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Evaluating the impact of demand-side response in Kosovo during the energy crisis: What can we learn?

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Assessing the impact of energy crisis in Kosovo and prospects for untapping the potential from demand-side

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Abstract:

The energy crisis in Europe due to war between Ukraine and Russia has led to an unprecedented situation. Volatility in gas supplies has driven the wholesale electricity prices to increase enormously. Fortunately, this crisis has prompted many European countries to prioritize energy sector and advance green agendas. While efforts to address the energy crisis have primarily focused on the supply side (i.e., subsidies to energy suppliers), less attention has been given to the demand-side. In this study, we analyze the electricity system of Kosovo during the energy crisis and evaluate the impact of demand-side measures. We analyze the data on electricity generation, demand, and prices from September 2021 (pre-crisis) until January 2023, when electricity prices stabilized. To assess the impact of demand-side we consider three measures: load-shifting, efficiency measures, and the deployment of photovoltaics (PV). For each of these indicators, we examine their effect on Kosovo's energy system in terms of avoided system costs depending on net imports volumes and costs. Finally, the aim of this study is to emphasize the importance of demand-side participation during energy crisis and highlight the need for policy measures that unlock this potential, particularly in future energy systems characterized by high electrification and intermittent renewable sources.

Keywords: Energy crisis, Flexibility, Demand-side, Load-shifting, Energy efficiency, PV, Kosovo.

1. Introduction

The European energy sector has undergone significant changes in recent years. First, during the COVID-19 pandemic, the energy sector witnessed significant low levels of energy demand, prices, and greenhouse gas emissions due to restrictions imposed [1]. However, the post-pandemic period was followed by a surge in economic activities, leading to higher energy demand. Second, the commencement of the war between Russia and Ukraine in February 2022, created an unprecedented situation in the energy sector. The volatility in gas supplies in European countries resulted in uncertainties, driving up gas prices, hence affecting the electricity prices in wholesale markets [2].

Prices in electricity markets are determined based on the merit-order principle. Generators are ranked in order of their bid prices, with the cheapest generator being at the top to the expensive ones with higher bid prices. The last generator selected to meet the demand determines the market price at which the electricity is traded. The reliance on gas power plants to meet the demand made electricity prices depended on gas prices. Therefore, the volatility and increase of gas prices (TTF Dutch [3]) were followed by the electricity prices as well (EPEX [4]). The electricity prices began to rise in September 2021 and reached their peak in August of 2022 with an average of 500 Eur/MWh. As electricity markets in Europe are highly interconnected and coupled the increase of gas prices was affected in most places.

On the other hand, the crisis created a new momentum for Europe that led to establishment of REPowerEU plan with the objective to push forward deployment of renewables, increase of energy efficiency, and energy security by diversifying the energy supply [1]. Regarding to demand-side (end-users), the most of European countries incentivized the deployment of PV [5] and efficiency measures through heat-pump or retrofitting [6]. Despite these initiatives, little attention has been placed on promoting demand-side management (DSM) or load-shifting [7]. New initiatives have started discussion to unlock the DSM [8]. In this study, we aim to assess the impact of demand-side measures, specifically DSM, efficiency measures, and PV deployment, on the electricity system during the energy crisis, with focus on Kosovo.

2. Methodology

2.1. *Description of Kosovo's electricity system*

The electricity system of Kosovo is characterized with a centralized production based on two power plants, Kosova A and Kosova B, which have five and two units, respectively. The Kosova A consists of five units of which three (A3, A4, and A5) are operational, with each unit have an installed net capacity of 144MW [9]. The two units in Kosova B, each have an installed net capacity of 264MW [9]. Wind power represents the second largest installed capacities with a total capacity of 137.5MW, divided between Kitka and Selac with 32.4 and 103.4MW, respectively [9]. Brown coal/lignite is the primary source of electricity production in Kosovo accounting for 83% of the total, followed by wind power with 12%. Solar capacitiy stands with 10MW.

