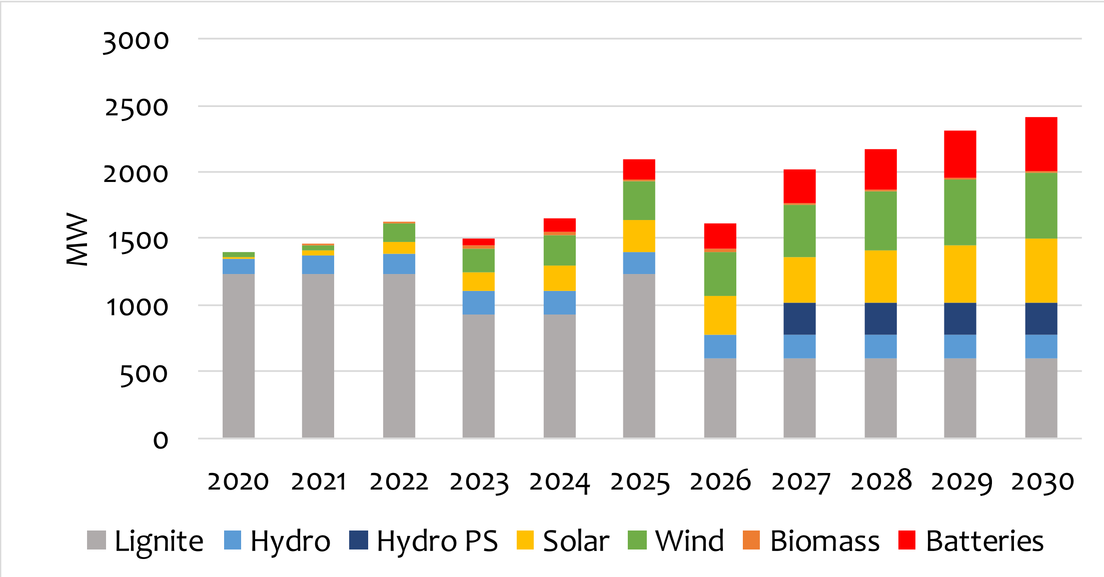

Figure 5-51 Total installed capacity per technology in Base without TPP Kosova e Re scenario with PS HPP Zhur

Electricity generation per technology type is shown in Figure 5-52, together with annual imports, exports and total demand. Average annual generation from PS HPP Zhur amounts about 100 GWh. In total demand net load of batteries is included as well as pump load of PS HPP Zhur. From 2027 engagement of batteries in system balancing is somewhat lower in scenario with PS HPP Zhur compared to the scenario without, due to engagement of PS HPP Zhur. Net import in the observed period from 2027 to 2030 is the same as in Base without TPP Kosova e Re scenario, but the sum of total imports and exports is slightly lower.

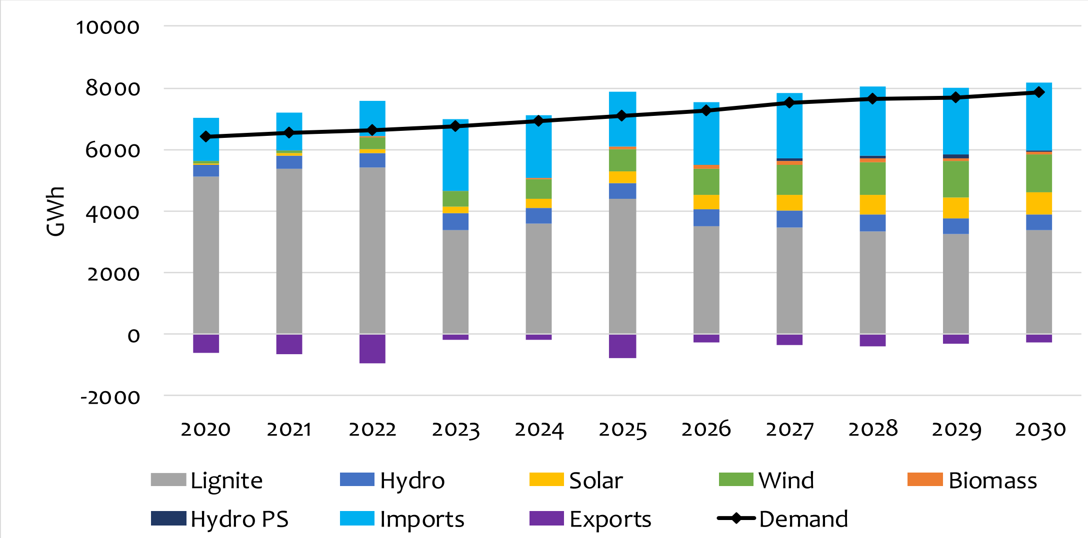

Figure 5-52 Electricity generation per technology in Base without TPP Kosova e Re scenario with PS HPP Zhur

RE generation shares in the total demand over the entire planning horizon are depicted in the following figure. Generation from pump storage hydro power plants is not considered in calculating RES-E share, thus the RES-E share with PS HPP Zhur in operation follows the trend from Base without TPP Kosova e Re also after 2027.

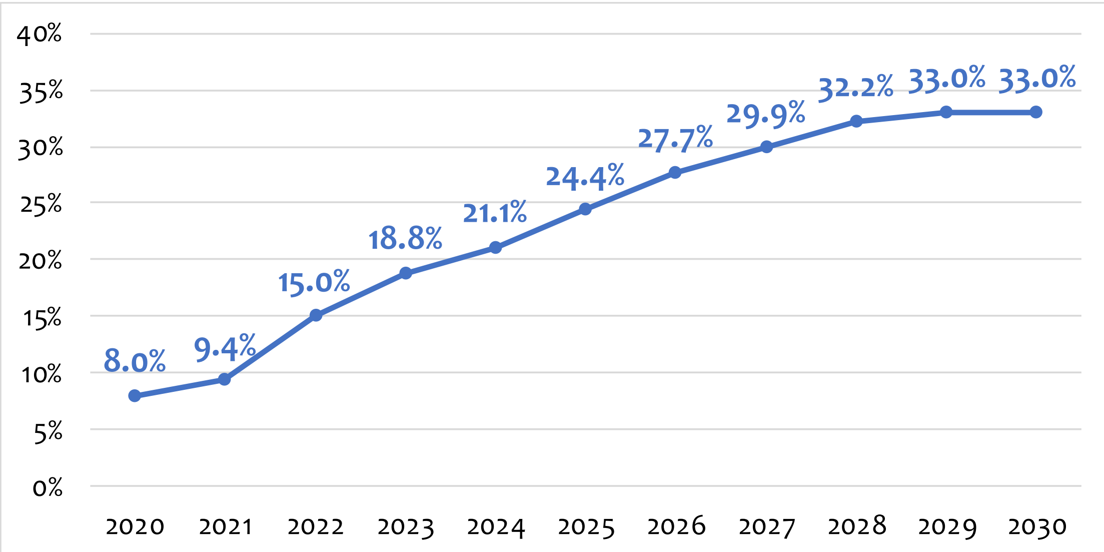

Figure 5-53 RES-E generation share in electricity demand in Base without Kosovo e Re scenario with PS HPP Zhur

5.6.2 Utility-scale PV park

Input data

The utility-scale PV park is modelled as a candidate in Prishtina area, with a unit size of 100 MW giving PLEXOS the possibility to build maximum of 5 units, i.e. 500 MW. In this way the total installed capacity at the depleted mine is the result of optimization. The earliest commissioning year is 2023. Hourly capacity factors are provided by the WB and presented in Table 5-27, together with other input data necessary to model PV park in PLEXOS.

Table 5-26 Input data for utility-scale PV park at depleted mine used in PLEXOS model

	Utility scale PV
The earliest COD (year)	2023
Installed capacity (MW)	100
Maximum units built	5
FO&M cost (EUR/kW)	10.8
Average annual capacity factor (%)	19.3
Economic life (yr)	25
Technical life (yr)	73

Build costs based on analysis in chapter 3 are presented in Table 5-27.

Table 5-27 Build costs for utility-scale PV park at depleted mine

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
680	667	654	642	631	620	609	599	589	580	571

Optimization results

Long-term optimization results for Base without TPP Kosova e Re scenario with included utility-scale PV at depleted mine show that a total of **1,436.7 MW** of new generation capacity (including batteries) is built over the planning horizon (2020-2030). In comparison to the S7 scenario without PV at depleted mine, that is 30 MW more. The sequence of newly installed capacities is shown in Table 5-28.

Table 5-28 Generation investment plan in Base without TPP Kosova e Re scenario with PV at depleted mine as candidate from 2023

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP (distr.)						50			30	10	10	**100**
Utility-scale PV					400	100						**500**
WPP			103.4	50	50	50	50	50				**353.4**
Batteries				50	50	50	50	50	50	50	50	**400**
TOTAL	**10.5**	**31.1**	**118.4**	**121.7**	**505**	**250**	**100**	**100**	**80**	**60**	**60**	**1436.7**

As in all other scenarios, by 2023 all small hydro candidates (63.3 MW) are commissioned. By 2024, 20 MW of biomass candidates are commissioned, which is the maximum that can be built over the planning horizon. In 2024, the model chooses to build 4 units of 100 MW of utility-scale PV at the location of the depleted mine, and one unit in 2025, resulting in a total of 500 MW. Regarding the PV plants at distribution level, the model chooses to build a total of 100 MW, starting with 50 MW in 2025, and another 50 MW in the last three years of the planning horizon. In 2022, WPP Selaci (103.4 MW) is commissioned, followed by 50 MW of new wind power plants in each year from 2023 until 2027. In total, there are 353.4 MW of new wind power plants in 2030. The model also chooses to invest in 50 MW of battery candidates each year from 2023 to 2030. Total installed capacities per technology type are presented in Figure 5-54.

