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Research Article

Role of wind energy in sustainable development in coal-based systems: Case of Kosovo

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Abstract: Most of the countries in South-East Europe primarily depend on fossil fuels to cover their energy demands. The paper discusses the future perspective on wind energy in the country, where over 90% of energy is generated in coal-fired thermal power plants. Given the energy crisis, that has gripped the world, the possibility of covering the increased energy demand is being studied, especially during the winter. Based on current trends on energy generation, with just symbolic participation of wind, hydro and solar energy, the potential for maximization of the use of wind energy is considered, which means the use of each identified adequate location throughout the country. The main advantage here is that the maximum energy produced by wind is during winter when demand increases. This is important to know that Kosovo faces significant heating problems and its demand is covered with electricity. Analyzes prove that the country has a generous wind capacity, which reduces to a certain extent the need to import and even enables the export of energy under certain conditions. The potential installation capacity in Kosovo is 510.9 MW, of which 32.4 MW is currently in operating conditions. From the analysis made for the current wind farm in operation, the plant capacity factor is 31.8%. The study of the results indicates a direct correlation between the increase in load during the winter season and the electricity production by wind farms, thereby, the energy demand can be sufficiently covered.

Keywords: *Capacity factor, Energy efficiency, Maximization, Renewable energy, Wind energy*

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Nomenclature	
P	power output,
C_p	turbine efficiency/coefficient of performance,
ρ	air density, kg/m^3
A	swept area in m^{2,}
w	wind speed, m/s
GP	gross potential of wind farm, kWh
PW	installed power of wind turbine
N	number of wind turbines
τ	period of time.

1. INTRODUCTION

Kosovo is a country in the Western Balkans that has high coal potential in terms of reserves or potential capacities. According to research conducted in this field, Kosovo ranks second in Europe and fifth in the world [1]. Until now, energy production in Kosovo has been continuously only through thermal power plants. However, due to the rise of concerns regarding the environmental protection and the sustainability of world development and the fact that thermal power plants do not guarantee this it is planned the diversification of energy sources [2]. In addition to raising awareness of the use of renewable resources and their diversification, the number of manufacturers of these technologies has also increased. In our case, the growth of wind turbine manufacturers affects the increase in competition and, consequently, the reduction of investment costs [3, 4]. The World Health Organization has highlighted that wind energy is one of the most pleasant forms of electricity generation without affecting people's health [5]. However, the study carried out by Strielkowski shows that investment in the establishment of wind farms are made by countries with a very high GDP [5]. The analyses carried out in this way show that most of the countries in the energy transition phase and achieving the decarbonization objectives also have the main problem in financing such projects [6]. Energy policies also play an essential role in underdeveloped and developing countries. Ref. [7] shows that the tariffs in the case of Kosovo are flexible for electricity generated by wind energy. Thus, in addition to the split unit system, wind turbines can also function quite well as hybrid systems [8]. In Ref. [8], the study performed for Kazakhstan shows the importance of energy policies for the development of a related energy field. Then, in the same study, different scenarios were shown for the energy and transport sector by integrating wind farms to a significant extent, thus influencing the reduction of CO_2 emitted. The studies carried out for the wind energy sector in Kosovo show that up to 450MW wind farms can be installed [9,10]. Recognizing this, the study carried out in this field shows that the penetration of wind energy in this field is of great importance. Likewise, the increase in the penetration of wind energy in global statistics is large [11,12]. Recognizing the stochastic nature of the wind, the integration of the energy produced in the electrical energy network remains more problematic [13], but the development of electronics in this field has influenced the reduction of this problem [14,15]. Another study [16] found that in the case of the large integration of wind farms in an energy network, it is important to try to make the points of connection-integration scattered and not close to each other. The reason here lies in the fact that when the number of farms connected to the public grid is large from a single station, power losses will increase. The next work further [17] explains the possibilities when the energy generated by the wind is maximized to realize energy storage. Other more important issue in the context of the increase in the considered participation of wind farms is the economic aspect to reach the optimal level of their participation. This is analyzed through the following work [18], where the possibilities of hydrogen production are shown through the use of the energy stored in the battery. This energy is produced by wind farms. In order to provide some other possibilities in addition to storage in batteries, pumped hydro storage is currently being discussed in Kosovo through pumping hydropower plants. Such a comparison of operation for the case when large capacities of wind farms are in operation is performed in the Ref. [19]. Based on the analyses, it appears that the market cost will be reduced in the case of the operation of wind farms and pumping hydropower plants. In the other paper [20], a connection is shown between the possibility of maximizing the energy produced by wind farms in function of the distribution of wind speed in a certain country. The follow-up study [21] carried out for Ireland shows the importance of maximizing wind energy to reduce the very large involvement of gas as well as to protect the environment. In the context of the penetration of wind energy for different countries, works have usually been analyzed that had to do with developed countries and that such an investment did not have risks as in the case of non-developed or developing countries. Such studies have also been performed only in terms of economic benefit based on the unit cost price. In the current factual situation in Kosovo, the energy sector is almost entirely based on coal. Other renewable energy sources are hydropower and wind energy. All possible wind farms are located in mountainous terrain [22]. For the studies conducted in Kitka, Koznica, Bajgora and Zatriq, knowing that there is a correlation between potentials and average wind speeds [23,24], then, similarly can be done for other places that are further presented through the study. The novelty brought by the work is related to the concentration of only one renewable source to cover the increasing loads since, from renewable energy sources, there is a correlation between the load during the winter and the energy production from the wind. As a novelty of the present study, it has to do with the fact that the entire sector of wind farms that will be realized is expected to be done in mountainous terrain. Then the whole study, which is performed based on the same terrain, assumes the same coefficient of performance for the turbines in the respective farms. This paper flows as follows: First, the real energy consumption for the respective year taken in the study is shown, and then the possible production with the whole farms in operation. Putting in the function, the maximum capacity of wind energy is further shown by considering the capacity factor and the energy that can be produced, and its role. Results are then compared for different scenarios.