Regarding to the transmission KOSTT (Kosovo's transmission system operator and market) has good established interconnections with neighboring countries, resulting in a total net import net capacity (NTC) of 1316 MW [10]. Electricity consumption in Kosovo depends on season, with low demand during the summer (600MW in average), while in winter with high electricity consumption, in average the load is 1000MW, with peak at 1372MW registered in December 2022. The residential sector is the largest consumer, accounting for 50% of total electricity consumption, followed by the commercial sector with 18% and industrial sector with 9% [9]. The significant difference between seasons is primarily due to high electrification of heating demand (electric heaters and boilers) and low temperatures. The heating sector in Kosovo is characterized with the high electrification (high use of electricity), biomass (wood and pellet), and cogeneration from coal power plants or biomass.

2.2. Data sources

The data for analyzing the operation of electricity production from power plants, consumption and are obtained from the transmission system operator KOSTT [2], while the electricity prices for exports and imports for Kosovo are taken from the stock market of Hungarian Power Exchange (HUPX) [11]. The data selected for this study are between September 2021 and December 2022 in a hourly basis.

2.3. Assessment of demand-side measures

In the following we assess three different measure options that could be implemented or encouraged at the demand-side.

2.3.1. Load-shifting

The assessment of flexibility from demand-side response through load-shifting is based on the following three factors: net-generation, electricity prices and hour. We have written a Python script, where for each day a load shifting is applied (for this study the values of load shifting capacities assumes are: 10, 20, and 30 MW). Load-shifting or DSM is activated during hours with the highest electricity prices between 18:00 and 23:00, while the shifted load is consumed between 01:00 and 07:00. This timing is chosen when net-generation is typically positive and electricity prices tend to be minimal during these hours. The aggregated net-generation and consumption for 24 hours is shown in **Error! Reference source not found.**. Net-generation is calculated using the equation $Net\_generation = \sum_{i=0}^{n} P_i - C_i$ (1), and is calculated for every hour.

$$Net\_generation = \sum_{i=0}^{n} P_i - C_i \ (1)$$

P_i represents electricity production, C_i is the consumption, and i are the specific hours between September 2021 and December 2022. It is important to note that the load and generation curves are given in aggregated form.

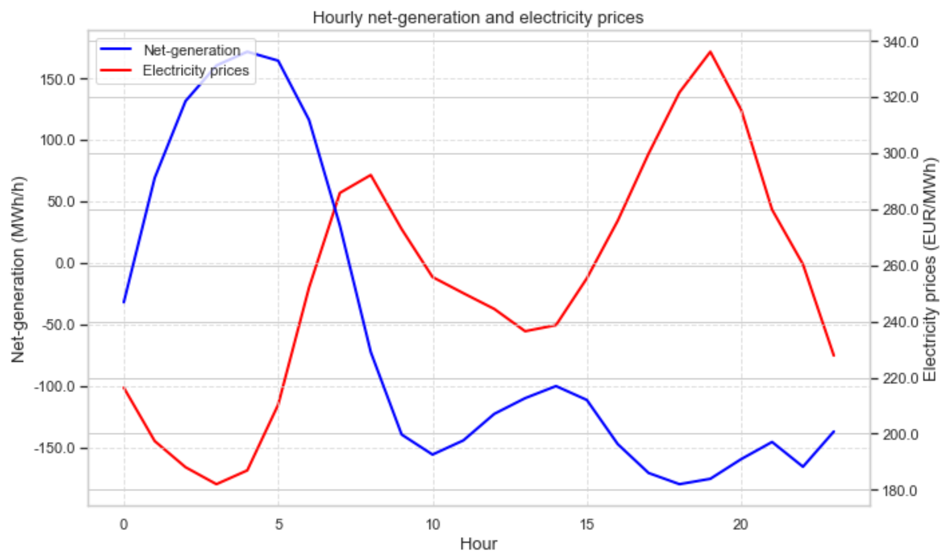

Figure. 1. The daily average of net-generation (generation minus consumption) and electricity prices.