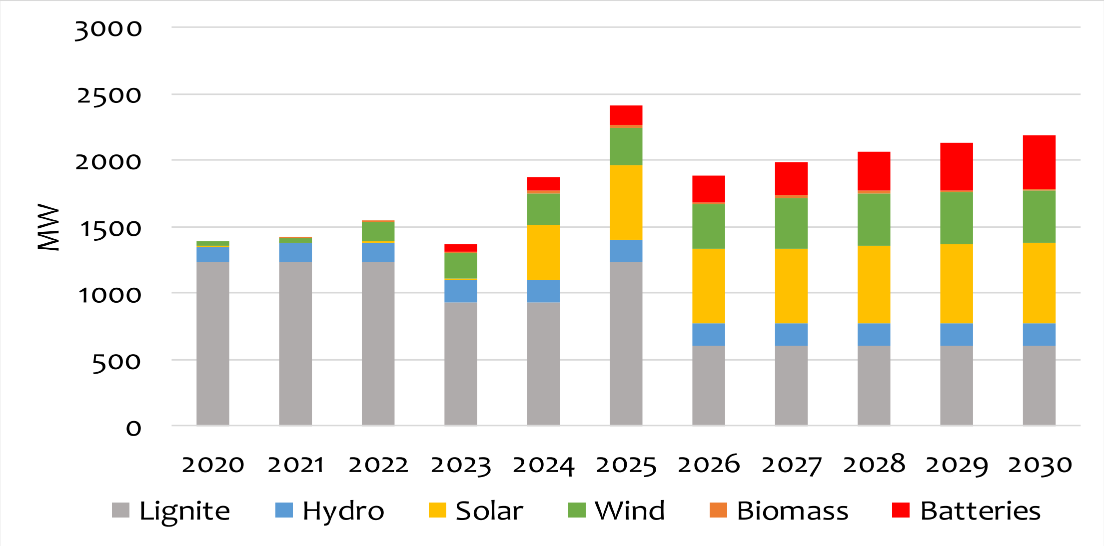

Figure 5-54 Total installed capacity per technology in Base without TPP Kosova e Re scenario with utility-scale PV candidate at depleted mine

Electricity generation per technology type is shown in Figure 5-55, together with annual imports, exports and total demand.

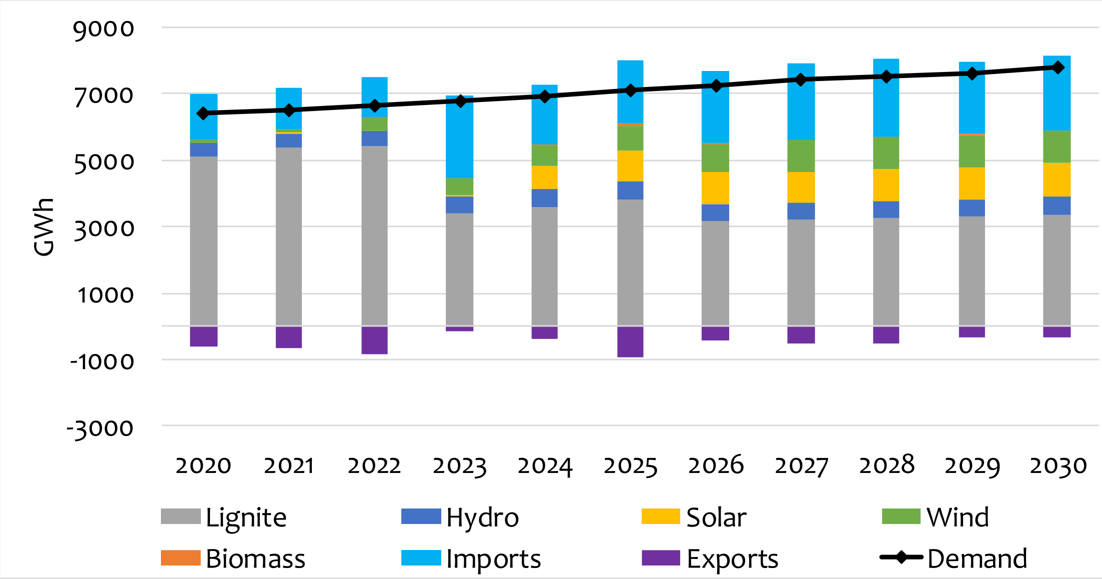

Figure 5-55 Electricity generation per technology in Base without TPP Kosova e Re scenario with utility-scale PV candidate at depleted mine

Total electricity generation increases from 5.6 TWh in 2020 to around 5.9 TWh in 2030, which is the same as in Base without TPP Kosova e Re scenario. However, in the case with utility-scale PV, total generation from solar power plants is higher, due to the higher installed capacity. Generation shares per technology are depicted in the following figure. Total generation from RES in 2030 is around 2.5 TWh, which is 43% of the total generation. Solar power plants (existing, new on transmission and new on distribution) produce more than 1 TWh in 2030, while generation of wind power plants amounts to 965 GWh.

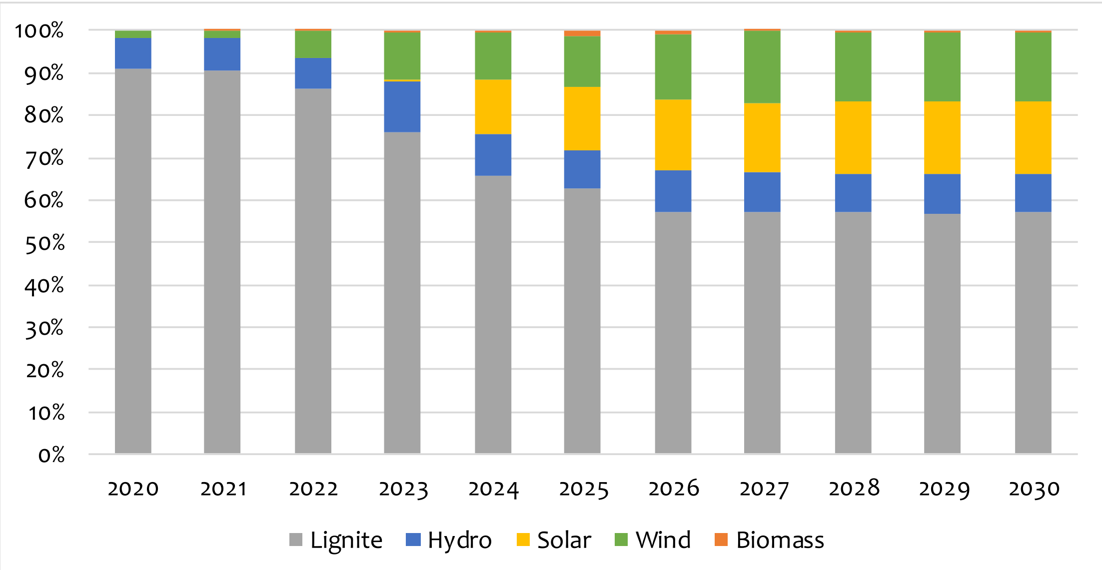

Figure 5-56 Generation shares per technology in Base without TPP Kosova e Re scenario with utility-scale PV candidate at depleted mine

RE generation shares in the total demand over the entire planning horizon are depicted in the following figure. Due to high penetration of utility-scale PV in 2024 (400 MW), high RES-E share of 27% is achieved in that year.

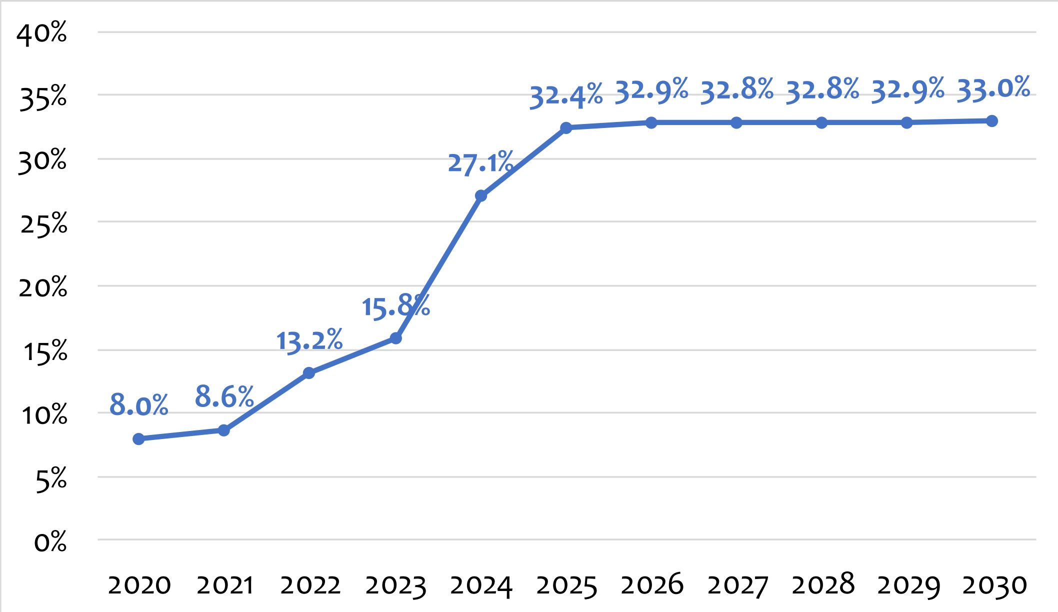

Figure 5-57 RES-E generation share in electricity demand in Base without TPP Kosova e Re scenario with utility-scale PV candidate at depleted mine

Comparison of NPV of total costs in Base without TPP Kosova e Re with the two scenarios analysed (large-scale utility PV and PS HPP Zhur) is shown in the following figure.