2. MATERIALS AND METHODS

Kosovo is in a deep energy crisis and is close to an energy collapse. Thus, in order to be able to cover energy needs, it relies on imports. The biggest energy challenges in Kosovo are during the winter. Although Kosovo has built some solar, water, and wind energy plants, there is a lack of load coverage. Hydro energy has problems in the context of limiting water sources. Solar energy is mainly focused on the prosumer system due to the large areas required to implement solar parks. Thus, wind energy currently remains the most promising in the context of renewable resources.

In Kosovo, wind energy development began with the installation of 3 small turbines in Golesh [25]. Seeing the growing need for renewable energy development, in this case, wind energy, the research in this field has increased. Performed analysis for wind energy in Table 1 shows the potentials in specific places as exploitable potentials for the whole country taken in analysis, Kosovo. For the performed analysis, 2019 is taken into consideration from the data provided by the Energy Regulatory Office and the Operating System, Transmission, and Energy Market in Kosovo. Energy consumption during each day of this year is shown in Fig. 1.

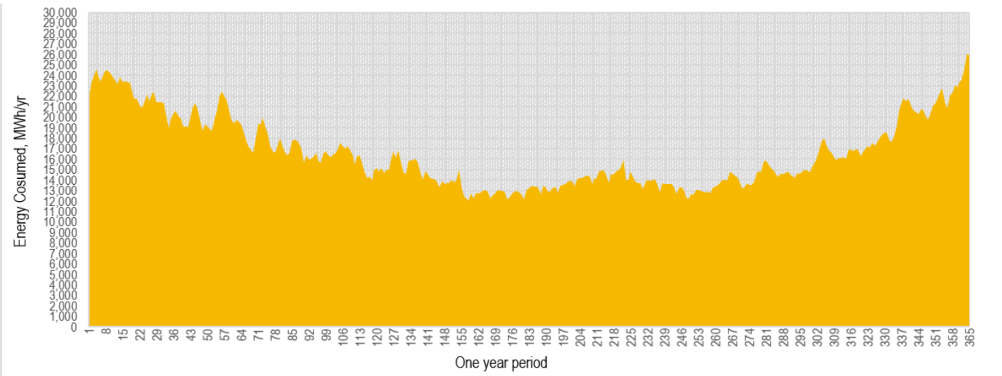


Figure 1. Total Energy Consumed during the year 2019 in Kosovo, in MWh.

Because renewable sources of energy are clean sources, their use has also started rising in Kosovo [26,[27]. All renewable energy sources are necessary for each country's proper energy transition. Of course, in this case, the problems that may arise during the implementation phase should also be taken into account [21]. In the study [28] authors concluded that Kosovo has the opportunity to develop each of these technologies and only the use of relevant technologies in the transport and energy sector will affect the reduction of pollutant emissions. The current energy situation in Kosovo relies mainly on thermal power plants, a small number of hydropower plants and wind farms that are in the initial stages. The thermal power plants are designated as Kosovo A and Kosovo B, where Kosovo A has five units and Kosovo B has two units. For Kosovo A, according to the order, the installed capacities are 65, 125, 200, 200 and 210 MW [22]. Meanwhile, the Kosova B thermal power plant consists of two units with the same capacity, 339MW [22]. In current conditions, due to obsolescence, the first two units of Kosovo A are not in operation [22]. In the case of hydropower, plants are Ujmani (35MW), Lumbardhi 1&2 (8+7 MW) as shown in the energy balance in Fig. 2. There are also small hydropower plants such as