2.3.2. Energy efficiency

To assess the impact of energy efficiency (EE) we apply a decrease in electricity consumption by 1 and 2%. However, it should be noted that the decrease of electricity due to efficiency measures might consists of a range of options, including upgrading lighting bulb to efficient ones, enhancing the performance of equipment (appliances or heating). To assess the net revenue after EE measures have been applied, we compared the exports and imports after and before and after EE measures are applied, as given in following equations.

$$Net\_revenue_{EE} = \sum_{i=0}^{n} (Exports_{after\_EE} - Exports_{before}) + (Imports_{before} - Imports_{after\_EE})$$

Finally, the cost of implementing EE measures per MWh is calculated by net-revenue and the difference between consumption before and after EE measures are applied.

$$EE\_price = Net_{revenue} / \sum_{i=0}^{n} (C_{before} - C_{after_{EE}})$$

2.3.3.Renewable deployment

To assess the impact of renewable deployment during the time of energy crisis, we focus on the deployment of different PV capacities. In this study we assume the capacities of PV to be 10, 20, and 30MW. The supply profiles for the PV are taken from renewables.ninja [12] and given in hourly basis. Afterwards, we calculate the net-revenue and the costs occurred from PV deployment for the electricity system of Kosovo during the crisis, which is calculated using the equations as below.

$$Net\_revenue_{PV} = \sum_{i=0}^{n} (Exports_{after\_PV} - Exports_{before}) + (Imports_{after\_PV} - Imports_{before})$$

3. How did power plants operate during the energy crisis?

In the following we analyze the power system of Kosovo from September 2021 and December 2022, by focusing on the availability of power plants, respectively the capacity factor of plants, net-generation (to assess the exports/imports volumes and costs), and electricity prices.

First, let's consider the capacity factor, which represents the percentage of time that power plant was operating during this period, as shown in Figure. 2. Brown coal power plants contributed significantly to with 94.4% or 7761.61 TWh of electricity production, while wind with 5.23% or 429.38 GWh. The total electricity consumption accounted for 8894.67 GWh, resulting, in a net difference for imports of 1149.29 GWh. During the winter of 2021, due to unexpected outages and scheduled maintenances of units (B2, A4, and A5) the dependency on coal units decreased, leading to instances of load-shedding. In Dec 2021, the coal plants operated at only 68% of the time, with an average consumption of 1070MW, resulting in an average mismatch of -400MWh. Moving forward to the summer of 2022, prices surged to an average of 495.3 Eur/MWh in August. Low availability of power plants (A5 and B2), due to planned maintenance, necessitated load-shedding measures again to avoid high-priced imports. Therefore, during this month the mismatch between generation and production reached near-zero levels.

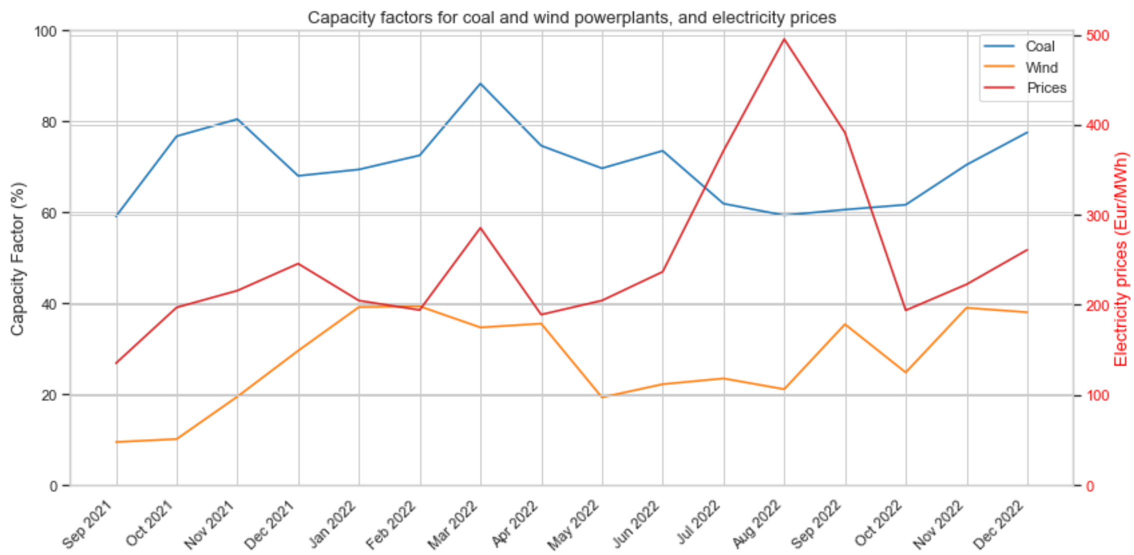

Figure. 2. Capacity factor of coal and wind, and average electricity prices in monthly basis.