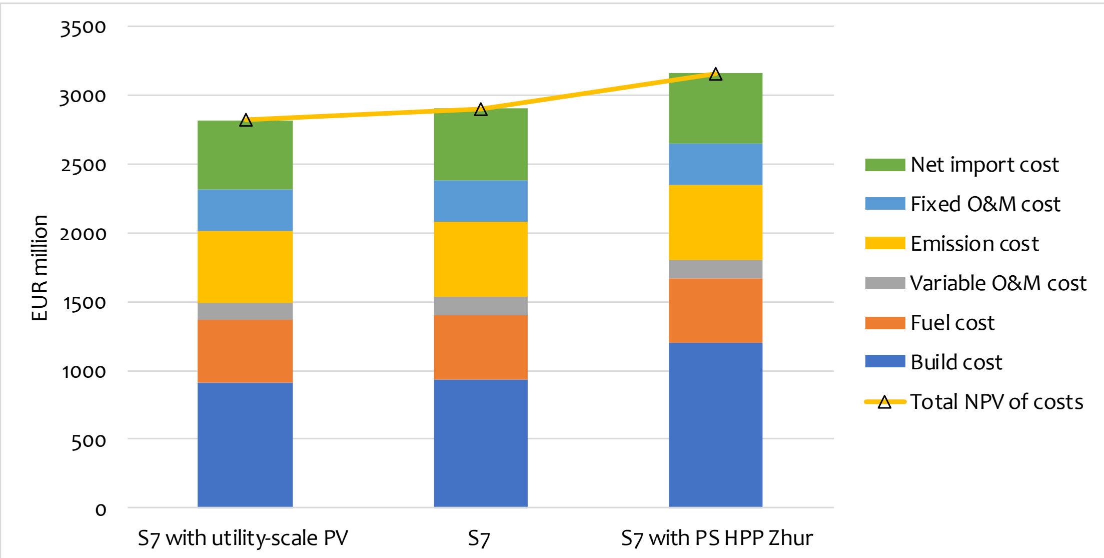

Figure 5-58 NPV of total costs in Base without TPP Kosova e Re scenario (S7) compared to the S7 with utility-scale PV and S7 with PS HPP Zhur

As expected, the highest NPV refers to scenario S7 with PS HPP Zhur due to the highest NPV of build costs. Net present values of fuel costs and emission costs are the lowest in scenario S7 with utility-scale PV park due to the decreased engagement of thermal power plants, resulting with lower variable NPV of O&M costs as well. NPV of net import costs in both scenarios (with large-scale PV and PS HPP Zhur) is lower compared to S7.

5.7 Additional analysis in S5 scenario

5.7.1 Assumptions

In addition to analyses made in previous section, four scenarios based on **Base with TPP Kosova e Re (S5)** were also analyzed in PLEXOS, following the request of Ministry of Economy and Environment of Kosovo (MOE). The focus of these scenarios was to examine the impact of new gas unit on the least cost RE expansion and to analyze this option with and without Co_2 price in the model. The main assumptions of the four scenarios are presented in Table 5-29.

Table 5-29 Main assumptions in additional scenarios based on the S5 scenario

	Additional Analysis			
	S5.1	S5.2	S5.3	S5.4
New gas unit	200 MW in 2027	200 MW in 2027	200 MW in 2027	200 MW in 2027
CO_2 price in Kosovo	Yes (from 2025)	No	Yes (from 2025)	No
Batteries	50MW in 2023	50 MW in 2023	50MW in 2023	50 MW in 2023
RES-E share in 2030	33%	33%	**25%**	**25%**

All four scenarios have new gas unit (200 MW) planned to be commissioned in 2027 and 50 MW of batteries built in 2023. In two scenarios RES-E target is set to 33% as in original S5 scenario, while in the other two scenarios RES-E target is set to 25%. One of the parameters analyzed in these scenarios is introduction of the CO_2 price in Kosovo, which is used to additionally diversify scenarios.

Input data necessary to model new gas unit in PLEXOS were collected from the MOE and ENTSO-E PEMMDB and presented in Table 5-30.

Table 5-30 Input data for new gas unit in PLEXOS

Parameter	Value	Source
Year of commissioning	2027	Ministry of Economy and Environment
Type of plant	CCGT	Pre-Feasibility Study MCC
Available capacity	200 MW	Ministry of Economy and Environment
Minimum stable generation	70 MW	ENTSO-E PEMMDB
Heat rate	6.21 GJ/MWh	ENTSO-E PEMMDB
Maintenance outage rate	7,.4%	ENTSO-E PEMMDB
Forced outage rate	5%	ENTSO-E PEMMDB
CO2 emission factor	57 kg/GJ	ENTSO-E PEMMDB

Minimum down time	2 hours	ENTSO-E PEMMDB
Minimum up time	2 hours	ENTSO-E PEMMDB
Build cost	1,095 EUR/kW	Pre-Feasibility Study MCC
FO&M cost	14.9 €/kW/year	Pre-Feasibility Study MCC
VO&M cost	1.6 EUR/MWh	ENTSO-E PEMMDB
Capacity factor	To be optimized in PLEXOS	
Location	District of Prishtina	Pre-Feasibility Study MCC
BESS capacity	50 MW in 2023	Ministry of Economy and Environment

Gas price is determined based on ENTSO-E TYNDP 2020 Report in which price of natural gas is the same in all development scenarios (Table 5-31).

Table 5-31 Projection of natural gas prices from 2027 to 2030

	2027	2028	2029	2030
Price (EUR/GJ)	6.64	6.73	6.82	6.91

5.7.2 Optimization results

Generation expansion plan for the four analyzed scenarios is presented in the following tables. In all scenarios committed units are TPP Kosova e Re (450 MW) in 2026, and new gas unit (200 MW) in 2027. Model chooses to build biomass units from 2021 to 2024, while all small hydro power plants (63.3 MW) are built by 2023. In all scenarios model must build 50 MW of batteries in 2023.

Table 5-32 Generation investment plan in S5.1 scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Gas								200				**200**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP			40	50	50	50	50	50	50	50	50	**440**
WPP			103.4	50	50	50	50	50	50	50		**453.4**
Batteries				50								**50**
TOTAL	**10.5**	**31.1**	**158.4**	**171.7**	**105**	**100**	**550**	**300**	**100**	**100**	**50**	**1676.7**

Table 5-33 Generation investment plan in S5.2 scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Gas								200				**200**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63.3**
SPP			40	50	50	50	50	50	50	50	50	**440**
WPP			103.4	50	50	50	50	50	50	50		**453.4**
Batteries				50								**50**
TOTAL	**10.5**	**31.1**	**158.4**	**171.7**	**105**	**100**	**550**	**300**	**100**	**100**	**50**	**1676.7**

Table 5-34 Generation investment plan in S5.3 scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Gas								200				**200**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63**
SPP					50	50	50	50	50	50		**300**
WPP			103.4	50	50	50	50					**303.4**
Batteries				50								**50**
TOTAL	**10.5**	**31.1**	**118.4**	**121.7**	**105**	**100**	**550**	**250**	**50**	**50**		**1387.4**

Table 5-35 Generation investment plan in S5.4 scenario

Candidate	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
TPP Lignite							450					**450**
TPP Gas								200				**200**
TPP Biomass		5	5	5	5							**20**
Small HPP	10.5	26.1	10	16.7								**63**
SPP					10	50	50	50	50	50	50	**310**
WPP			103.4	50	50	50	50					**303.4**
Batteries				50								**50**
TOTAL	**10.5**	**31.1**	**118.4**	**121.7**	**65**	**100**	**550**	**250**	**50**	**50**	**50**	**1397.4**

Wind and solar capacities are built with the objective to fulfill the RES-E target of 33% in S5.1 and S5.2, and 25% in S5.3 and S5.4, respectively. Thus, in first two scenarios model choses to build 440 MW of solar power plants and 350 MW of wind power plants. With the committed WPP Selaci, the total wind capacity is 453.4 MW in 2030. In scenarios S5.3 and S5.4 total capacity of solar and wind power plants in 2030 is lower, due to lower RES-E target. It can be seen in Table 5-34 and Table 5-35 that model chooses to invest in WPPs earlier during the planning horizon, while investments in solar power plants are made latter in the horizon. The following figures depict total available capacity in scenarios S5.1.-S5.4.

