International Journal of Computational and Experimental Science and Engineering (IJCESEN)

Vol. 10-No.3 (2024) pp. 517-526
http://www.ijcesen.com

ISSN:2149-9144

Research Article

Assessment of Climate Change Mitigation potential of the Kosovo energy and transport sector

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Article Info:

DOI: 10.22399/ijcesen.325
Received : 22 May 2024
Accepted : 01 October 2024

Keywords:

Climate change mitigation,
thermal power plant RES,
Electro-mobility.
EnergyPLAN model,
pumped hydro.

Abstract:

The Energy and transport sector in Kosovo are the main emitter of greenhouse gases (GHG) with a share of about 85% in total annual emissions. In energetic sector, 95-97% of emissions are associated with the electricity generation due to the predominant role of lignite fuelled power plants. The electricity sector contributes about 80% of total CO_2 emissions in Kosovo. Those make the energy and transport sector the main emitters of CO_2 and also the main target for CO_2 emissions reduction. The National Energy and Climate Plan 2021-2030 aims to ensure a reliable supply of energy for Kosovo and proposes targets for renewable, energy efficiency, and greenhouse gas reductions. This paper presents analyses of different time frame scenarios for development of the Kosovo energy system in relation to climate change mitigation potential of the Kosovo energy and transport sector. The national energy system of Kosovo is modelled using EnergyPLAN software which integrates energy for electricity, transport and heat, and includes hourly fluctuations of energy demand and energy production. Three scenarios of Kosovo Energy system are modelled; starting point scenario 2019 and two long term scenarios 2030 with 23.3% and 41.8% share of renewable. An analysis of the overall energy system costs and security of supply with a main focus in electricity sector of the three scenarios is performed.

1. Introduction

In October 2014, The European Council endorsed 4 targets on the 2030 climate and energy policy framework at EU level: (a) a binding EU target of 40% less greenhouse gas emissions by 2030, compared to 1990; (b) a target of at least 32% renewable energy consumption;(c) a 32.5% improvement in energy efficiency; (d) and electricity transmission interconnection of at least 15%.
On 18 November 2015, the European Commission adopted its first Communication on the State of the Energy Union, stating that integrated national energy and climate plans (NECPs), addressing all five key dimensions of the Energy Union: decarbonisation, energy efficiency, energy security, the internal energy market, research, innovation and competitiveness, as crucial tools for the development of more strategic energy and climate policy planning. Mostly of Member States submitted their draft 2030 NECPs at the end of 2018.
Similar to the European Union, the Contracting Parties of the Energy Community in which Kosovo is one of the members are committed to preparing their NECPs focusing on monitoring and reporting in the areas of renewable energy efficiency, and greenhouse gas emissions as well as other information relevant to climate change. The ongoing development of National Energy and Climate Plan of Kosovo 2021-2030 which will be finished at the

end of the actual year sets out the basic goals of the Government of Kosovo in energy sector development, taking into account sustainable economic development, environmental protection, sustainable and reliable energy supply to final customers, efficient use of energy, development of new conventional and renewable generation capacities, creation of a competitive market, development of the gas system, and creation of new jobs in the energy sector. Kosovo National Energy and Climate Plan which is an update of Energy Strategy 2017-2026, is focused on policies and measures that will increase the share of renewable and distributed energy sources, increase energy savings and improve energy efficiency [1].

The aim of this work is to develop a set of models of the Kosovo energy-system based on targets set in the National Energy and Climate Plan of Kosovo. Furthermore, this work shows how these targets are met, and analyze the technical and cost implications of these targets.

