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Power system analysis: The case of Albania

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ABSTRACT

Climate change, sustainability and supply security are today priority themes worldwide. This paper presents the results of an Albanian power system analysis. An energy system analysis model based on linear programming is used for modelling and optimization. The analyses cover a number of scenarios where the studied system is subjected to changes by introducing other renewable energy sources, energy conservation measures and measures to promote renewable energy. The study shows that because of a combination of cheap hydropower, low electricity prices and rather high investment costs, it is very hard for new non-hydro renewable energy sources to be profitable with the prevailing market condition. Regional power exchange based on bilateral agreement in some way or another encourage dependency on import instead of facilitating the introduction of new renewable energy sources. On the other hand, solar wind power could be viable if market-based power prices or other policy measures are introduced to promote the use of solar and wind power.

Keywords: Power System; Renewable Energy; Modelling; Optimization; Analysis; Green; Sustainable; Production.

1. INTRODUCTION

Access to energy has and will have a significant impact on a wide range of development indicators in a society. This includes not least health, education, food security, poverty etc. Energy has played and will play a key role in the industrialization of nation and it affects the lives of everyone. All activities related to the different sectors such as households, service, industry and agriculture involve energy as a basic input and that makes energy a key source of economic growth [1]. On the other hand, providing energy has not been problem free, particularly due to its connection to environment and climate. The fact that most of the energy used in our world comes from hydrocarbon-based resources makes the situation more difficult.

As a basic condition to keep the economic engine moving constantly, it is important to have a stable energy security. Energy security is the uninterrupted availability of energy sources at an affordable price [2]. In the twelfth chapter of its book "Clean Coal Engineering Technology", the author presents the key issues in terms of energy security, such as resource availability (i.e, long-term security), which is the actual available amount of the energy resource and system reliability (i.e., short-term security), which is the continuous supply of energy, to meet consumer demand at any time [3]. The lack of energy security is consequently associated with undesirable economic and social effects in terms of such as absence of energy or volatile prices to prices. Thus, diversified production and energy security policies are a country's key security points.

The growing demand for oil, natural gas and other non-renewable sources is endangering the security in the world, leading to an energy crisis, hence the focus is concentrated more and more towards renewable energy sources. Furthermore, due to exploitation and application of these traditional energy sources, the whole world is facing the environmental pollution problems. These problems must be resolved by the large-scale deployment of renewable energy [4].

While in developed countries researches, politics and new energy projects are focused on flexible generation and demand-side management in order to maintain secure and stable operation in the grid [5, 6], much of the focus in developing countries like Albania is on meeting domestic energy needs and securing a stable power system. In the Nordic countries particularly Norway, not only the power system is stable, but it is also has exceptionally low carbon emissions. These countries seem to have utilized their natural sources to generate renewable energy and also produce a large share of energy by using combined heat and power CHP which is one of the most efficient ways of producing both heat and electricity simultaneously [7].

A detailed analysis of the power system must be carried out in order to find the weakness and strength of a power system and thereby contribute to the stability of the system. This analysis is essential to ensure sustainability. Western Balkan countries, including Albania, facing great challenges, but at the same time with a tremendous potential for renewable energy, have the potential to improve their energy production situation, increasing the chances of securing a sustainable development for their countries [8]. One of the most important goals of sustainable development is clean energy, and it remains a crucial objective that has to be fulfilled by many developed and developing countries [9]. Results from studies that analyze the power systems of these countries, for example for Kosovo, show that the goal of a flexible and sustainable energy system can be achieved and implemented successfully [10].

Given the problems of the Albanian energy system, especially during certain periods of the year, this paper aims to analyse and provide possible optimization options for this system. Integration of new renewable energy sources specifically solar and wind energy into Albania's energy system will diversify the country's power production mix, increase domestic capacity, and minimize future environmental impacts. In addition, rational investment in new renewable energy systems will also allow Albania to maintain its power system's position as one of the greenest in the region [11].

Albania is endowed with abundant hydro energy sources and the power supply is dependent mainly on hydropower. However, the capacity is not sufficient to meet the demand particularly during dry season. The fact that electricity production is completely dependent on hydrological conditions results in an insecure power supply system. For instance, the year 2017 marked a huge reduction of power reduction compared to 2016 [12]. This has led to significant increase in import. This means Albania has to depend not only on a single energy resource but also on import. There are however times where Albania enjoys plentiful production from hydro for instance 2018 [13, 14].