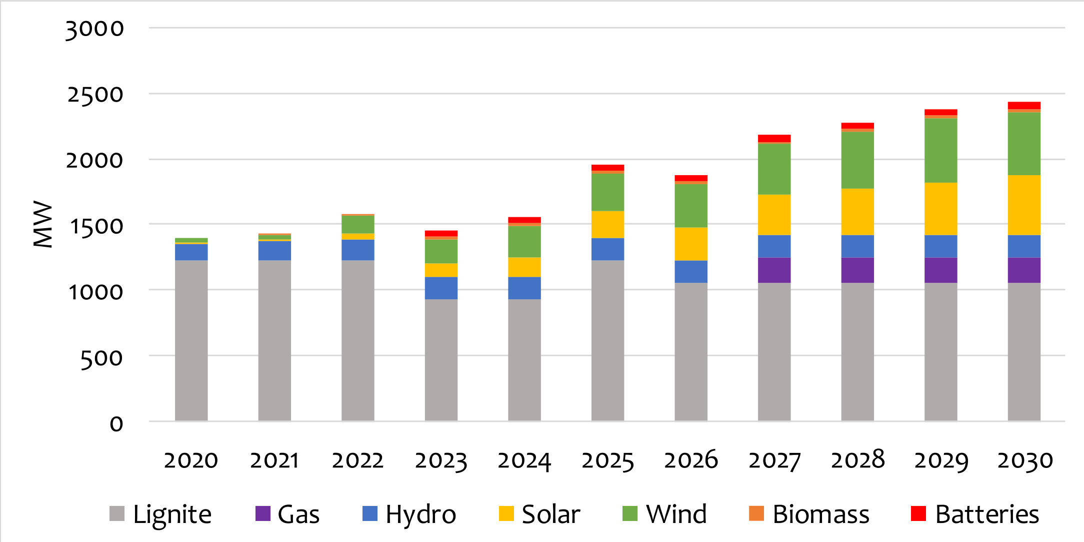

Figure 5-59 Total installed capacity per technology in S5.1 scenario

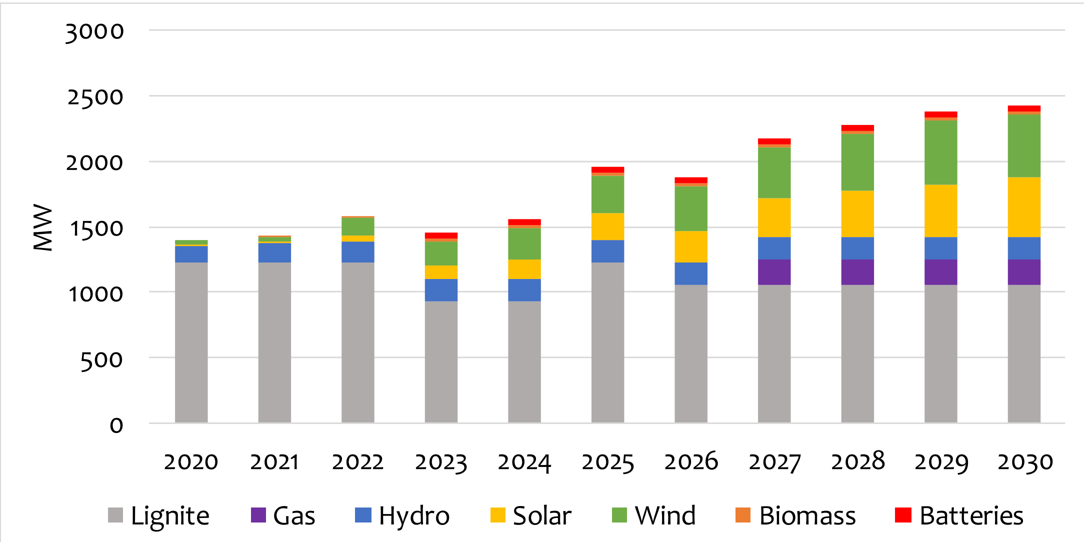

Figure 5-60 Total installed capacity by technology in S5.2 scenario

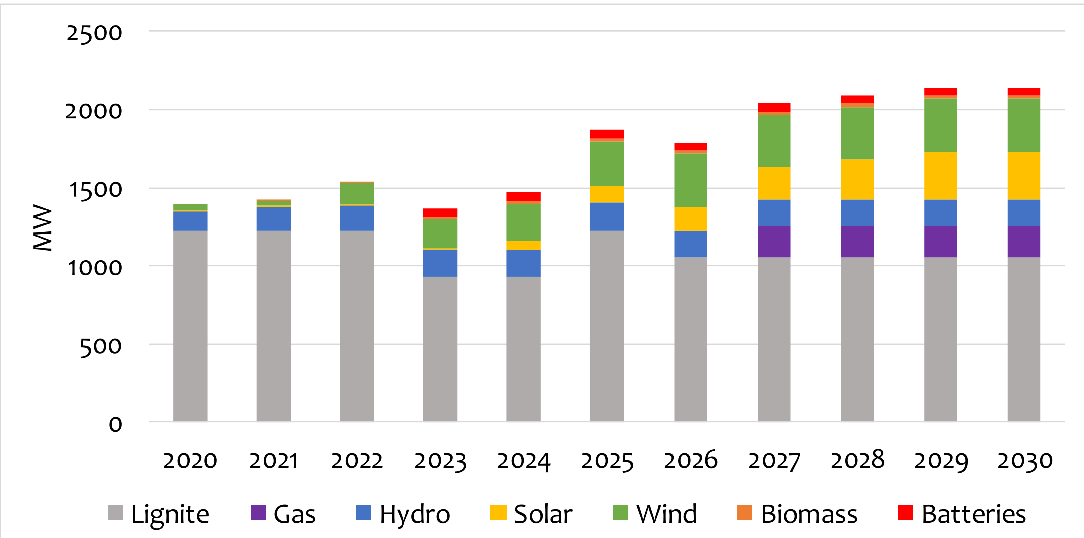

Figure 5-61 Total installed capacity by technology in S5.3 scenario

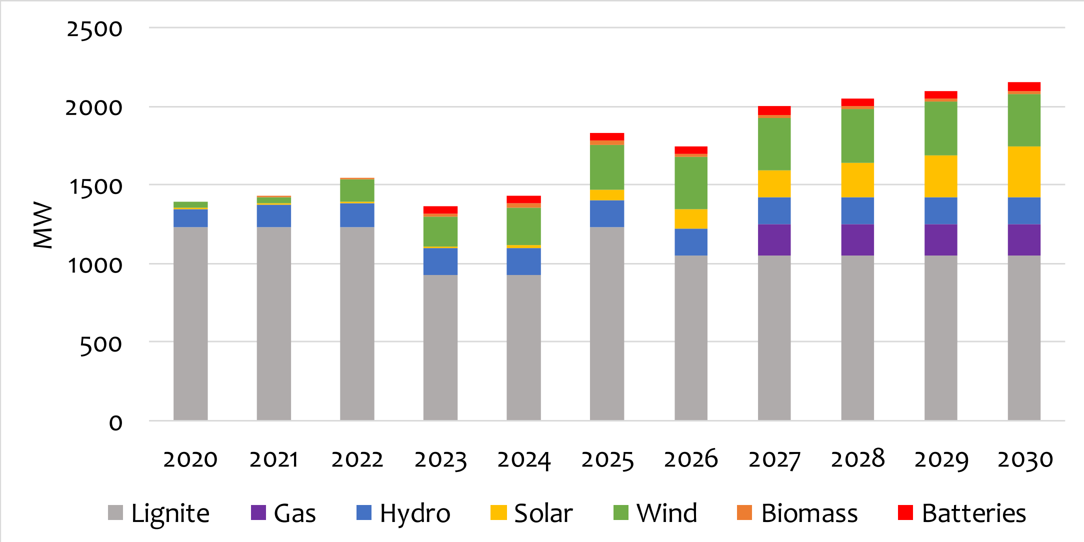

Figure 5-62 Total installed capacity by technology in S5.4 scenario

Electricity generation per technology type is presented in Figure 5-63, together with annual imports, exports and demand in S5.1 scenario. Total generation increases from around 5.6 TWh in 2020 to 6.6 TWh in 2030. RE generation in 2030 amounts 2.5 TWh, i.e. 33% of the projected electricity demand in Base scenario. Regarding the net interchange, net import is lower than 15% of demand in all years, except in 2023 and 2024. Annual generation of lignite TPPs is decreasing from 2026 to 2030, affected by the CO_2 emission price which causes increase of TPPs' marginal generation costs. Due to lower emission factor compared to lignite, marginal generation cost of gas units is under lower influence of rising CO_2 prices. Thus, annual generation of gas TPP increases from 2027 to 2030.

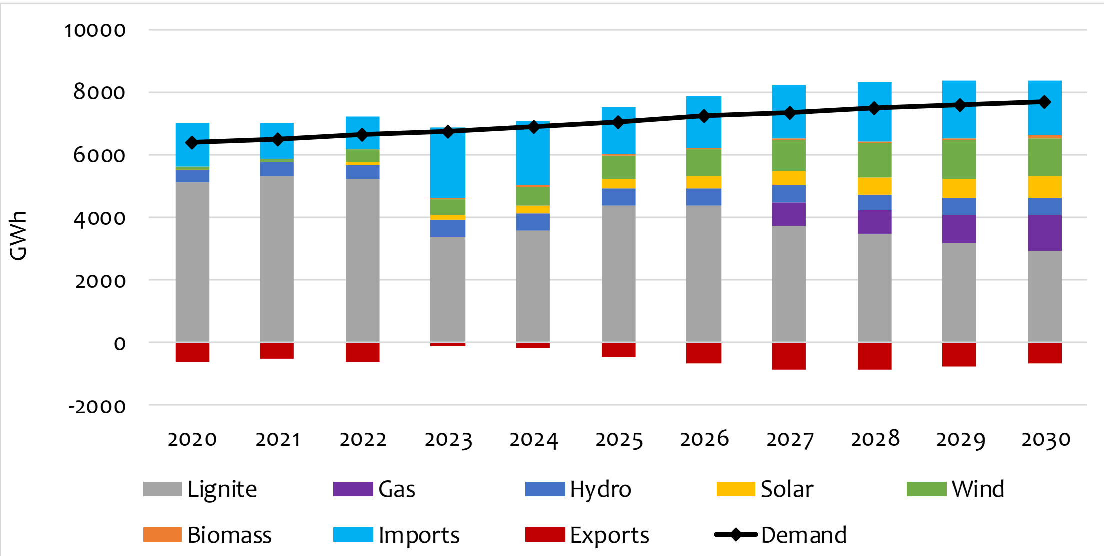

Figure 5-63 Electricity generation per technology in S5.1 scenario

Electricity balance in S5.2, in which CO_2 price is not included in the optimization is depicted in the following figure. In 2030 RE generation is approximately the same as in S5.1 scenario, i.e. 33% of the projected electricity demand. However, there are significant differences in generation of thermal power plants and electricity exchange, compared to S5.1 scenario.