The methodology used in this work consists of fourth steps:

-The first step is to create a reference model of Kosovo's energy system which represents the year 2019 and to model using EnergyPLAN software on the basis of confirmed relevant energy system data.
-The second step is to perform the simulations and calibrate the model to the required accuracy level by comparing it with the known real data.
-The third step is to create two energy system models that reflect the year 2030 with different goals and targets about RES penetration and CO_2 emission.
-The fourth step is to perform several simulations with different simulations strategies in the EnergyPLAN software and to choose the proper one which fits Kosovo Energy System behavior.
In this work, two different scenarios of the future development of Kosovo's energy system for the year 2030 are presented and discussed, based on the goals set in the NECP 2021-2030. Both future energy models are compared with a reference scenario in relation to RES penetration, reduction of CO_2 emission and always considering the security of energy supply as a main impacting factor for the sustainable economic development of the country. The first scenario so-called "business as usual" is moderate in regard with RES penetration and reflects the base case scenario in the Kosovo Energy Strategy 2017-2026 [2], however, the second scenario presents intensive penetration of wind and solar power in electrical system with a 41.8% share, and appreciably reduction of power production from lignite TPPs which reflects Energy Transition scenario in line with targets set by the European Union on the 2030 climate and energy policy.

2. Reference Energy System

A detailed energy system of Kosovo is modelled using EnergyPLAN (Aalborg University 2009). The model is an input/output model that performs annual analyses on an hourly basis. Inputs are energy demands and energy supply for different available technologies which include also demand distributions, and varying renewable energy distributions through a year time period, with 8784 entered values. A number of technologies can be included enabling the reconstruction of all elements of an energy system and allowing the analyses of integration technologies. The model is specialized in making scenarios with a large amount of intermittent renewable energy and analysing CHP systems with large interaction between the heat and electricity supply [3]. The start point year for modelling of the Kosovo Energy System is considered the year 2019 which forecasted input data are available on the web page of the Statistical Institute of Kosovo and System and Transmission Operator of Kosovo (KOSTT) [4].

2.1. Demand and supply data for the reference model 2019

The main input data of energy demand for the referent scenario of the Kosovo Energy system are presented in table 1. With a share of around 59.6 % of total primary energy consumption, lignite is the most important energy resource in Kosovo. For electricity production uses 90% and the rest of household heating and industry. Oil accounted for around 24 % of primary energy consumption in 2019 and continues to be the major fuel in the transport sector. Consumption increased at an average annual rate of 4.4 % over the period 2012-2019, mainly as a result of increased demand for diesel and petrol in the transport sector, although this was tempered by a decline in the use of oil in other sectors, such as for district heating of Pristina (Capital City) after implementation of cogeneration project – or the connection of "Kosova B" thermal power plant in the District Heating company [5]. Because Kosovo is not linked with regional gas infrastructure, the share of gas is only 2.9% and is used mostly for household heating, industry and transport. Biomass

(wood, pellets, briquettes, etc.) are still playing a significant role in household heating with a share of around 13.3 %. The main input data on energy supply for the referent scenario of the Kosovo Energy system are presented in table 1. With a share of around 93.6 % of total produced electricity, lignite Power Plants with available capacity of 800 MW are still the most important power generation of Kosovo. Small run river hydropower plants built in different time periods, 32.4 MW Wind Park Kitka and 10 MW solar mainly carry the remaining part of about 6.4% of electricity production from RES in the country. Electricity consumption in Kosovo in the time period 2000-2012 has been steadily increasing with an average growth rate of 6% [6]. Over 2012 in the last 7 years the electricity consumption is reduced to an extent of 1.7%, mainly as a result of the reduction of commercial losses at the distribution company, and partly from activation of the Co-generation in the capital city and the measures and initiatives taken from the government for the efficient use of electricity. Still, households are main consumers of electricity with 49% share in total electricity consumption mainly used for heating, cooking and recent years also for cooling systems. The industry consumes around 22% and commercial buildings and public lighting consumes 17% of total national electricity consumption. The rest of electricity consumption is attributed to the distribution losses (commercial and technical), and only 2.5% of the transmission losses which is very well developed in the last decade after significant investments done on transmission reinforcement infrastructure.