Another important aspect to consider is the relationship between net-generation and electricity prices. These factors played an important role in the power system during this time as the volume of electricity to be imported depended on the local electricity production and prices at the market. During periods of high electricity prices, importing a substantial volume of electricity could impact end-users significantly, leading thus to increased electricity tariffs. To counteract this, load-shedding measures were implemented.

Two critical periods during the energy crisis are observed in Figure. 3. The first occurred during the winter months, specifically in Q4 of 2021 and Q1 of 2022, due to power plant outages in both Kosova A and B units. During these periods, Kosova A and B operated with capacity factors of 59.65% and 68.19%, respectively. These outages resulted in an average shortage of 330GWh (90GWh from unit A3 and 240GWh from B2). The second critical phase of the energy crisis occurred during the summer of 2021 particularly in July and August, when electricity prices reached their peak. While Kosovo typically operates as a net-exporter of electricity during the summer, the plant outages made it more challenging to meet the demand, therefore, necessitating load-shedding. However, it is very important to emphasize that, primarily, energy deficits were managed through imports from Albania. Load-shedding was implemented as a secondary measure (for instance, in times when even Albania was unable to produce sufficient energy). The two countries have an agreement to exchange energy (i.e., Albania exporting to Kosovo during the winter when its hydropower plants generate more, and Kosovo exporting during the summer when Albania's consumption increases due to cooling needs and tourism).

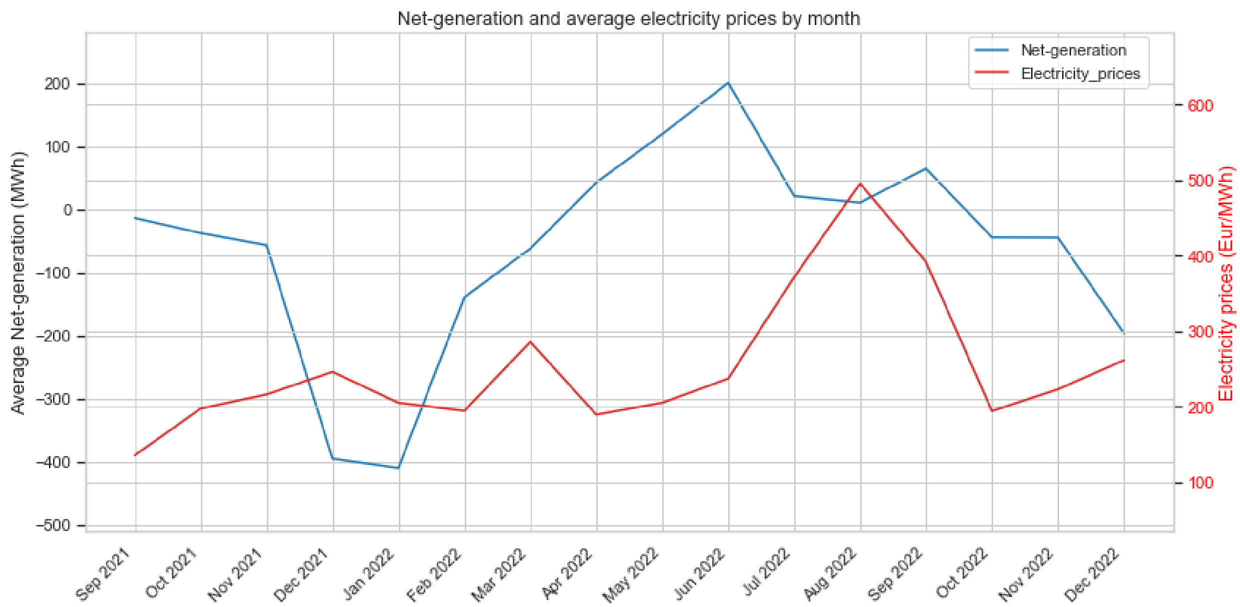

Figure. 3. Net-generation and average electricity prices (from HUPX) based in monthly basis. Negative net-generation values are referring to imports, while positive net-generation are referring to exports.