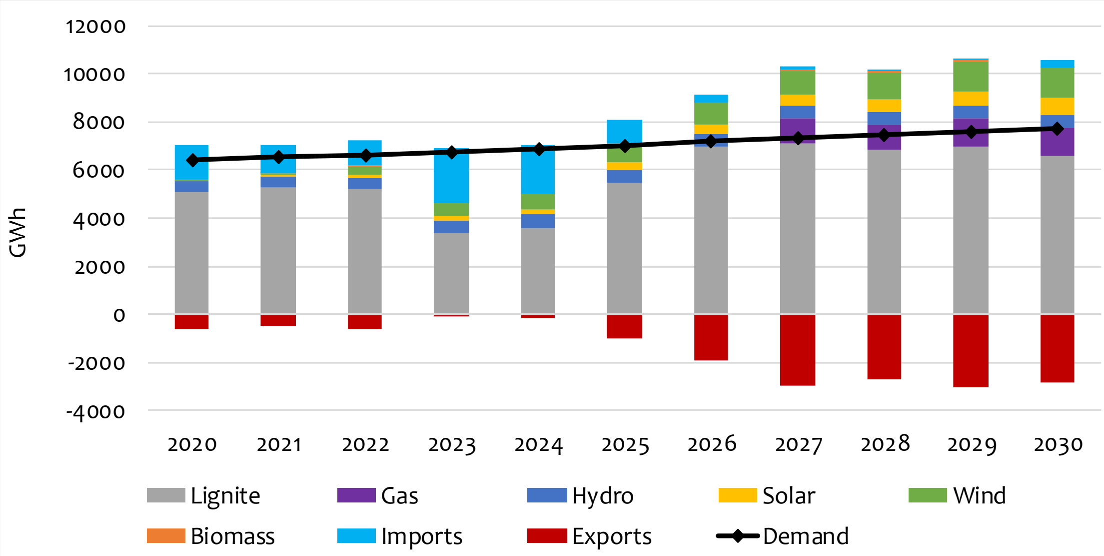

Figure 5-64 Electricity generation per technology in S5.2 scenario

Without CO_2 price, lignite TPPs are more competitive and country is a net electricity exporter from 2026, with more than 10 TWh of domestic generation in 2030. Similar trends can be noticed in electricity balance in S5.3 and S5.4 scenarios, depicted in Figure 5-65 and Figure 5-66, respectively. While in S5.3 generation of lignite TPPs is decreasing from 2026 to 2030, in S5.4 scenario generation of TPPs is increasing, due to their low marginal generation costs.

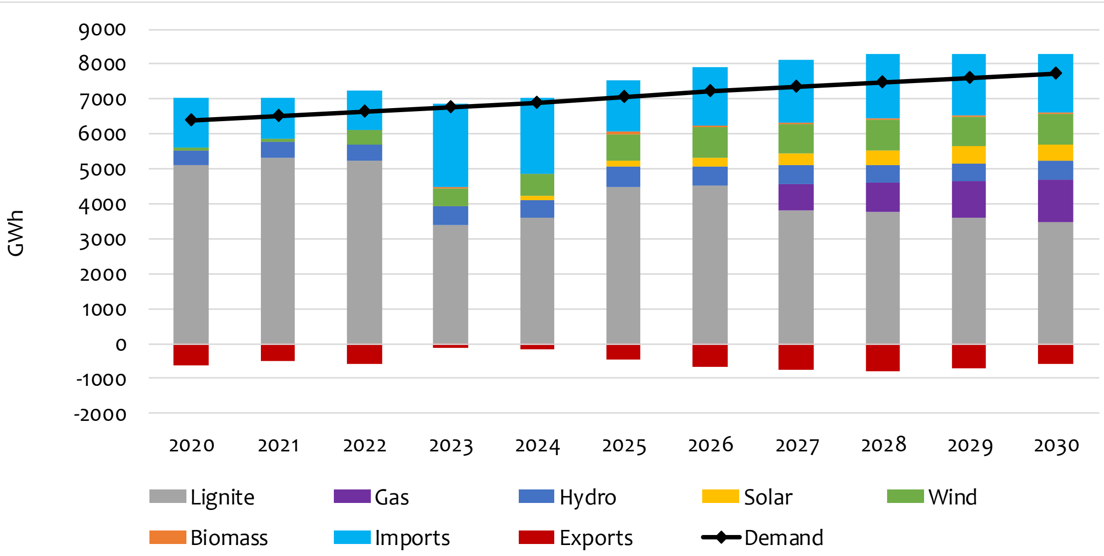

Figure 5-65 Electricity generation per technology in S5.3 scenario

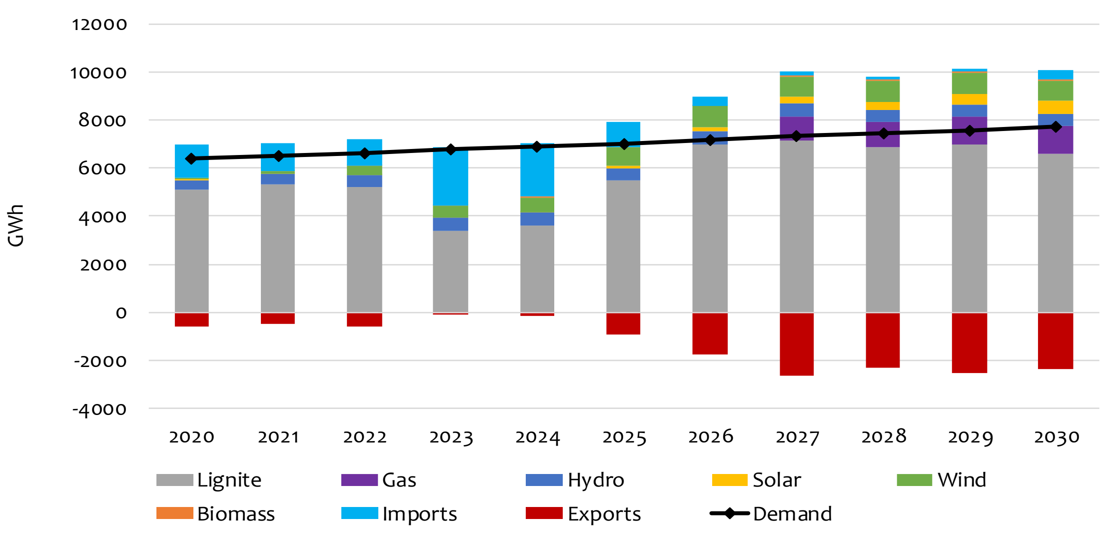

Figure 5-66 Electricity generation per technology in S5.4 scenario

It should be emphasized that in scenarios S5.2 and S5.4 it is assumed that there will be no introduction of carbon payments in Kosovo during the planning horizon. However, projections of prices in the external markets were not subject to change in these analyses, i.e. the prices in neighbouring countries are in line with ENTSO-E TYNDP projections in DE scenario (as described in section 5.2.7.). Without carbon payments and with the external prices according to DE scenario, Kosovo becomes net exporter. However, if the possibility of no carbon payments was analysed in neighbouring countries as well, the amount of electricity exported from Kosovo would probably be lower.

5.7.3 Net present value of costs

All future costs are discounted to their net present value in the year 2020 applying the reference discount rate of 8%. The structure **of total NPV of costs** is presented in the following table.

Table 5-36 Total net present value of costs in S5.1 – S5.4 scenarios (EUR million)

Scenario	Build cost	Fuel cost	Variable O&M cost	Emission cost	Fixed O&M cost	Net import cost	Total NPV of costs
S5.1	1,591	532	132	489	330	349	**3,423**
S5.2	1,591	679	166	-	330	-104	**2,662**
S5.3	1,423	547	135	529	316	374	**3,325**
S5.4	1,417	679	166	-	314	-19	**2,558**

For the four analyzed scenarios the NPV value of build costs ranges from EUR 1.42 billion to EUR 1.59 billion. Build costs are higher in scenarios with higher RES-E target (33%), due to greater investments in RE. The lowest net present value of total cost has S5.4 scenario, which has the lowest NPV of build costs. NPV of fuel costs and variable O&M costs are higher in scenarios without CO_2 price, due to greater engagement of thermal power plants. Net import cost (as the difference between costs of electricity imports and revenue from electricity exports) is negative in scenarios with higher exports compared to imports.

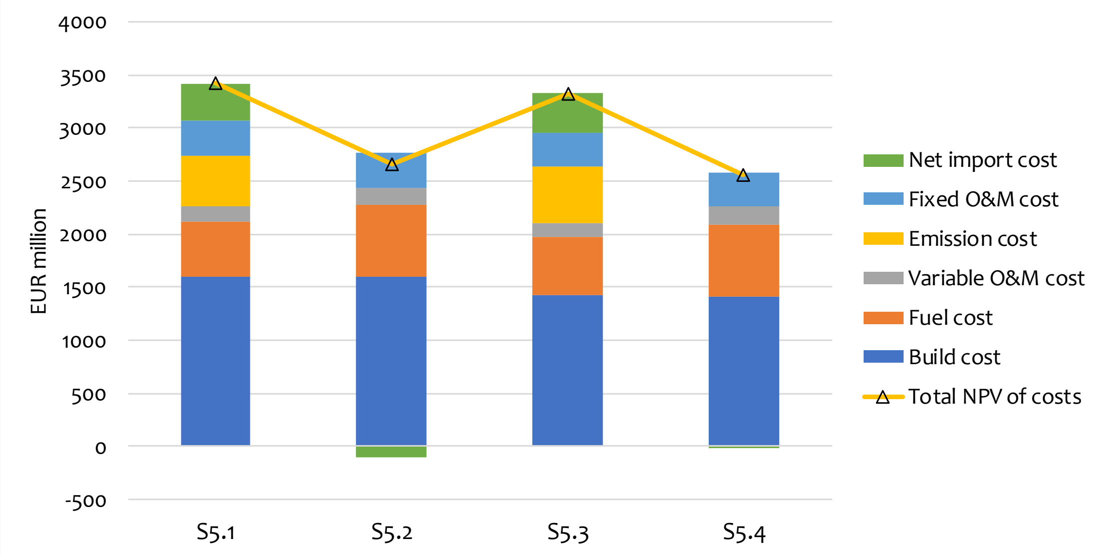

Figure 5-67 Net present value of costs in S5.1 – S5.4 scenarios

The structure of total NPV of costs when local environmental pollution costs are considered is presented in the following table. In comparison to S5 scenario, all scenarios presented in the table, have lower NPV of total costs.