2.2 Simulation results obtained by EnergyPlan

The Kosovo energy system is modelled based on actual condition. Simulations performed by using Energy Plan show inflexible energy system with very low possibility for optimisation, due to the dominance of inflexible and very old power generation based on lignite power, and lack of flexible units such a hydro power plan with an ability to provide power system reserves needed for maintaining power balance in real time. Kosovo Power System imports during the high loads which occurs in the winter and exports during light load. Hungarian Power Exchange is considered as a reference for hourly import and export prices. As is shown from simulation results for electricity presented in Table 2, Kosovo imports when the price of electricity per MWh is higher and exports when the price is very low. The average price of 2019 based on distribution file: "Hourly Hupex" based on hourly recorded data from Hungarian Power Exchange is around 50.36 € per MWh, maximal prise is 139 € per MWh and the minimum price is 3 € per MWh. The total import payments for 2019 are around 57 M€ and export payments 29 M€. In total Kosovo power system is close to be balanced in terms of electrical energy, but the generation adequacy is negative during the high load regime which occurs in the winter. That means the peak demand and load variations cannot be covered by power generation available capacities, so in those circumstances power imports is needed The total amount of CO2 emissions in Kosovo caused by energy use is around 9.26 million tons. The electricity sector contributes about 78% of total CO2 emissions in Kosovo, transport with 18% and district heating and individual heating with 4%. South European Countries are not part of the European Emissions Trading System (ETS) which charges power plants and factories for each tonne of carbon dioxide they emit. Furthermore, considering the actual cost of 20 euro/t (CO2) the total hypothetical cost of CO2 emission for the year 2019 for the Kosovo Energy sector is estimated to be around 185 M€. The overall yearly total cost of the energy sector (without CO2 cost) is estimated to be around 1.24 billion € for the year 2019. The total share of renewable energy sources including biomass in reference to the total produced energy for the year 2019 is around 14.5 %. The main contribution goes to the biomass (wood) which mostly is used for household heating and cooking. In figure 1 are shown two typical operation regimes of electricity production and demand for three selected days in January. Even currently, with the limited capacity of RES with the domination of almost 95% by low flexibility TPPs, our system urgently needs flexible units and additional backup power to be activated in case of unpredictable failures of existing units.

3. Forecasted Energy system 2030

The energy system for the year 2030 is modelled in Energy Plan software which includes all relevant input data from Kosovo Energy Strategy 2017-2027 and National Energy and Climate Plan of Kosovo

Table 1. *Demand and supply data of Kosovo Energy System referent model 2019*

Annual consumptions 2019	**TWh/year**	Annual production 2019	**TWh/year**	**Capacity MW**
Fuel Consumption		Electricity production		
Lignite	20.18	TPP	5.54	800
Oil	8.14	HPP run river	0.28	75
Naturalgas	0.90	Wind	0.09	32.4
Biomass	4.55	Solar	0.02	10
Total Fuel	**34.16**	**Total electricity**	**5.93**	**882.5**
Electricity	6.07	District heating	0.25	
Heat	4.93	Individual heating	4.68	

Table 2. *Simulation results obtained by EnergyPlan for referent model 2019*

Annual 2019	Demand	RES	TPP	Import	Export
Energy	TWh	TWh	TWh	TWh	TWh
	6.07	0.39	5.54	0.95	0.81
Power	MW	MW	MW	MW	MW
Average	701	44	643	108	89
Max.	1260	89	800	367	179
Min.	292	18	450	0	0

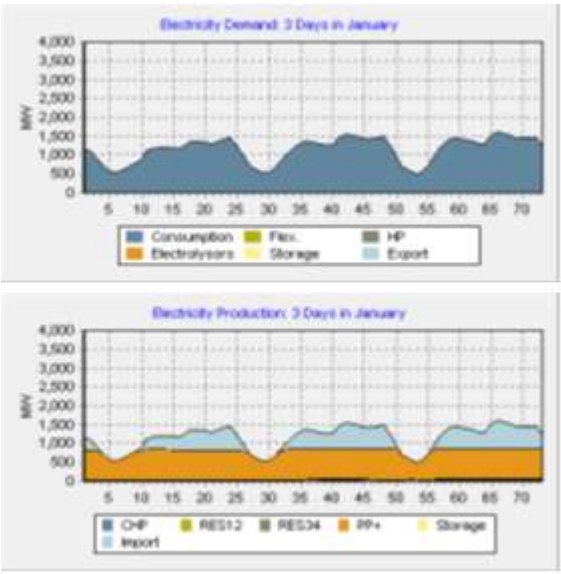

Figure 1. *Electricity demand and production for the selected three days in January 2019*