Decani (9.5 MW), Brodi 1&2 (4.7+1 MW), Belaja (7.5 MW) Restelica 1&2 (2.4 MW), Albaniku 2 (4 MW) and Dikanci (3 MW) [22]. In addition, energy balance is shown in Fig. 2 for the energy generated from Kitka wind farm.

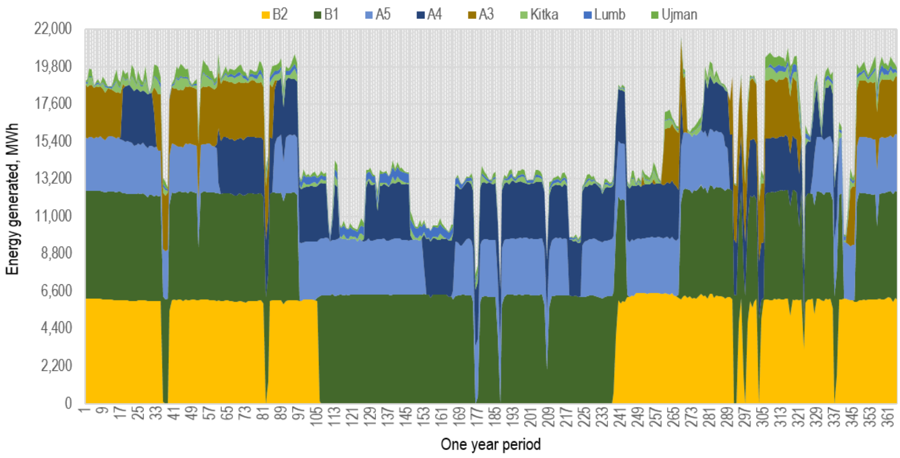


Figure 2. Daily energy production in Kosovo from all power plants during 2019, in MWh.

Until recently, in Kosovo, there was only one wind power plant in Kitka. In the last part of 2021, the wind farm in Selac, which has a considered installed capacity, was put into operation. To motivate that, it is also studied with hypotheses that there can be a maximization of the energy produced until the following; the monthly energy produced in the Kitka farm is shown, in MWh. From Fig. 3, it can be seen that the largest production of energy from the wind is produced in the months of November and February, while the minimum is during the month of August.

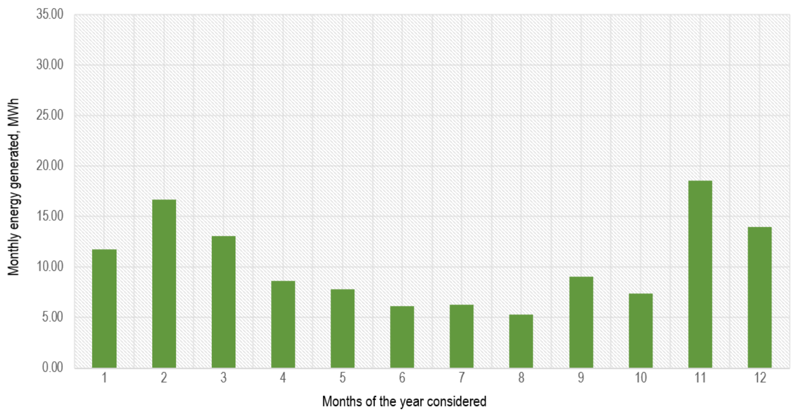


Figure 3. Energy generated during each month for 2019, in MWh.

The wind projects that are foreseen to be built in Kosovo, respectively, their potential exploitable in the entire territory of Kosovo is shown in Table 1 [29].

Table 1. Potential of wind energy in Kosovo.

Name of Project	Installed Capacity (MW)
Kitka	32.4
Bajgora – Sowi	105
Çyçavica	100
Koznica	34.5
Budakova	46
Zatriq	45
Krajkove	21
Shtime 1	100
Shtime 2	27
Total	510.9

Wind farm in Golesh is not included in this table because, for the respective reasons, it is not allowed to enter the network of energy produced by this farm. The analysis was performed by considering the current state of energy demand coverage and utilization of the entire potential of wind energy. This means, in this case, the total potential of installed power is 510.9 MW. A summary of all power generation units, both renewable and conventional, over the months and energy consumption for the respective months are shown in Fig. 4. From this figure, it can be seen that when having an increase in the demand for energy in the winter months, and this is related to the fact that, especially in the part of cities, the vast majority of them are heated with electricity.