This instability of the power system comes because of its dependence on hydropower, resulting in dependence on hydrological conditions, thus endangering unpredictable electricity purchases, mostly in dry periods of the year (summer-autumn), because of the limited generation capacities. Another issue related to this system is the location of the three main hydropower plants: Fierza, Komani and Vau I Dejes, which generate most of the electricity in Albania. These hydropower plants are located in the north part of the country, while the largest consumption of power is in the central and southern parts of the country.

Through system analysis, this paper aims to assess whether Albania has the potential to meet firstly its own domestic power demand and become a possible "green battery" for Balkan Peninsula.

2. METHOD

The method used in this paper is system analysis. This method is useful when it comes to understanding a given energy system and show how different resources may be used optimally to achieve different objectives such as low system costs, reduced primary energy use or low overall emissions.

The system under study in this paper is the Albanian power system. To reflect its features is used an energy system optimization model called MODEST, which stands for Model for Optimization of Dynamic Energy Systems with Time-dependent components and boundary conditions. This model is used in different other studies which analyse the power systems in countries like Sweden and Chile [15, 16], by highlighting renewable energies and measuring the impact of industrial energy conservation.

MODEST's flexible time division enables the reflection of demand peaks and diurnal, weekly, seasonal and long-term variations in demand, costs, capacities, etc. depending on the time horizon, each year can be divided into seasons, which in turn are sub-divided into diurnal periods. One of the strengths of the model its ability to offer the optimal kind, magnitude and time of investment and the best operation of all system components can be determined.

3. CURRENT SYSTEM

With a population of 2,845,955 Inhabitants [17], and a domestic power production heavily dependent on hydropower, Albania has one of the lowest per capita power consumptions of the Balkan countries. The total power production and demand were 5.206 and 7.943 TWh respectively in 2019 [18]. As the figure states, the demand is much higher than the domestic production which is heavily dependent of precipitation. There are many hydropower plants which are in operation to meet the demand. For simplicity sake the plants are classified as follows:

- Hydropower plant I: Fierza, Koman and Vau i Dejes
- Hydropower plant II: Banja, Fangu, Ashita, Lanabregasi, Ulez Shkopet Bistrica and Peshqesh
- Hydropower plant III: others

The main power consumers are the residential sector, followed by the service sector and industry [13].

The characteristic feature of electricity consumption, resulting from the study of the annual profile electricity consumption is almost a complete symmetry of winter – summer consumption. This comes as a result of using electricity for heating and cooling. So, changes in the environment's temperature are reflected immediately in the daily consumption of electricity. The monthly variation of the production curve is different in different times of the year. Regarding the gathered data, February, March and November, were the months with the highest production, when there were a lot of rainfalls. The curve is lower in summer as the country is mostly forced to import from neighboring countries. As mentioned earlier, Albania is dependent on imports, especially during dry periods in summer, because of limited generating capacities and non-diversified sources of energy.

A model was set up based on installed capacities, annual power production and a proper time division. The chosen time division consists of 10 hourly values during 24 hours, for every month of the year. This was done to reflect the demand variation over the year. Evolved from this, the production of every plant, together with their output, efficiency and energy price were added into the model. The demand of electricity varies from year to year, but the total demand used in this study was 7.943 TWh for the year 2019.

4. STUDIED SCENARIOS

Given that Albania has considerable potential for the exploitation of other renewable sources, a number of scenarios are proposed, as shown in Table 1. The scenarios in general considers new generation and changes in the electricity market.

Table 1. List of considered scenarios

Scenario	Description of scenario
1	Reference scenario based on 2019 data
2	Scenario with new production plants
3	Scenario 2 + increased demand due to change in road traffic
4	Scenario 3 + new electricity market

4.1 The Existing Energy System-Reference Scenario

The existing power system of Albania is shown in the figure below. In this scenario, all existing generating power plants hydropower plants are considered. Most of the supply comes from hydropower plants but there are some limited generation from existing solar PV and incinerators. This scenario includes also existing import and export connection with the surrounding countries where power generation is mainly based on non-renewable energy sources.