2021-2030. For this work we have selected two main scenarios:

-Business as usual scenario (Base scenario of Energy Strategy)

-Intensive RES scenario (Base Scenario of Energy and Climate Plan)

As is presented in Energy Strategy and in National Energy and Climate Plan the new generation development in Kosovo for both scenarios till 2030 will be a mix of conventional and renewable sources. The Business as Usual Scenario included in Model 2030 consists of significant improvements in generation capacities and environmental improvements:

-1050 MW TPP in operation.

-250 MW pump storage HPP to provide system regulation reserves (secondary and tertiary) and to support RES integration

-150 MW run river hydropower, 250 MW wind power, 100 MW solar and 30 MW biomass power plants
-Extension of Cogeneration from TPP Kosova B and new district heating's plants in main Kosovo cities based on biomass and gas.
-Improvements in energy efficiency performance (buildings, solar thermal, efficient apparatus)
-Improvements in transport sector (Electro-mobility, the vehicle with low CO2 emissions, electrical railway etc.)
While the Intensive RES scenario foresaw that new TPP based on lignite will not be built, and Kosovo Power System will operate till 2040 with only one TPP Kosovo B (3x300 MW). This scenario is more import depended and intensive installation of RES and flexible unit are proposed as follow:
New 250 MW pump storage HPP to provide system regulation reserves (secondary and tertiary) and to support RES integration
-700 MW wind power
-350 MW solar

3.1.Climate change mitigation model of Kosovo Energy System -2030

The Energy Strategy aims to create a developed sustainable energy sector, which is friendly to the environment and health, supporting economic development and social wellbeing in Kosovo, under a free and competitive market. The National Energy and Climate plan 2021-2030 has focused on fulfilling Kosovo's obligations about concerning to emission reduction, generation diversity, energy efficiency and the integration of renewable sources. Significant development on RES integration will be expected, mainly in wind and run river hydro power plants. So far, 32.4 MW of wind power is being built, while by the end of 2021 are expected to be built up to 105 MW, confirmed based on already signed connection agreements with KOSTT (Transmission System Operator in Kosovo). Till now around 600 MW of wind power and 150 MW solar power are connection application in the transmission network received and the trend is increasing year by year. The implementation of the RES project will be mainly depended from selected supporting mechanism and market signals in electricity sector. Regarding energy efficiency, Kosovo has committed to meet the savings target of 9% of overall energy consumption, in accordance with Directive 2006/32/EC. Kosovo has also taken the obligation to implement new EU policies deriving from Directive 2012/27/EC on energy efficiency [7]. In this paper, the efficient use of energy is mainly considered the reduction of energy consumption through improvements on efficient buildings and apparatus, systematically replacement of 50% of existing low efficient vehicles with highly efficient vehicles. This is reflected in electricity demand reduction and fuel reduction. We assumed also an integration of more than 20000 electric vehicles in the transport sector till 2030 for both scenarios, which will reduce additionally fuel demand but will increase electricity demand for around 100 GWh considering 100 kWh (400 km) vehicle battery and 20000 km driving distance per vehicle. Actually, in Kosovo in circulation are around 360000 motorised vehicles, of which 260000 are cars dominated by diesel engine cars with 70% share [8].To enable the integration of renewable resources into a power system dominated by thermal power plants such is a Kosovo Power system, it is more than necessary the construction of flexible units that provide the power regulating reserves to ensure a balance between load and generation in real-time. More RES is penetrating in the power system than more regulating power reserves is needed, especially when RES is dominated by wind and solar [8,9]. The most optimised solution is a construction of 250 MW pump hydro storage as is presented in the Energy Strategy of Kosovo. Other storage technologies are now in discussions in the Kosovo Electricity Sector such battery storage but still, there is some technical unknown aspect about lifetime and market issues and regulations regarding private investments which are driven by market signals. Based on European regulations the TSO's do not have the right to be an owner or to invest in battery storage or pump storage. Additional support for RES integration in each power system is the share of reserves between countries on a regional basis, through market integration. A smaller power system needs more power reserves when operates alone than when they operate in a larger integrated power system. The first step already is done by creating the LFC Block between Kosovo and Albania. Albania operates mainly with HPP, and two complementary power systems can optimise the operational cost.