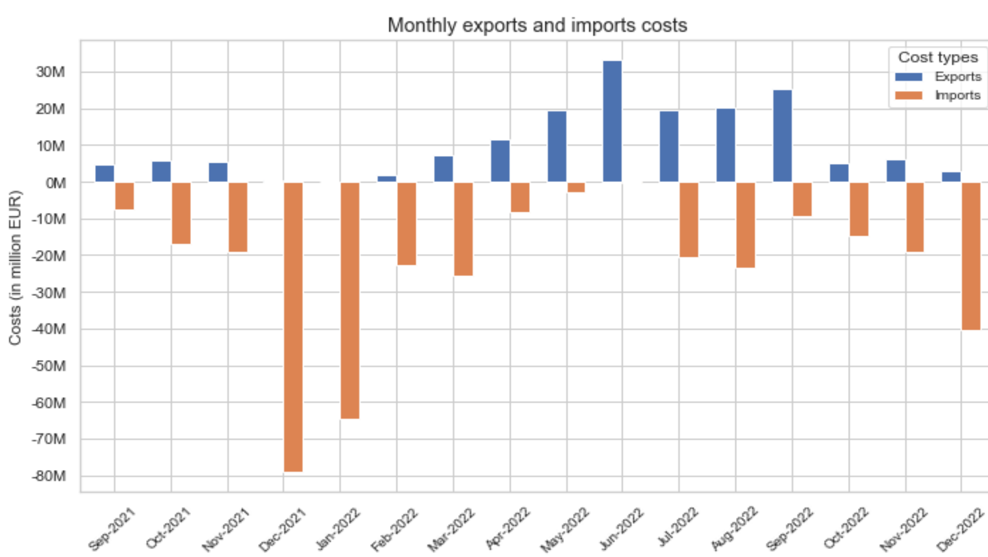

Figure. 4. The exports and imports calculated based on net-generation and average electricity costs (September 2021 to December 2022).

The monthly net costs for electricity exports and imports from September 2021 to December 2022 are shown in Figure. 4. In 2022, the net-difference between exports and imports amounted -94.5 million Euro, when compared to the maximum import allowance provided to the supplier Kosovo Electricity Distribution and Supply (KEDS) by Energy Regulatory Office (ERO), which stands 21.8 million Euro [9], and considering +75 million Euro provided by the government as a subsidy [13], give same numbers. As previously mentioned, the critical months were during the winter (December, January, and February) due to high electricity demand and unexpected power plant outages. As expected, electricity imports peaked between December 2021 and February 2022. Interestingly, during July and August, was observed that despite having a positive net-generation (15.66 and 7.89 GWh/month), the net-import costs were negative at -0.84 and -2.93 million Euro for July and August, respectively. This is attributed to inflexible generators, where the electricity exports occurred during periods of lower electricity prices, while imports during times of higher prices. Figure. 1, illustrates the typical hourly pattern of net-generation and electricity prices, showing that Kosovo primarily exports electricity from 1am to 7am, when average prices are lower, while imports are required when prices are higher. This pattern is particularly observed, during peak demand at 19:00, corresponding to peak electricity prices.

4. Untapping the potential from demand-side

The increase of electrification in demand-side through sector-coupling (i.e., heat or transport), is leading to an increase of electricity demand. Furthermore, demand-side is transforming from a conventional passive role to that of an active participant. The demand-side can provide various benefits for the system which involves DSM or load-shifting (i.e., consuming electricity during surpluses of energy or when electricity prices are lower), efficiency measures (i.e., upgrading appliances to better energy performance ratings), and the deployment of renewable energy sources (PV).