Table 5-37 Total net present value of costs with included local cost of environmental pollution in S5.1 – S5.4 scenarios (EUR million)

Scenario	Build cost	Fuel cost	Variable O&M cost	Emission cost	Local environ. costs	Fixed O&M cost	Net import cost	Total NPV of costs
S5.1	1,591	532	132	489	1,584	330	349	**5,007**
S5.2	1,591	679	166	-	1,819	330	-104	**4,481**
S5.3	1,423	547	135	529	1,602	316	374	**4,926**
S5.4	1,417	679	166	-	1,819	314	-19	**4,377**

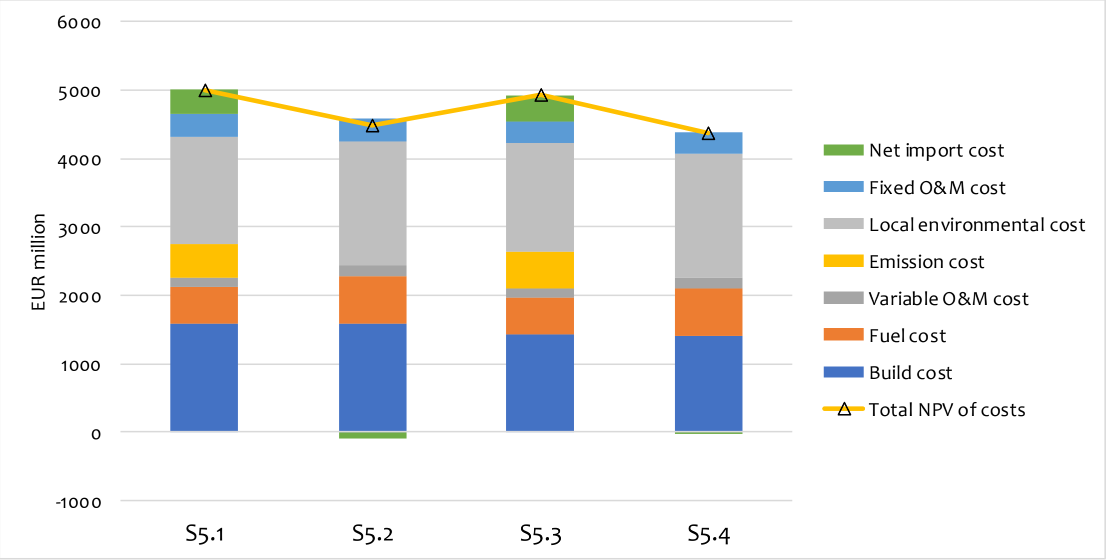

Figure 5-68 Net present value of costs in S5.1 – S5.4 scenarios with included local environmental costs

6 CONCLUSIONS

The long-term planning of the generation expansion for the power system of Kosovo was carried out in several phases. The first phase focused on input data collection and preparation of a power system model in PLEXOS. Input data collection was an iterative process in collaboration with the Beneficiaries and the WB. During that process, two scenarios were developed for the total demand of Kosovo until 2030.

Regarding the candidates for generation expansion, relevant and feasible technology options in the near future were taken into account, with the emphasis on increasing the share of renewable generation to meet the given RES-E targets by 2030. Assessment of wind, solar and hydro potential in Kosovo was performed in order to develop a model within the limits of technically feasible RE potential. The only conventional thermal candidate considered under this analysis is TPP Kosova e Re with 2026 as the earliest commissioning year.

After finalizing the input data collection and modelling the assumptions, a PLEXOS model has been set up. Existing and planned power units were represented with detailed operational characteristics and a long-term expansion model was established. Long-term simulations were carried out for different development scenarios. Based on the long-term simulations, a **generation expansion plan was determined for each scenario**. The identified optimal expansion solution for each scenario was then verified through short-term optimization and hourly simulations.

Two scenarios were analyzed without setting any target for RES-E generation share in total demand (BaU with TPP Kosova e Re and BaU without TPP Kosova e Re). **The two 'BaU' scenarios, resulted in the same expansion plan for RE candidates by 2030**. The model choses to build around 1000 MW of new wind and solar power plants which generate around 2.1 TWh in 2030. Additional RE generation comes from existing RE plants and newly built hydro and biomass plants. Both scenarios resulted in a RES-E share higher than **36% in the total demand in 2030**.

An analysis of scenarios with a defined target for RES-E share in 2030 was also performed, with assumptions which differ in electricity demand projections (Base and High) and commissioning of TPP Kosova e Re (yes or no). In order to fulfil 33% share in 2030 in each scenario, the model chooses to build between 976 and 1,036 MW of new RE capacities, depending on the scenario. Their combined generation, together with the existing RE capacities in 2030, amount to 2.5 and 2.6 TWh, depending on the projected demand scenario.

In all scenarios without TPP Kosova e Re, short-term optimization showed that with limited net imports to 15% of annual demand, unserved energy occurs for years after the decommissioning of TPP Kosovo A. In order to reduce unserved energy, the constraint on net imports was relaxed in the respective scenarios. Short-term verification of the long-term expansion plan showed that **without TPP Kosova e Re in operation, and RES-E shares between 33 and 36% in 2030, annual net imports must be higher than 15%, in order to avoid**

unserved energy. In other words, Kosovo will have to rely to a greater extent on neighboring markets in order to ensure the security of supply.

In all scenarios, the model chooses to build 400 MW of batteries up to 2030. Given the current market situation in the region, in terms of current installed capacity and lack of experience in neighboring countries in battery systems implementation in general, **it is unlikely to expect such high penetration of batteries in Kosovo in the next 10 years**. However, the model chooses to build batteries due to their assumed low capital costs (765 EUR/kW) and high contribution to firm capacity (100%). Batteries also provide more balancing options in terms of variable renewable energy integration.

When it comes to RES-E targets, **in scenarios without TPP Kosova e Re, higher RES-E shares are realized earlier in the planning horizon,** e.g. 27.7% in 2026 in S7 compared to 25.2% in the same year in S5 scenario. Namely, in these scenarios Kosovo will have to rely more on RE capacity from 2026 given the lower capacity of conventional lignite plants. Moreover, in scenario S7 RES-E target of 33% is already achieved in 2029.

All analyzed supply scenarios are compared based on their total costs that consist of the following components: generation build costs, fuel costs, other variable O&M costs, CO_2 emission costs, fixed O&M costs, net import costs and costs of local environmental pollution. Net present value of total costs was calculated applying the reference discount rate of 8%. **The Base without TPP Kosova e Re scenario (S7) has the lowest net present value of total cost**, together with the lowest NPV of build costs, fuel costs and other O&M costs. Moreover, based on the current demand growth and followed by the low probability of TPP Kosova e Re project realization, due to the Contour Global's suspension of the project activities, this scenario currently **seems as the most realistic for possible implementation in terms of least-cost RE development up to 2030, with the 33% RES-E share**. However, it should be emphasized that 33% share is not implemented in any of the Kosovo's national strategic documents related to RE, neither was the result of this study. This share was determined through the discussions in the inception phase of the project and agreed with the Beneficiaries to be used as an input target in the model.

In addition, four scenarios based on **Base with TPP Kosova e Re (S5)** were also analyzed in PLEXOS. The focus of these scenarios was to examine the impact of new gas unit on the least cost RE expansion and to analyze this option with and without Co_2 price in the model. Also, new RES-E target of 25% for 2030 is introduced in two scenarios**.** In scenarios without CO_2 payments there are significant differences in generation of thermal power plants and electricity exchange, compared to the scenarios with CO_2 price. Without Co_2 price, lignite TPPs are more competitive and country is a net electricity exporter from 2026, with more than 10 TWh of domestic generation in 2030. However, projections of prices in the external markets were not subject to change in these analyses, i.e. the prices in neighboring countries are in line with ENTSO-E TYNDP projections in DE scenario. If the possibility of no carbon payments was analyzed in neighboring countries as well, the amount of electricity exported from Kosovo would probably be lower.

When it comes to the technology development, it is certain that the renewable energy sources will be key drivers for of the future electricity generation in Kosovo. Looking at the LCOE calculation and RE curves assessment, **solar power plants are the most favorable option due to their lower capital investment costs in comparison to other technologies**. However, optimization process observes RE candidates taking into account wider context other than competitiveness of a certain technology. More specifically, entire power system of Kosovo is analyzed considering technical constraints of existing and planned units, firm capacity needs and contribution of RE to the firm capacity (10% for wind power plants and 0% for solar power plants), load profiles by distribution areas, RE capacity factors for Kosovo (between 26% and 32% for wind power plants and around 19% for solar power plants). Therefore, **the optimization process provides more accurate RE mix** to meet the growing demand and given RES-E targets by 2030.

Considering all these factors, in all scenarios model chooses to build approximately similar amount of wind and solar generation capacities. It is important to emphasize that WPP Selaci (103.4 MW) is committed project and enters into the operation in 2022 regardless of other constraints in optimization process. Finally, it can be concluded that model chooses to build more generic solar than wind **project candidates**, even though the sum of overall wind and solar capacity is approximately the same. This can be particularly noticed in scenarios with 25% share in 2030. In the respective scenarios, model chooses to build 200 MW of wind candidates earlier in the horizon, followed by investments in around 300 MW of solar candidates later in the horizon, due to their decreasing investment costs over time. This can be an indicative information for the future investors and project developers, as well as the Beneficiaries. But it should be noted that **model doesn't take into account legislation, state laws and procedures** regarding the implementation of future solar power plants into the distribution network and this is something that should be considered before the project development in general. This also implies to the wind projects, but all wind candidates are assumed to be large scale and connected to the transmission network, so the procedure would probably be less extensive than in case of greater number of small-scale projects.

The results presented within this study **should inform the Beneficiaries about the least cost RES electricity mix** and the impact of a wider range of scenario assumptions for the development of RES in Kosovo, taking into account related RE policy in terms of RES-E target achievement.