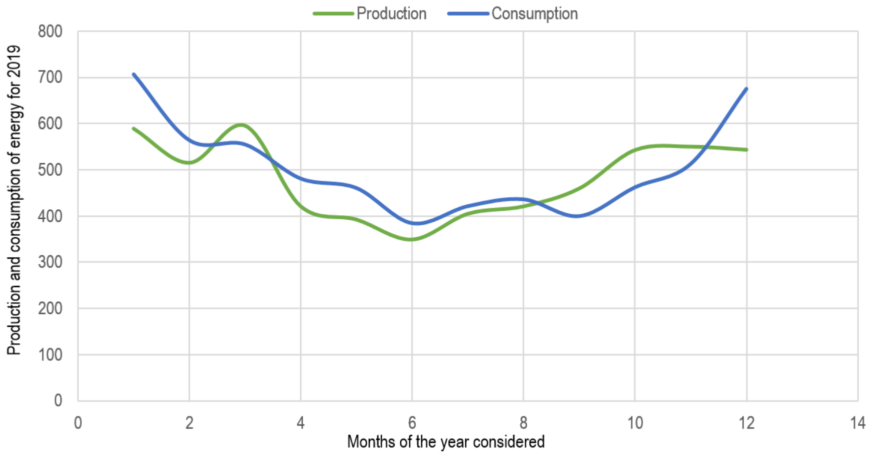


Figure 4. Production and consumption of energy during 2019, in GWh.

As shown in Fig. 5, the most significant difference between energy consumption and production with current plants in Kosovo is for December and January. Two months when the demand for heating is at its peak. In December, this difference is -133GWh and in January is -119GWh. It is shown that during the summer season, there is more energy produced than is real consumption. This is of course economically favorable that enables the increase of electricity exports, especially for Albania, which during the summer season encounters a lack of capacity because over 90% of energy is generated by hydropower plants.

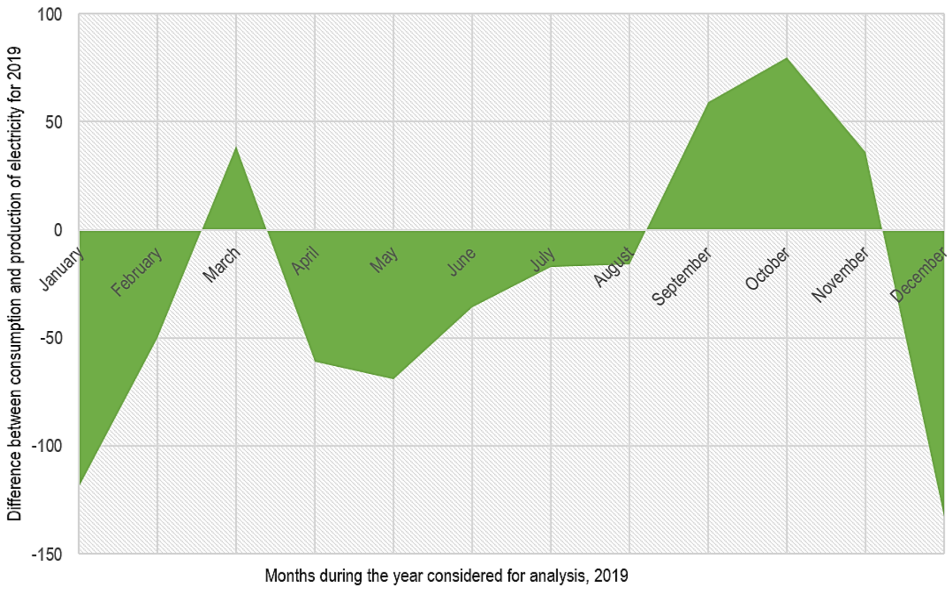


Figure 5. The difference between energy consumption and production during the year

The same diagram shows that even during the spring season, there is a significant imbalance between consumption and energy production. Of course, this increase is a good correlation between the wind potential in that season and the energy needs. To be more precise, the role that maximizing wind energy will play show the difference between demand and energy produced. Fig. 6 shows the plant activities, import and export amounts of energy in detail in units of GWh/yr. The produced energy is maximum in winter times and minimized in summer. Here, also the differences between the generations of plants can be seen in detail.