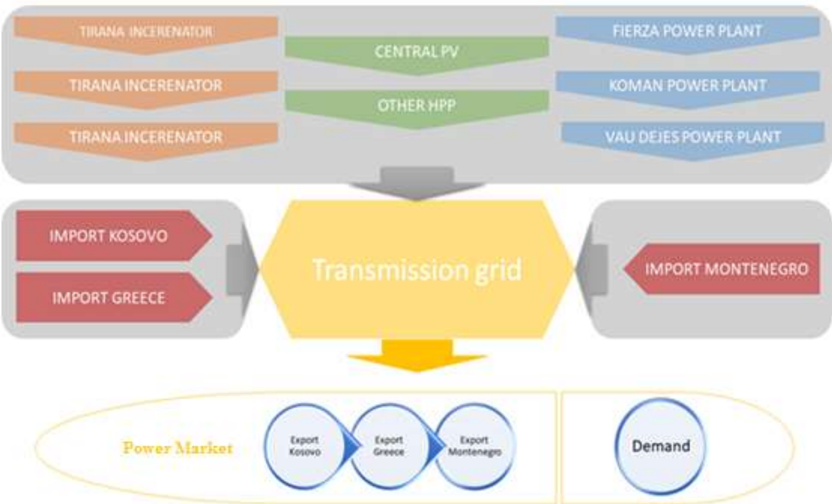

Figure 1. Existing power system in Albania.

4.2 Scenario with new production plants

This scenario is based on the reference scenario and it takes into consideration the possible integration of new capacities of PV plants and wind power into the system. This scenario takes into consideration the new hydropower plant built by Norwegian company Statskraft, which will start operation in 2020. According to Statskraft which also owns another hydropower plant already in operation, the new plant has a capacity of 184 MW and will have annual generation of 450 GWh [19].The investment costs of large utility scale PV plant is estimated to be 830 thousand Euro/MW. Currently Albania has only 1 MW installed PV capacity and it has a considerable available land area that can be used for installing new capacities. According to IRENA the technical potential of solar energy in 2030 is around 2,4 GW with equivalent annual generation potential of 3.7 TWh [8]. This high potential could be exploited to also implement microgrid PV systems, similar to a techno-economic feasibility study done for Bangladesh, to investigate the prospects of renewable energy-based islanded microgrids in support of rural electrification to power households and irrigation systems [20]. The increasing interest for floating PV on existing hydropower plants and reservoirs has also made the Albanian hydropower more attractive. Such types of plant could complement existing hydropower. In addition to the newly built hydropower, this scenario includes the floating solar PV which is going to be tested on the reservoir of the Banja hydropower plant.

It is however not clear whether floating PV is considered in the IRENA report. It is therefore assumed in this paper the solar potential includes floating PV. The report from IRENA reports that Albania has substantial potential of wind power. According to IRENA the technical potential of wind power in 2030 is around 7,5 GW with equivalent annual generation potential of 13.6 TWh [8]. These new installed capacities are estimated with investment costs of 1MEUR/MW, as calculated by IRENA.

4.3 Scenario with increased power demand

This scenario considers increased power demand due to a possible change in the transport sector. The change in the transport sector will mean a switch from traditional fuel-based vehicles to battery electric vehicles (BEV). This is motivated by the need to reduce the CO2 emissions and particle pollution from road traffic. This situation demands change particularly in highly populated areas such as Tirana, the capital of Albania and also other areas. Based on data from directory of Transport Service of Albania, the number of registered passenger cars in Albania was estimated to 499 005 in 2019 [21, 22]. The average annual mileage per vehicle is assumed to be between 10-12000 km/year.

Globally, the number of BEV is increasing. For instance, about 1,5 million new BEV were added to the global fleet in 2019 making the total 4.8 million BEV by the end of 2019 [23]. This development will surely affect the future Albanian fleet. The fact that Albania has substantial renewable resources could be a driver in electrification of the transport sector.

The specific electricity consumption for BEV depends on many factors such as the vehicle type and season of the year. In order to determine the additional electricity demand caused by electrification of passenger cars, an average electricity consumption corresponding to 20 kWh/100 km is assumed. Based on the total number of passenger cars with assumed annual mileage of 11,000 km/vehicle and specific consumption, the potential additional electricity demand would be around 1 TWh/year. This will mean a huge increase in electricity demand requiring a lot of import or enormous investment in new domestic generation capacity together with other essential investment associated with it. It is currently difficult to make any sort of prediction regarding the future development of road transport electrification in Albania. Here, different scenarios could be considered to investigate the impact of the electrification of Albanian fleet. For simplicity reason, although it is not known how the development along this line would be, the electricity demand is assumed to increase by 0.5 TWh as a result of electrification long term. If this would not be the case, the increase in demand can be motivated by other electrification activities. However, the fact that the residential sector is a major consumer of energy particularity electricity [24], energy conservation measures within the residential sectors may result in reduced use of energy.