ANNEX 1:

Table 6-1 Existing hydro power plants in Kosovo

HPP	Installed capacity (MW)	Connected to
HPP Ujmani	35.00	Transmission network
HPP Lumbardhi 1	8.08	Transmission network
HPP Belaja	8.06	Transmission network
HPP Deqani	9.80	Transmission network
HPP Lumbardhi 2	5.40	Transmission network
HPP Brodi 2	4.80	Distribution network
HPP Restelica 1&2	2.28	Distribution network
HPP Brodi 3	4.70	Distribution network
HPP Albaniku 3	4.27	Distribution network
HPP Albaniku 2	3.55	Distribution network
HPP Brezovica	2.10	Distribution network
HPP Orqusha	4.00	Distribution network
HPP Binqa	1.00	Distribution network
HPP Bresana	0.31	Distribution network
HPP Lepenci 3	9.98	Distribution network
HPP Radavci	0.90	Distribution network
HPP Burimi	0.85	Distribution network
HPP Dikanci	3.34	Distribution network
TOTAL	**108.42**	

ANNEX 2:

Table 6-2 Planned projects of small hydro power plants in Kosovo

HPP	Installed capacity (MW)	Overnight build cost (EUR/kW)	The earliest COD
HPP Shtrpce	6.45	1385	2021
HPP Vica	4.60	1560	2020
HPP Sharri	5.03	1200	2021
HPP Lepenci 1	9.98	1110	2022
HPP Soponica	1.30	1390	2021
HPP Brodi 1	2.48	1560	2020
HPP Restelica 3	2.35	1560	2021
HPP Albaniku 4	1.19	1310	2021
HPP Albaniku 1	1.89	1120	2021
HPP Dragash	3.40	1350	2020
HPP Kotlina	4.90	1380	2021
HPP Soponica 2	3.00	1250	2021
HPP Lepenci 2	3.30	1460	-
HPP Ecodri	9.56	1480	-
HPP Sharr Planina 1	1.65	1420	-
HPP Sharr Planina 2	2.20	1870	-
TOTAL	**63.28**		

ANNEX 3:

Table 6-3 Installed generation capacity by technology type in BaU scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	503.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar		50	100	150	200	250	300	350	400	450	500
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1473.8**	**1642.1**	**1513.9**	**1668.9**	**2118.9**	**2088.9**	**2238.9**	**2388.9**	**2538.9**	**2688.9**

Table 6-4 Installed generation capacity by technology type in BaU without TPP Kosovo e Re scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	600	600	600	600	600
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	503.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar		50	100	150	200	250	300	350	400	450	500
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1473.8**	**1642.1**	**1513.9**	**1668.9**	**2118.9**	**1638.9**	**1788.9**	**1938.9**	**2088.9**	**2238.9**

Table 6-5 Installed generation capacity by technology type in Base with TPP Kosova e Re scenario (S5)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	453.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar			40	90	140	190	240	290	340	390	440
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1423.8**	**1582.1**	**1453.9**	**1608.9**	**2058.9**	**2028.9**	**2178.9**	**2328.9**	**2478.9**	**2578.9**

Table 6-6 Installed generation capacity by technology type in High with TPP Kosova e Re scenario (S6)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	503.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar			30	80	130	180	230	280	330	380	430
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1423.8**	**1572.1**	**1443.9**	**1598.9**	**2048.9**	**2018.9**	**2168.9**	**2318.9**	**2468.9**	**2618.9**

Table 6-7 Installed generation capacity by technology type in Base without TPP Kosova e Re scenario (S7)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	600	600	600	600	600
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	453.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar		30	80	130	180	230	280	330	380	420	470
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1453.8**	**1622.1**	**1493.9**	**1648.9**	**2098.9**	**1618.9**	**1768.9**	**1918.9**	**2058.9**	**2158.9**

Table 6-8 Installed generation capacity by technology type in High without TPP Kosova e Re scenario (S8)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	600	600	600	600	600
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	503.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar		40	90	140	190	240	290	340	390	420	450
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	100	150	200	250	300	350	400
TOTAL	**1392.7**	**1463.8**	**1632.1**	**1503.9**	**1658.9**	**2108.9**	**1628.9**	**1778.9**	**1928.9**	**2058.9**	**2188.9**

ANNEX 4:

Table 6-9 Electricity balance in BaU scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5297.1	5226.8	3390.9	3603.2	4307.2	4372.7	4267.1	4138.0	4059.8	3925.0
Existing hydro	377.6	360.4	343.4	344.1	332.6	356.1	324.9	322.6	336.2	351.0	335.3
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1116.2	1233.5
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar		79.3	158.6	237.9	317.7	396.5	475.8	555.1	635.3	713.7	793.0
Biomass		2.5	6.2	12.0	19.0	66.0	36.7	52.4	74.9	91.4	126.9
RES Generation	512.8	641.6	1032.0	1307.6	1500.8	1766.8	1902.9	2112.8	2347.2	2573.4	2789.8
Total Generation	5623.8	5938.8	6258.8	4698.4	5104.0	6074.0	6275.6	6379.9	6485.2	6633.2	6714.8
Demand	6407.2	6522.8	6630.9	6765.6	6908.3	7078.0	7264.0	7403.2	7540.7	7682.5	7810.9
Imports	1391.7	1117.2	1010.7	2197.6	1963.4	1556.4	1709.5	1834.7	1840.6	1870.2	1917.2
Exports	608.3	533.2	638.7	130.4	159.1	552.5	721.0	811.4	785.1	820.8	821.2

Table 6-10 Electricity balance in BaU without TPP Kosova e Re scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5361.2	5417.2	3388.0	3603.2	4353.8	3485.0	3393.7	3292.2	3162.4	3082.6
Existing hydro	375.2	360.2	338.8	334.7	314.8	321.4	366.7	345.2	345.4	339.6	335.7
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1116.2	1233.5
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar		79.3	158.6	237.9	317.7	396.5	475.8	555.1	635.3	713.7	793.0
Biomass		4.4	8.1	11.4	19.3	76.4	95.3	116.8	126.3	131.4	144.0
RES Generation	510.4	643.3	1029.3	1297.6	1483.4	1742.5	2003.2	2199.8	2407.8	2602.1	2807.2
Total Generation	5621.4	6004.6	6446.5	4685.6	5086.6	6096.3	5488.2	5593.6	5700.0	5764.4	5889.9
Demand	6407.2	6526.3	6637.9	6769.4	6912.9	7087.5	7245.3	7387.6	7520.7	7617.6	7790.8
Imports	1392.4	1193.0	1149.3	2282.6	2039.1	1790.2	2041.9	2170.6	2256.1	2165.2	2259.0
Exports	606.6	671.2	957.9	198.8	212.7	799.0	284.8	376.6	435.4	312.0	358.0

Table 6-11 Electricity balance in Base with TPP Kosova eRe scenario (S5)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5308.6	5226.9	3391.0	3603.2	4395.5	4460.7	4358.5	4226.4	4150.3	4183.5
Existing hydro	377.4	360.6	343.4	344.2	329.4	359.4	324.5	325.1	340.9	356.9	323.7
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1116.2	1116.2
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7

New solar			63.4	142.7	222.4	301.3	380.6	459.9	540.0	618.5	697.8
Biomass		2.5	6.2	12.0	19.3	71.5	39.9	54.8	76.8	92.2	95.8
RES Generation	512.6	562.6	936.8	1212.6	1402.7	1680.4	1810.5	2022.5	2258.5	2485.0	2534.6
TOTAL Generation	5623.6	5871.1	6163.7	4603.6	5005.9	6075.9	6271.2	6381.0	6484.9	6635.2	6718.1
Demand	6407.2	6526.1	6634.7	6768.4	6910.6	7078.5	7264.8	7403.7	7542.3	7685.7	7815.4
Imports	1391.8	1159.8	1078.6	2283.0	2042.6	1534.5	1688.7	1809.9	1826.5	1842.1	1891.0
Exports	608.2	504.9	607.6	118.1	137.9	531.9	695.0	787.2	769.2	791.7	793.7

Table 6-12 Electricity balance in High with TPP Kosova eRe scenario (S6)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5104.7	5312.6	5245.4	3391.0	3603.2	4543.1	4608.6	4546.9	4452.4	4407.0	4372.0
Existing hydro	377.6	360.4	343.2	342.5	325.1	365.6	322.3	322.7	337.9	362.7	326.1
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1116.2	1233.5
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar			47.6	126.9	206.5	285.5	364.8	444.1	524.1	602.7	682.0
Biomass		2.5	8.7	12.0	19.1	74.8	43.1	60.0	83.6	98.8	110.4
RES Generation	512.8	562.4	923.3	1195.0	1382.4	1674.0	1795.6	2009.6	2246.4	2481.5	2653.1
TOTAL Generation	5617.5	5874.9	6168.7	4586.0	4985.6	6217.0	6404.2	6556.5	6698.9	6888.5	7025.1
Demand	6408.2	6563.0	6720.3	6891.9	7060.0	7242.1	7426.9	7608.4	7795.1	7986.7	8173.0
Imports	1396.7	1179.6	1126.3	2411.1	2191.7	1541.9	1676.2	1808.0	1846.3	1857.2	1928.9
Exports	606.0	491.6	574.7	105.3	117.3	516.8	653.5	756.1	750.1	759.0	781.1

Table 6-13 Electricity balance in Base withot TPP Kosova eRe scenario (S7)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5109.7	5361.3	5419.5	3388.0	3603.2	4381.7	3497.4	3405.5	3304.0	3268.3	3352.8
Existing hydro	375.2	360.2	338.8	335.0	314.2	321.8	382.5	363.2	360.0	323.2	305.4
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	90.7	91.1
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1112.6	1113.7
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6
New solar		47.6	126.9	206.2	285.9	364.8	444.1	523.4	603.6	664.4	743.6
Biomass		4.4	8.2	11.5	19.7	79.6	99.1	118.0	127.0	92.7	71.5
RES Generation	510.4	611.6	997.7	1266.2	1451.5	1714.4	1991.1	2187.4	2391.4	2493.0	2534.6
Total Generation	5620.1	5972.8	6417.2	4654.3	5054.7	6096.0	5488.6	5592.8	5695.3	5761.3	5887.5
Demand	6407.1	6527.8	6639.0	6769.9	6913.8	7087.8	7245.6	7387.6	7519.2	7611.4	7791.4
Imports	1392.7	1210.1	1160.1	2307.7	2061.6	1779.4	2037.7	2162.2	2252.5	2141.4	2206.2
Exports	605.7	655.1	938.3	192.0	202.5	787.6	280.7	367.3	428.7	291.3	302.3