3.2.Input data and simulation results for Business-as-Usual scenario

The main input data of energy demand and supply for Kosovo Energy System for Business-as-Usual Scenario model 2030 are presented in Table 3. With a share of around 49% of total primary energy consumption, lignite will be also in 2030 the most

important energy resource in Kosovo but significantly reduced compared to the reference model 2019 in the amount of 5.69 TWh. The oil will account for around 21.8 % of primary energy consumption in 2030. Oil consumption used by transport is assumed to decrease due to improvements in transport efficiency and developments in electro-mobility. The gas use is assumed to increase considering the early phase of gasification of Kosovo through the TAP gas pipeline. Biomass use will also increase with a share of 23.4 % due to the extension of the use of biomass for district heating developments and power plants based on biomass. Regarding electricity production in model 2030, the share of TPP's based on lignite will be around 76.7% and RES production will reach 23.3% of total electricity production. In total the RES, including biomass will contribute with 28% in total primary energy used in 2030.

Table 3. *Demand and supply data of Kosovo Energy System model 2030 base scenario*

Annual consumptions 2030	**TWh/year**	**Annual production 2030**	**TWh/year**	**Capacity MW**
Fuel Consumption		Electricity production		
Lignite	14.49	TPP Kosovo B+New	5.49	1000
Oil	6.46	HPP run river	0.45	150
Ngas	1.72	Wind	0.51	250
Biomass	6.96	Solar + biomass	0.44	130
Total Fuel	**29.63**	Pump storage HPP	0.57	250
		Total electricity	**7.46**	**1830**
Electricity	7.33	District heating	1.5	
Heat	6.42	Solar heating	0.2	
		Individual heating	4.72	

Simulations performed by using Energy Plan show significant improvements in CO2 emission reduction. The total amount of CO2 emissions caused by energy use in 2030 will be around 7.24 million tons, or 2 million tons less than in the reference energy system. Kosovo Power System in 2030 will be fully sustainable and mostly balanced with a small amount of export. The role of the 250 MW Pump storage hydro will be essential in increasing the flexibility and optimization of the power system due to the high penetration of RES. Part of the pump storage HPP capacity in both operation regimes in pumping and generating mode will be used by system operators for secondary and fast tertiary power reserve which will be increased from RES integration, and the rest will be used for the optimisation of generation and load. The electricity demand of pump storage HPP is included in total electricity consumption. Figure 2 shows simulation results for production and demand for three selected days. As is shown in the demand diagram, pump storage consumes electricity during the night, contributing stabilisation of the load. The district heating from co-generation from thermal power plants will contribute to the electricity demand reduction, but also to CO2 reduction due to the elimination of electricity conversation of the heat energy. The significant role will play also district heating facilities based on biomass. The electricity used for heating of household and commercial buildings will be replaced by thermal energy produced from biomass and gas [10, 11]. The electro-mobility combined with smart grid technology and a surplus

of RES production will contribute in CO2 reduction even some parts of the electricity demand of electric vehicles will be covered by TPP's. The summarised simulation results are presented in Table 4.

As is shown in Table 4, around 2.119 billion € are investment costs in new generation capacities which should be invested during 2020-2030. The annual fuel cost will reach the amount of 0.765 billion € in 2030, mostly dominated by the transport sector. Total annual operational and maintenance of generation facilities will be around 38 M€. A calculated yearly cost of CO2 is shown to be around 181 M€, with the assumed carbon price of 25€/t in 2030.