4.4 Scenario with new electricity market

As mentioned earlier, almost all power production comes from hydropower plants mainly owned by the state. The market as it is now is fully regulated with KESH (Korporata Elektroenergjitike Shqiptare) and OSHEE (Operatori i Shpërndarjes së Energjisë Elektrike) being the most influencing producer and distributer respectively. Produced electricity is currently sold in a regulated market resulting in low revenue for producers and this situation does not encourage the development of new renewable-based power generation. There are however other plants owned by foreign companies that do not operate under similar market condition as the ones owned by the state.

Electricity consumption in Albania has increased slightly in recent years and this trend is expected to continue.

Albania is taking steps to introduce more market-based support schemes, but there are still concerns about the auction scheme being a suitable model [8].

This scenario is the combination of the previous two scenarios. In this scenario, the system was changed by adopting market-based prices for import and export of power within the system boundary. The new prices are based on the electricity market in the South-Eastern Europe, which is an organized electricity market operated by a market operator called South East Europe power exchange (SEEPEX). Daily average prices from SEEPEXs monthly report for the year 2019 [25] are considered as import and export prices in this case. This situation will give a better market condition for power companies and could lead to profitable future investment. This condition may also enable the penetration of Albanian green energy in the region.

5. RESULTS

Based on applied data, the Albanian power system does not have enough capacity to meet domestic demand. For the reference scenario, hydropower I, a group of hydropower plants which consists of the three main hydropower plants; Fierza, Komani and Vau I Dejes, play a crucial role in meeting the domestic electricity demand followed by hydropower plant group II and III. A large part of power demand is however, covered by import, which in this case has a share of 38%, see Figure 2.

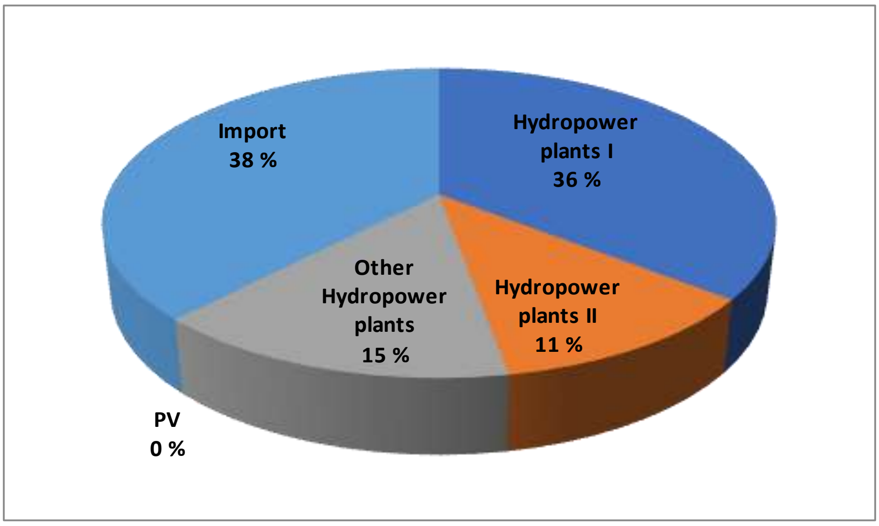

Figure 2. Production share reference scenario

A main reason for this situation is the dependence on hydropower, thus dependence on hydrological conditions, which in some cases leads to new, unpredictable electricity purchase agreements, which are even more expensive than the predictable ones. The results show that it is very important for the Albanian Energy System to diversify its generating sources of electricity.

In the Figure 3 we have introduced new plants in the form of solar and wind power does not bring any new solution. On the other hand, the new hydropower plant together with the floating PV contribute to reduced import. Based on applied data, the Albanian power system does not have enough capacity to meet domestic demand. In the same way as in the reference scenario, the major hydropower plants group I continues to play a crucial role in meeting the domestic electricity demand followed by hydropower plant group II (this includes in this case the newly built hydropower) and hydropower plant group III. Although the contribution is insignificant compared to the hydropower plants, there is minor contribution from solar PVs. A large part of power demand is still, covered by import, which in this case has a share of 32%. The decline in import in this case is mainly due to the newly started hydropower.