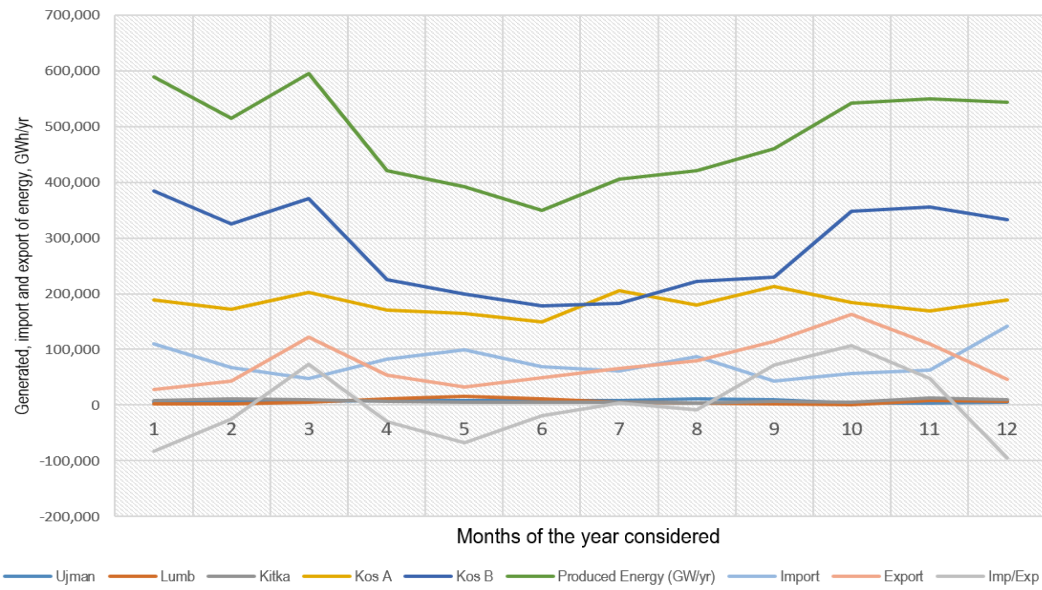


Figure 6. Energy generated, import, export, and the relationship between them, in GWh.

In the absence of wind data at the height of the placement of wind turbines in each location to take as a potential location then our analysis should include some approximations. The calculation of the power which can be achieved is calculated by the following formula [30]:

$$P = \frac{1}{2} \cdot C_p \cdot \rho \cdot A \cdot w^3 \quad (1)$$

Where P is the power in W, C_P is coefficient of performance in percentage, ρ is air density in kg/m^3, A is the wind turbine area in m^2 and w is the wind speed in m/s. The gross energy potential of the output that could be produced by all the assumed farms is described by the following expression [31]:

$$GP = \sum P \cdot N \cdot \tau \quad (2)$$

Where GP is the gross production Wh, P the power of wind turbines in W, N is the number of wind turbines and τ is the number of hours of working of wind turbines based in coefficient of performance. Another issue that can be taken in the study has to do with the issue of CO_2 emission. It is known that renewable technologies use energy sources that do not emit harmful gases during their operation. However, during the construction phase of the components that make up the wind turbines, a considerable amount of energy is consumed. The consumption is also high during the transportation phase. During the decomposition phase, a significant amount of harmful gases are also released [32]. Based on the study [33], it appears that on average wind energy systems will emit 11 grCO_2/kWh compared to 980 gr CO_2/kWh for coal-fired power plants. According to the New Energy Strategy for the Republic of Kosovo from 2030, Kosovo will pay the carbon tax due to the emission caused. This naturally encourages a rapid development of renewable technology. CO_2 emission is calculated with the following equation [27, 34]:

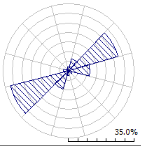
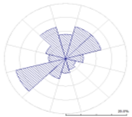
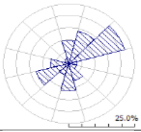
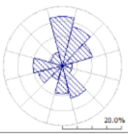
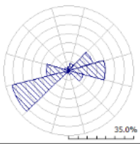
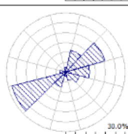
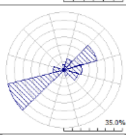
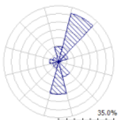
$$\text{Emission} = \sum_{i=1}^{n} \text{Emission}_i = \sum_{i=1}^{n} \text{Activity Level}_i \cdot \text{Emission Factor}_i \quad (3)$$

Emission$_i$: Amount of CO_2 emitted from the consumption of material i (e.g. iron) [29].
Activity Level$_i$: Material consumption for material i [29].
Emission Factor$_i$: Consumption of material i's emission factor [29].