3.1.Input data and simulation results for Intensive RES Scenario model 2030

The main input data of energy demand and supply for the Kosovo Energy System for Intensive RES scenario model 2030 are presented in Table 5 and 6. The simulation results are presented in Table 7. It is assumed the same energy and electricity demand as in the base case scenario. Regarding electricity production, the share of TPP's based on lignite and gas will be reduced from 79.6% to 58.2% in reference to the Business -as Usual Scenario, and RES production will reach 41.8% of total electricity production. The CO2 emission will be reduced from 7.24 Mt to 5.57 Mt compare to the Business-as-Usual Scenario, respectively 40% reduction of CO2 emission compared to the reference model. The CO2 cost savings are around 41.75 M€ yearly. The system will need around 0.71 TWh imports with an associated cost of 63 M€ yearly. As is shown in Table 6, around 1.875 billion € are investment costs in new generation capacities which should be invested during 2020-2030. The annual fuel cost will reach the amount of 0.731 billion € in 2030, mostly dominated by the transport sector. Total annual operational and maintenance of generation facilities will be around

Table 4. *Simulation results obtained by EnergyPlan for model 2030*

Annual 2030	Demand	RES	TPP	Import	Export
Electricity	TWh	TWh	TWh	TWh	TWh
	7.33	1.97	5.49	0.06	0.09
Power	MW	MW	MW	MW	MW
Average	835	214	625	7	10
Max.	1549	534	1000	120	250
Min.	415	32	400	0	0
Annual fuel costs			Generation costs	CAPEX M€	Annual O& M costs M€
Coal	77		TPP	1339	20
Fuel Oil	123		Wind	275	8
Diesel	318		Solar	80	1
Petrol/JP	67		River HPP	180	4
Gas	16		Pump HPP	250	4
Biomass	164		Biomass	45	1
Total	**765**		**Total**	**2169**	**38**

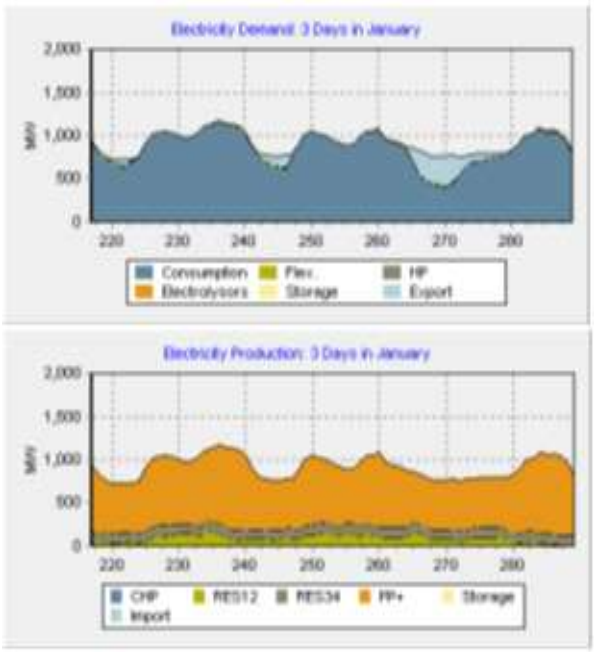

Figure 2. *Electricity demand and production for the selected 3 days in January for Business-as-Usual Scenario*