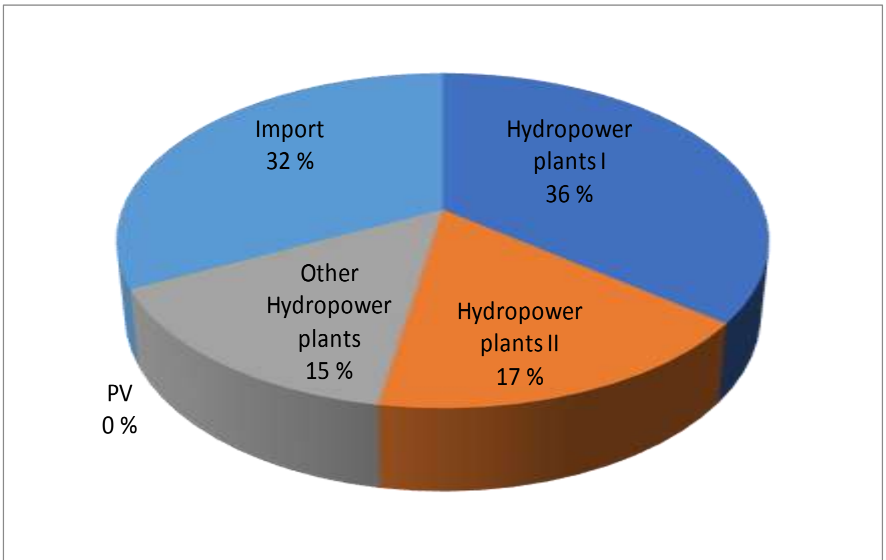

Figure 3. Production share new production plant scenario

Increasing electricity demand due to electrification does bring a slightly different solution than the previous scenario. Compared to the previous scenario, there is a slight contribution from solar PVs both from the existing and the new. Increased demand has in a way triggered a small increase in the use of solar energy instead of increased dependence on import to cover the additional demand. As it was the case in the previous scenario, the major hydropower plants group I continues to play a crucial role in meeting the domestic electricity demand followed by hydropower plant group II and hydropower plant group III. A large part of power demand is still, covered by import, which in this case has a share of 35 %, see Figure 4. If it had not been for the newly started hydropower and small contribution from solar PV contribute, the import would have been higher due to increase in demand.

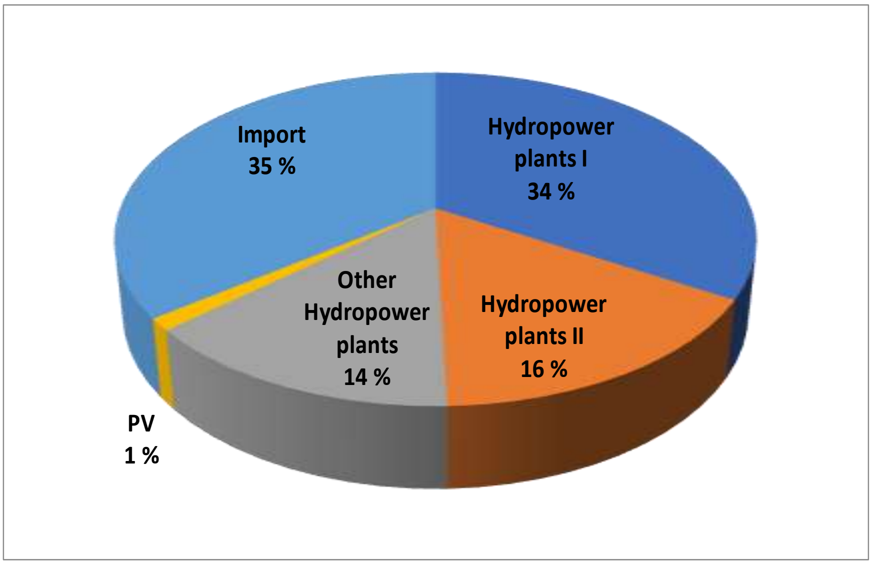

Figure 4. Production share increased power demand

The introduction new power market indicates a very different solution compared to all the previous scenarios. Here, investment in new renewable energy is highly triggered by the market-based import and export prices. The production share is shown in Figure 5.