3. RESULTS AND DISCUSSIONS

For the current Kitka farm and those as potential sites further presented the average speed and wind rose. The data for wind roses and the average speed in the terrains with potential for the whole country are obtained from the data presented for the 100 m measurement height by Denmark Technical University wind atlas. It can be noticed that Zatriqi and Bajgora have the highest wind potential. The average wind speed at an altitude of 100m is shown in Table 2.

Table 2. Wind rose and average wind speed for each location.

Potentially place name	Wind rose	Average wind speed, m/s
Zatriq		5.3
Bajgora		6.98
Qyqavica		5.5
Koznica		6.16
Budakova		5.25
Krajkove		5.51
Shtime		5.38
Kitka		6.69

The presentation of the wind rose for each location, considered as potential, and the one in operation, is taken based on the Global Wind Atlas. Now, since is not the same capacity factor in all possible farms and since the conducted studies show values from 20-40%, then some scenarios will be built 20, 25, 30, 35, and 40% will be considered as a capacity factor for farms in general. Using Eqs. (1,2,3) make it possible to calculate how much annual energy is produced by each potential site. The difference between each scenario is shown in Fig. 7. It can be seen that since the change in the annual energy produced is not that big, the change in the emitted grams of CO_2 is significant.

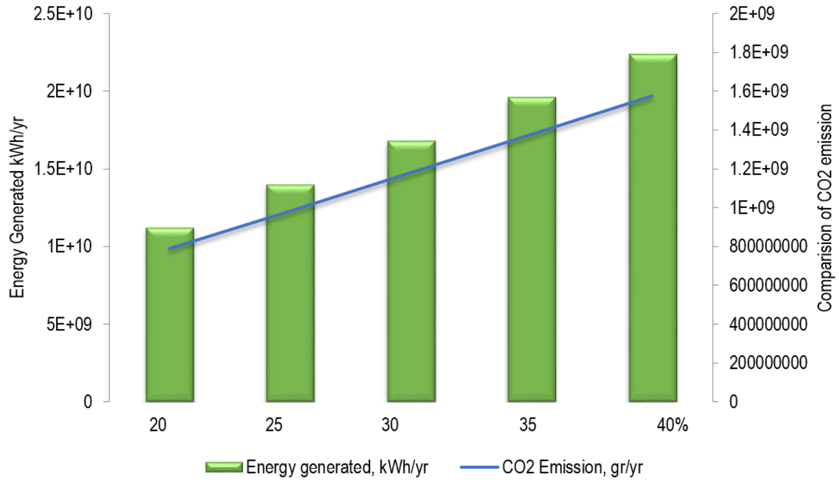


Figure 7. Comparison of CO_2 emission and energy generated in each scenario.

Therefore, if the annual electricity production from the two power plants is taken into account and using the CO_2 emission factor of 980 gr/kWh, the results will be as in Fig. 8.

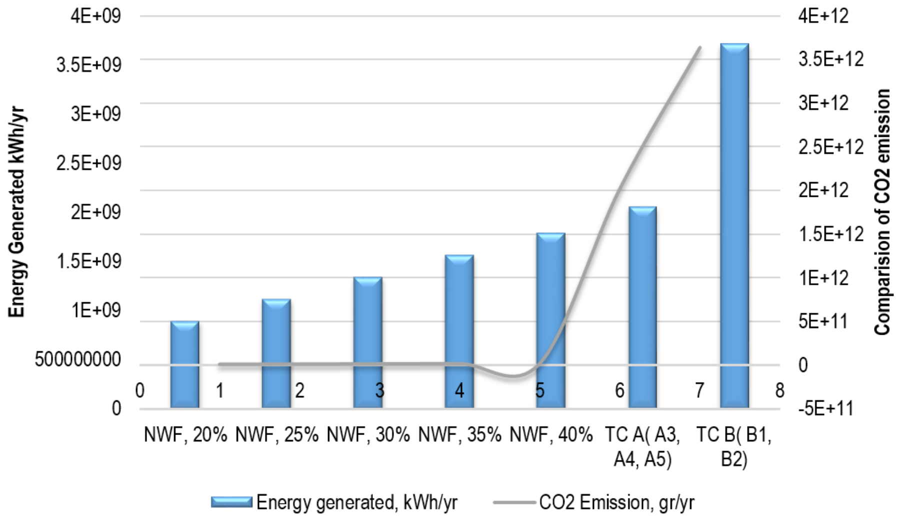


Figure 8. Annual energy and CO_2 emission for new wind farms and thermal power plants in Kosovo.