Among these options, load-shifting stands out due to its immediate implementation and relatively low investment costs, particularly in the context of energy crisis. Efficiency measures and PV deployment, on the other hand, often require longer timeframes (day to years). Regarding to investments costs, DSM or load-shifting typically involves lower costs, attributed to hardware (smart meters) and software costs. In Kosovo, incentives for load-shifting are offered through time-of-use tariffs, other incentive programs for DSM are currently lacking. Regarding energy efficiency, Kosovo has established programs that subsidize energy efficient measures, through the body named Kosovo Energy Efficiency Fund (FKEE). PV deployment still faces barriers, due to regulatory barriers and complex administrative procedures.

	Time of implementation	**Investment costs**	**Incentives**
Load-shifting	Fast	Low	Low
Efficiency measures	Fast/Medium	Low/Medium	Low/Medium
Renewables (PV) deployment	Medium/High	High	Low

Table. 1. The interplay between flexibility options from demand side and main variables (time of implementation, investment costs, and incentives) used to implement them.

4.1. Assessing the interplay between load-shifting, efficiency measures, and PV deployment

In the following section, we present the results of implementing load-shifting or DSM, energy efficiency (EE) measures, and PV deployment in the context of Kosovo power system during the crisis period from September 2021 to December 2022. Figure. 5 shows the potential cost savings when three measures were implemented. Results show that the load-shifting measures yield the highest net-values, with an average cost of 315 Eur/MWh, followed by EE and PV with average costs of savings ranging 250 to 255 Eur/MWh.

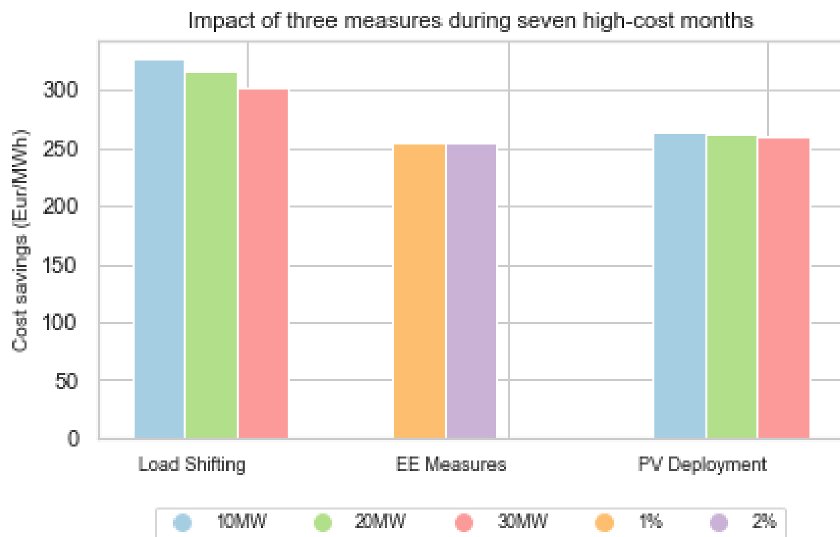

Figure. 5. Assessment of costs savings calculated when three different measures (load shifting, EE measures, and PV deployment) have applied.

DSM or load-shifting was mainly activated between 18:00 and 20:00, with 18:00 being the peak hour for demand shifting accounting for 49% of the load shifting activities during this time. Then followed by 37% and 13% for 19:00 and 20:00. Conversely, the activation of DSM for resuming the consumption was most frequent at 3:00, representing 53% from September 2021 to December 2022, which aligns with Figure. 1, which reduce the amount of energy surpluses during the low prices. Subsequent activation of DSM was followed by 22% at 4:00, and 2:00 with 12%. Moreover, DSM demonstrated its most impact for the system during the months with high electricity prices (i.e., between July and August) as well as during the winter season. To give an example, implementing a 10MW DSM during the August when average prices were 495.3 Euro/MWh, could potentially yield benefits of approximately a quarter of million Euro (with 160,000 Euro avoided on imports and 90,000 to additional exports).