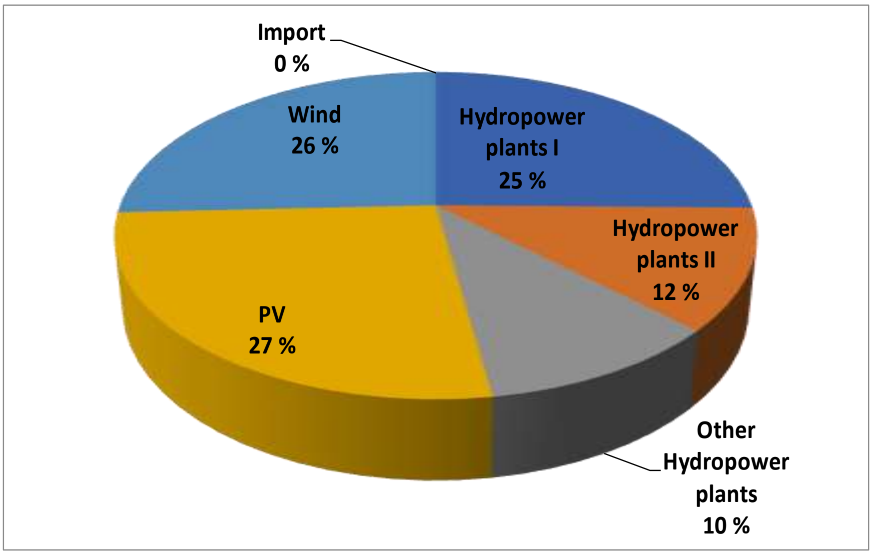

Figure 5. Production share: new plants+ increased demand+ new market

Since both solar energy and wind energy are considered simultaneously in this case and the applied specific investment cost of solar PV is less than that of wind, investment in solar PV is more attractive than wind. However, wind energy is also has shown to be attractive due to potential energy limit set on solar energy. As it can be seen in the above figure, the contribution from new solar PVs and wind power is higher than all contributions from all hydropower together. Although solar PV and wind have a dominating role in meeting a large part of the domestic demand and contribute to net export, the major hydropower plants group I still play a crucial role in meeting the domestic electricity demand followed by hydropower plant group II and hydropower plant group III. In this scenario, the system is independent of import making Albania net exporter of green energy.

If on the other hand only solar is considered, a higher share of solar PV can be obtained. As it is shown in Figure 6, the share of solar PV increases to 39 % compared to the case where both wind and solar energy are considered. Even though only solar PV is taken into consideration, the system still will be independent of import and there is plenty of energy for export.

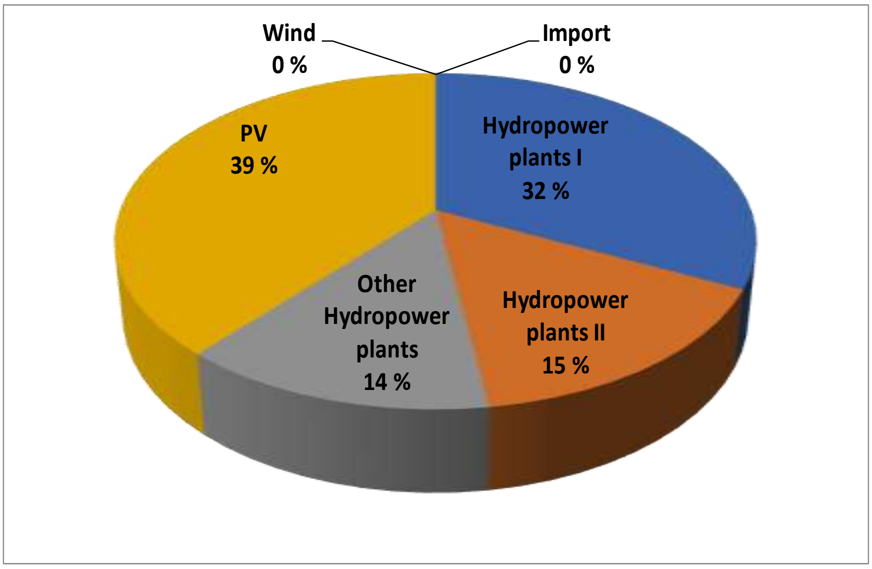

Figure 6. Production share: only solar+ increased demand+ new market

If instead only wind is considered, a higher share of wind power can be obtained. As it is shown in figure 7, the share of wind power increases to 56 % compared to the case where both solar and wind energy are considered.