The difference in the energy produced for each unit in TPP Kosovo A and Kosovo B is not as high as the difference in CO_2 emitted. To clearly reflect the difference in the level of CO_2 emitted by the current power plants and the full capacity of the new wind farms, Fig. 9 is presented. Here, it can be seen that the ratio is higher for the case when the capacity factor is lower because the energy generated by the wind will be lower and the emission as well.

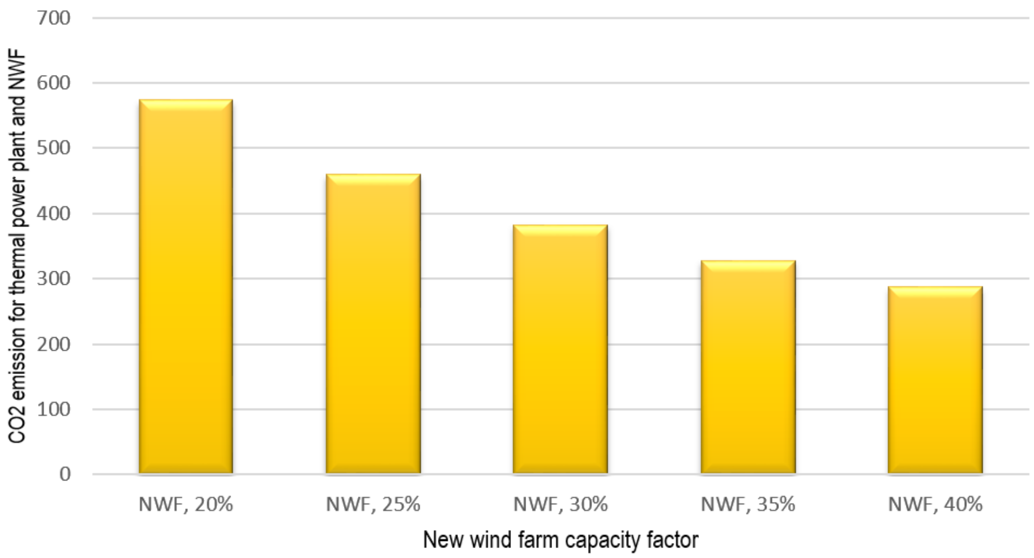


Figure 9. The ratio between CO_2 emissions for both thermal power plants and NWF, according to the energy generated in 2021.

According to the Report of the Energy Regulatory Office, for the year 2021, which is known as the year of the energy crisis, the import was 1,311 GWh [35]. Thus, according to the scenarios built for wind energy, which also includes a farm that is currently in operation, that is, that of Kitka, the diagram given in the Fig. 10 will be built. It can be seen that in an average capacity factor of 31.8%, the need for energy import can be covered. Then, with the increase in the capacity factor, the possibilities for energy export also increase, especially during the winter.

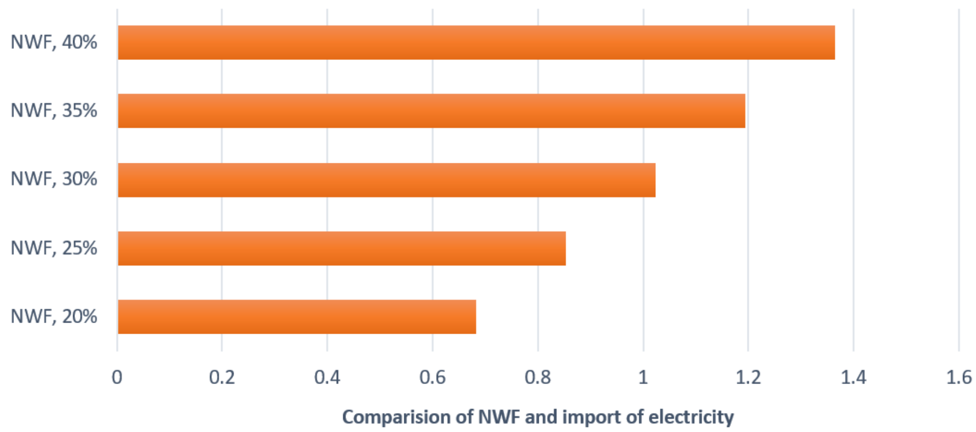


Figure 10. Ratio of New Wind Farms energy generated and import of electricity for 2021 year.