Table 6-14 Electricity balance in High without TPP Kosova e Re scenario (S8)

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5110.8	5374.0	5410.9	3388.2	3603.2	4503.8	3599.1	3538.6	3469.1	3421.5	3504.7
Existing hydro	374.2	358.7	338.1	334.6	315.1	324.7	375.0	358.9	366.7	344.8	288.9
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	90.5
New wind			295.2	412.5	529.8	647.1	764.3	881.6	999.0	1116.2	1230.1
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6
New solar		63.4	142.7	222.0	301.8	380.6	459.9	539.2	619.4	666.1	711.8
Biomass		4.4	8.1	11.5	19.4	80.9	107.8	125.9	130.0	133.0	122.5
RES Generation	509.4	625.9	1012.7	1281.7	1468.0	1734.3	2008.3	2206.8	2416.9	2561.2	2653.1
TOTAL Generation	5620.2	5999.9	6423.6	4669.9	5071.2	6238.2	5607.3	5745.4	5886.0	5982.8	6157.8
Demand	6408.3	6564.0	6724.4	6891.3	7061.3	7251.6	7408.8	7590.0	7774.3	7911.4	8146.1
Imports	1394.0	1229.8	1213.0	2398.0	2171.8	1801.0	2065.2	2185.1	2283.0	2245.8	2301.6
Exports	606.0	665.6	912.2	176.6	181.6	787.6	263.8	340.5	394.8	317.2	313.3

ANNEX 5:

Table 6-15 Installed generation capacity by technology type in S5.1 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Gas								200	200	200	200
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	453.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar			40	90	140	190	240	290	340	390	440
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	50	50	50	50	50	50	50
TOTAL	**1392.7**	**1423.8**	**1582.1**	**1453.9**	**1558.9**	**1958.9**	**1878.9**	**2178.9**	**2278.9**	**2378.9**	**2428.9**

Table 6-16 Installed generation capacity by technology type in S5.2 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Gas								200	200	200	200
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	353.4	403.4	453.4	453.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar			40	90	140	190	240	290	340	390	440
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	50	50	50	50	50	50	50
TOTAL	**1392.7**	**1423.8**	**1582.1**	**1453.9**	**1558.9**	**1958.9**	**1878.9**	**2178.9**	**2278.9**	**2378.9**	**2428.9**

Table 6-17 Installed generation capacity by technology type in S5.3 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Gas								200	200	200	200
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	303.4	303.4	303.4	303.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar					50	100	150	200	250	300	300
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	50	50	50	50	50	50	50
TOTAL	**1392.7**	**1423.8**	**1542.1**	**1363.9**	**1468.9**	**1868.9**	**1788.9**	**2038.9**	**2088.9**	**2138.9**	**2138.9**

Table 6-18 Installed generation capacity by technology type in S5.4 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	1230	1230	1230	930	930	1230	1050	1050	1050	1050	1050
Gas								200	200	200	200
Existing hydro	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
New hydro	10.5	36.6	46.6	63.3	63.3	63.3	63.3	63.3	63.3	63.3	63.3
Existing wind	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8	33.8
New wind			103.4	153.4	203.4	253.4	303.4	303.4	303.4	303.4	303.4
Existing solar	10	10	10	10	10	10	10	10	10	10	10
New solar					10	60	110	160	210	260	310
Biomass		5	10	15	20	20	20	20	20	20	20
Batteries				50	50	50	50	50	50	50	50
TOTAL	**1392.7**	**1423.8**	**1542.1**	**1363.9**	**1428.9**	**1828.9**	**1748.9**	**1998.9**	**2048.9**	**2098.9**	**2148.9**

ANNEX 6:

Table 6-19 Electricity balance in S5.1 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5308.5	5226.9	3391.0	3603.2	4371.0	4404.3	3754.8	3466.1	3169.1	2938.5
Gas								751.8	747.5	915.3	1148.2
Existing hydro	377.4	360.7	343.3	344.2	332.1	357.3	336.8	326.5	335.4	340.8	329.5
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	534.7	666.3	772.3	891.5	1013.8	1134.8	1137.8
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar			63.4	142.7	222.4	301.3	380.6	459.9	540.0	618.5	697.8
Biomass		3.6	8.5	15.7	15.9	55.9	30.4	36.4	46.9	62.0	73.7
RES Generation	512.6	563.7	939.1	1216.2	1406.9	1682.0	1821.3	2015.4	2238.0	2457.3	2540.0
Total Generation	5623.6	5872.2	6165.9	4607.2	5010.0	6052.9	6225.6	6522.0	6451.6	6541.7	6626.7
Demand	6407.2	6526.0	6633.8	6767.6	6897.5	7053.5	7229.0	7356.0	7489.5	7603.8	7719.9
Imports	1391.8	1159.1	1076.8	2278.8	2051.2	1480.0	1676.3	1685.0	1885.3	1835.9	1763.5
Exports	608.2	505.2	608.9	118.3	163.8	479.5	672.9	851.0	847.4	773.7	670.3

Table 6-20 Electricity balance in S5.2 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5308.5	5226.9	3391.0	3603.2	5472.3	6989.1	7127.8	6875.3	6993.0	6579.8
Gas								1022.2	1017.7	1149.5	1196.5
Existing hydro	377.4	360.7	343.3	344.2	344.1	343.6	343.8	340.6	333.6	328.0	320.3
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind	0.0	0.0	295.2	412.5	534.7	653.4	771.2	890.1	1010.6	1128.9	1130.6
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar			63.4	142.7	222.4	301.3	380.6	459.9	540.0	618.5	697.8
Biomass		3.6	8.5	15.7	15.9	21.1	24.7	30.3	36.5	40.7	47.0
RES Generation	512.6	563.6	939.1	1216.3	1418.8	1620.6	1821.5	2022.0	2222.6	2417.2	2496.9
Total Generation	5623.6	5872.2	6166.0	4607.3	5022.0	7092.9	8810.6	10171.9	10115.5	10559.7	10273.2
Demand	6407.2	6526.0	6635.1	6768.7	6897.4	7030.8	7207.6	7346.8	7471.0	7591.6	7712.4
Imports	1391.8	1159.1	1077.6	2279.9	2039.6	970.3	318.7	131.1	90.7	109.5	303.8
Exports	608.2	505.2	608.5	118.5	164.2	1032.4	1921.7	2956.3	2735.2	3077.5	2864.6

Table 6-21 Electricity balance in S5.3 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5111.0	5308.5	5231.2	3391.0	3603.2	4502.0	4543.0	3814.3	3763.1	3615.5	3465.2
Gas								752.2	825.3	1034.2	1239.6
Existing hydro	377.4	360.7	343.2	344.0	325.0	364.8	342.1	343.1	344.4	308.1	326.1
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.6	91.7
New wind			295.2	412.5	534.8	667.6	773.3	774.4	777.0	774.0	776.5
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar					79.4	158.6	237.9	317.2	397.1	475.6	475.5
Biomass		3.6	8.7	15.7	16.3	60.7	32.7	37.9	39.8	33.8	44.2
RES Generation	512.6	563.7	875.8	1073.4	1257.4	1552.8	1687.1	1773.7	1860.0	1892.5	1923.4
Total Generation	5623.6	5872.2	6107.0	4464.4	4860.6	6054.8	6230.1	6340.2	6448.4	6542.2	6628.2
Demand	6407.2	6526.0	6636.7	6772.4	6902.7	7055.9	7232.5	7360.9	7493.7	7608.7	7724.3
Imports	1391.8	1159.1	1120.2	2416.8	2188.7	1467.9	1678.1	1780.1	1829.6	1762.3	1660.9
Exports	608.2	505.2	590.4	108.8	146.6	466.8	675.7	759.4	784.3	695.8	564.8

Table 6-22 Electricity balance in S5.4 scenario

Technology	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lignite	5109.7	5308.5	5231.2	3391.0	3603.2	5474.1	6989.2	7130.4	6882.4	6993.4	6580.3
Gas								1025.2	1022.2	1154.3	1196.1
Existing hydro	377.4	360.7	343.2	344.3	344.1	343.7	343.7	341.9	336.2	330.4	315.2
New hydro	29.8	94.0	123.2	195.7	196.4	195.7	195.7	195.7	196.4	195.7	195.7
Existing wind	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7	91.7
New wind			295.2	412.5	534.8	653.6	771.4	772.9	776.0	777.1	777.0
Existing solar	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.7
New solar					15.9	95.2	174.5	253.8	333.5	412.3	491.6
Biomass		3.6	8.7	15.7	16.3	22.7	26.6	31.4	37.8	42.2	42.3
RES Generation	512.6	563.7	875.8	1073.7	1212.8	1416.3	1617.3	1701.1	1785.4	1863.2	1927.2
Total Generation	5622.2	5872.2	6107.0	4464.7	4816.0	6890.4	8606.5	9856.6	9690.0	10010.9	9703.6
Demand	6407.1	6526.0	6636.7	6772.4	6903.8	7036.0	7210.8	7350.0	7474.0	7594.8	7715.7
Imports	1392.1	1159.1	1120.2	2416.5	2230.7	1067.7	376.9	164.1	112.9	142.7	362.6
Exports	607.3	505.2	590.4	108.8	142.9	922.1	1772.6	2670.8	2328.9	2558.8	2350.5