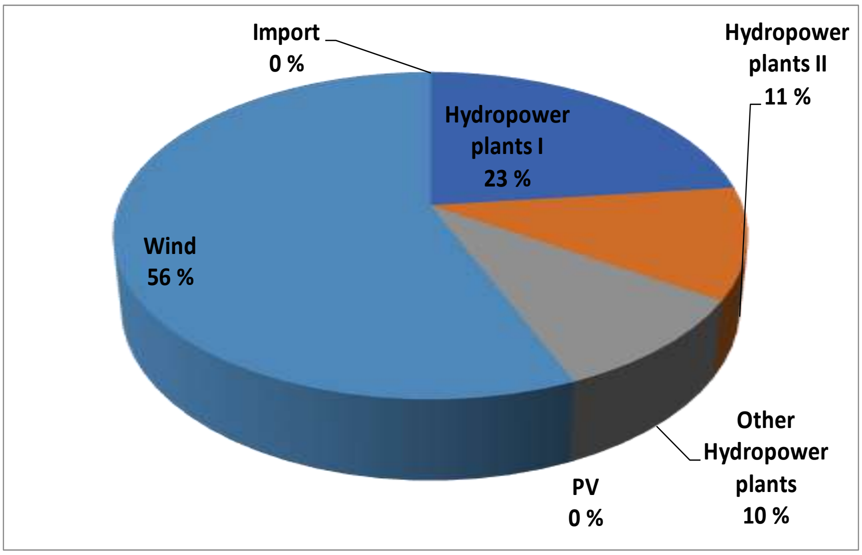

Figure 7. Production share: only solar + increased demand + new market.

When the penetration share of solar PV and wind power are compared with each other, wind power higher share due to higher technical potential than solar. The system in this case is independent of import and there is much more excess energy for export.

6. DISCUSSIONS AND CONCLUSION

In this paper, the Albanian power system is analysed by using energy system analysis model based on linear programming. The possibility of integrating solar and wind energy and the impact of market-based electricity market is studied.

Based on given data and considered assumptions, the Albanian power system have challenges regarding meeting domestic power demand. The virtually fully hydro-based power system is not enough to meet the demand not only in dry seasons but also in times of good precipitation. It is true that wet seasons contribute to reduced reliance on import but there is a need for more capacity to resolve the challenges both during wet and dry seasons.

With prevailing market condition and a system with a high reliance on hydropower and import, it is difficult for new none-hydro renewable sources to compete with existing hydro power plants. Even though Albania has abundant renewable energy sources like solar and wind, these resources are by far less exploited. Market incentives that promote the development of such sources are lacking. Furthermore, the existing regional power exchange system based on bilateral agreement offer short term solution in solving domestic power shortage issues. On the other hand, this situation might be a barrier for the development of none-hydro renewable sources such as solar and wind in the long term. There is therefore a need for a policy measures that encourages regional cooperation with climate and sustainability highlighted.

The system as it is today is not suitable to be able to absorb new renewable energy sources. Generally, the study shows that there is a substantial need of a certain form of incentives nationally or within the region to help promote the integration of solar and wind energy. In this study, market-based prices are used as a possible incentive to encourage future investments in renewable energy sources. If market-based prices are applied, both solar and wind energy could be attractive investments. Presented results related to a new open market show enormous penetration of solar and wind energy as a result of high power prices assumed in this study. Another way to encourage the deployment of renewable energy could be the introduction of tradable green certificates in the region like the one in operation between Norway and Sweden. This policy measure has proven to be successful in achieving renewable targets both in Sweden and Norway. A combination of a regional open market and a tradable green certificate would further promote the integration of new renewable energies.

Lastly, Albania has a substantial renewable energy potential in the form of solar and wind energy and this potential can be of great value not only nationally but also for the whole Balkan region and Europe as a whole. The fact that supply security and environment are top priority in Europe, the development in Albania can be of great importance within this context.

It is at this stage difficult to draw any final conclusion, since this case study is based on assumed data and several simplifications to describe the system. The results could be different if other reference year is used. There is a need for further study to better describe the system under study. It is therefore very important that presented results should be interpreted cautiously from this point of view.

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CONFLICT OF INTERESTS

The authors would like to confirm that there is no conflict of interests associated with this publication and there is no financial fund for this work that can affect the research outcomes.

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