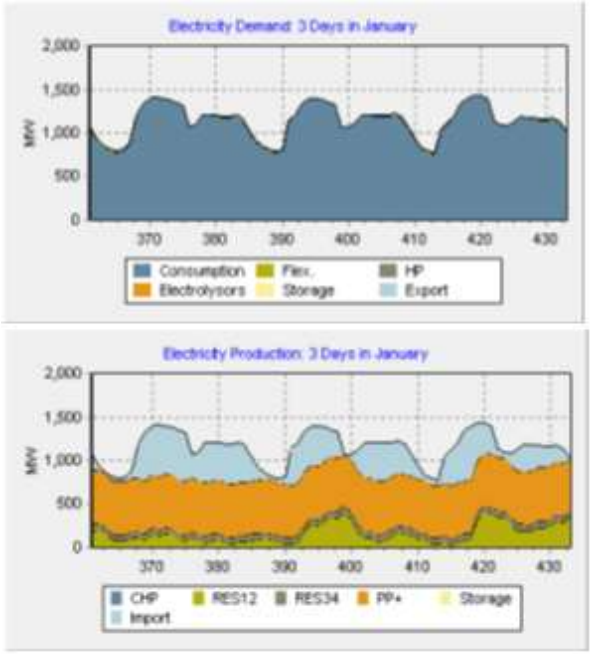

Figure 3. *Electricity demand and production for the selected 3 days in January Intensive RES Scenario*

Table 5. *Demand and supply data of Kosovo Energy System model 2030 for Intensive RES scenario*

Annual consumptions 2030	**TWh/year**	**Annual production 2030**	**TWh/year**	**Capacity MW**
Fuel Consumption		Electricity production		
Lignite	9.84	TPP Kosovo B	3.5	600
Oil	6.74	HPP run river	0.45	150
Ngas	2	Wind	1.44	700
Biomass	6.96	Solar + biomass	0.82	380
Total Fuel	**25.54**	Pump storage HPP	0.57	250
		Total electricity	**6.78**	**1830**
Electricity	7.33	District heating	1.5	
Heat	6.42	Solar heating	0.2	
		Individual heating	4.72	

Table 6. *Simulation results obtained by EnergyPlan for model 2030 Intensive RES Scenario*

Annual 2030	Demand	RES	TPP	Import	Export
Electricity	TWh	TWh	TWh	TWh	TWh
	7.33	3.28	3.5	0.71	0.1
Power	MW	MW	MW	MW	MW
Average	835	196	398	81	13
Max.	1549	1200	600	803	573
Min.	415	37	220	0	0
Annual fuel costs			Generation costs	CAPEX M€	Annual O& M costs M€
Coal	51		TPP	350	5
Fuel Oil	123		Wind	770	22
Diesel	318		Solar	280	3
Petrol/JP	67		River HPP	180	2
Gas	16		Pump HPP	250	4
Biomass	156		Biomass	45	1
Total	**731**		**Total**	**1875**	**37**

37 M€. As is shown in Table 6 the maximal export of power will reach 803 MW due to power output variation of the RES, and 573 MW for exports. This will be challenging for System Operator to balance in real time the power system. System will need additional flexible units such a battery storage or gas units. Figure 2 shows simulation results for production and demand for three selected days.

4. Conclusions

The paper presents a new approach to the assessment of climate change mitigation potential of the Kosovo energy system using Energy Plan software. Two future energy system scenarios were analysed: Business as Usual and Intensive RES Scenarios for the year 2030 and compared with a referent Scenario for the year 2019. Implementation of National Energy and Climate Plan 2021-2030 will lead to a significant improvement in environmental issues and sustainable energy system in Kosovo. The most promising scenario regarding climate change mitigation of the Kosovo Energy and Transport sector is a scenario with intensive penetration of RES into the Energy System of Kosovo. The amount of CO_2 emission will reduce 3.7 M tons per year as a result of reducing lignite consumption and oil consumption, or 40% less CO2 emission compared with a reference model 2019. Penetration of 700 MW wind and 350 MW solar will challenge system operators concerning balancing the system in real-time. Therefore, the role of 250 MW pump storage hydropower plants will be significant for further penetration of RES. It also shows the importance that regional integration of small power systems is essential to mitigate the problem of balancing issues in real-time and to cut the costs of system operations. Furthermore, significant potential for CO_2 reduction is shown to be the transport sector and in the efficient use of energy. Kosovo should follow the global trends in electro-mobility, smart grids, and net-zero energy buildings.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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