Thus, considering an average factor of the capacity of wind farms in all those farms under consideration of 35%, the annual energy that can be produced is shown in Fig. 11. The same figure also shows the energy produced by all sources in Kosovo that are currently in operation.

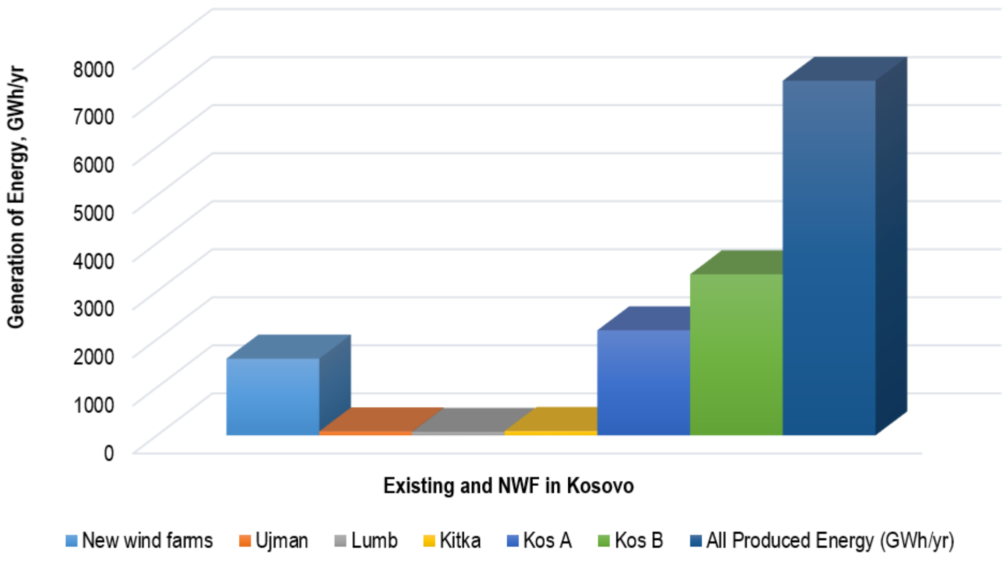


Figure 11. Energy generated in Kosovo, GWh/yr.

What is natural, and worth noting, is that Kosovo will not be able to create sustainable energy strategies without thermal power plants. Other sources, especially renewable energy, will be used to cover vacancies and imbalances. This is also clear from Fig. 11, where even with the maximum wind capacity cannot be achieved, even half of the energy produced by the two power plants A and B.

4. CONCLUSIONS

Kosovo, the country considered in the analysis, except that over 90% of the energy it generates is based on fossils, has the problem of outdated technologies in these plants. Thus, the emission of CO_2 and other greenhouse gases that are caused because of the burning of coal remains a concern. Renewable energy sources and energy development are the current global challenges, which need to be answered. In the context of the Kosovo case analysis, it is worth noting that there are scarce hydropower resources, but solar energy and wind resources are large. The study shows that Kosovo has the potential for wind energy. This potential, if operational, will be able to cover current and growing needs, especially during the winter. The studied solution enables, among other things, the export of energy, which will be achieved during the summer and autumn. The participation of significant amounts of renewable resources in the country will enable the emission of various gases to decrease.

Conclusions from this study can be summarized below:

1. Therefore, if comparing the emission ratio, here can be concluded that in the case, when the average capacity factor for all farms is 20%, the ratio between the CO_2 emissions of thermal power plants and NWF is 580.
2. In the case when the production is with an average capacity factor of 40%, the ratio between the CO_2 emissions of thermal power plants and NWF is 280.
3. The geographical position of Kosovo, being on the border with Albania, which has the highest energy coverage from hydropower plants, enables the export of energy generated during summer and autumn in Albania with the smallest transmission losses.
4. Energy will not only come from potential wind farms but also from the two main thermal power plants, Kosovo A and Kosovo B, with the respective units shown, as well as the mini-hydropower plants. The reason that makes such a scenario sustainable is the fact that it is associated with scarce water resources and scarce free land spaces to build solar power plants. This is because the efficiency of solar modules is low, and they require a lot of space to achieve the necessary capacity.

5. With the addition of so many renewable resources regarding wind farms in Kosovo, of course, the level of voltage variability will increase, which harms the network, and a system must be found that accepts these voltage fluctuations.
6. A possibility discussed quite a lot in Kosovo is the hydro-pumped storage system, which has an average reaction time/change of the flow regime of 8 seconds.
7. A subsequent study that takes into account the maximization of wind and solar energy, as well as the use of the pumped energy storage system in the scenario, would complete the current study.

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