In scenarios when EE measures were applied an average reduction in cost of imports by 9% and increased exports by 8% were observed when a 2% reduction in electricity consumption was imposed. Due to high electricity consumption during the winter, EE measures had a significant impact on reducing energy imports with an average of -15 GWh/month, while the additional energy exports increased to +2GWh/month. Lastly, in scenarios when PV deployment are applied, the impact of PV correlated with the generation pattern. During sunny months, the reduction in energy imports was more pronounced, as compared to colder months. Over the energy crisis period, the net-revenues for the national electricity system due to PV deployment ranged from 5.2 million to 15 million Euro for 10MW and 30MW installations, respectively, with an average of 260 Euro/MWh.

5. *Conclusion and discussion*

The war between Russia and Ukraine created an unprecedented situation in energy sector in Europe, leading to a significant surge in electricity prices. This study analysis the time during the energy crisis in Europe with a particular focus in Kosovo, covering the period from September 2021 to December 2022. In following we discuss the key findings.

Having a centralized and predominantly baseload power generators (from brown coal), calls for additional flexibility sources. Currently, the main flexibility source are interconnectors with neighboring countries (i.e., energy exchanges with Albania where both countries have a complementary system; for instance, during the summer, Kosovo exports electricity to Albania due to increased consumption, while during the winter, Kosovo imports from Albania). Nevertheless, with the growing deployment of renewables, there is an increasing need for flexibility. According to energy strategy of Kosovo 2022-2031, Kosovo plans to install 140 MW (340MWh) stationary battery storage and 1400 MW (PV and wind) [10]. While the deployment of battery storage represents a significant step toward integrating flexibility source into the electricity system and supporting the integration of renewables, however, it is crucial to assess additional flexibility sources [14], [15], [16].

DSM or load-shifting can play a pivotal role as a flexibility sources, in addition to planned battery storage. As results showed DSM provided high benefits for the electricity system. Unfortunately, in national energy strategies lack concrete objectives and pathways for the use of explicit or even implicit demand side response. This study reveals that the implementation of load-shifting holds great potential as a flexibility source. First, in terms of monetary value, it can reduce imports and increase export revenues. During the energy crisis, the implementation of load-shifting provided savings in average of 260 Euro/MWh, depending on load-shifting capacity. Secondly, DSM implementation is fast and requires low investments costs compared to other flexibility options such as installation of battery storage. Furthermore, DSM shows additional benefits in higher integration of renewable sources [16] [15], as well. Consequently, we recommend that energy policymakers incentivize the use of load-shifting. To achieve this, smart meters should be deployed, and incentives and mechanisms should be created to encourage the entrance of new market actors to tap into this potential.

Regarding to efficiency measures in electricity consumption, public authorities have several pathways to explore. While existing energy efficiency programs already subsidize citizens to buy high-performance appliances and heating equipment, these programs are often characterized by lengthy administrative procedures and limited coverage. Thus, additional measures targeting larger audience are necessary. This might involve implementing, short-term efficiency measures that are swift and effective such as change of conventional light bulbs to LED lightning or installing automatic sensors, particularly in public building stocks. Moreover, enforcing laws and regulations that encourage both authorities and citizens to invest in high-performance appliances and heating equipment through energy efficiency law and public procurement that consider energy-performance criteria. Lastly, when it comes to PV deployment, administrative procedures remain the main barriers whether for large scale PV projects or small-scale such as prosumers.

The assessment of various demand-side options in this study comes with limitations which calls for future research work. First, it would be beneficial to quantify the potential capacity of load-shifting and identify the incentives for citizens, particularly from the residential sector. Second, when evaluating the potential of efficiency measures, a more detailed approach that would involve creating load curves based on the actual usage of appliances, as shown in [17]. This would enhance the accuracy of efficiency measure implementation and provide policymakers with a more precise and effective guide when designing energy efficiency programs.

However, it is crucial to emphasize that the discussion and interpretation of the results should not be regarded as a comparison among flexibility options but rather as insights that can be derived when considering their implementation, taking into account the variables as outlined in Table. 1. Our findings can serve as base resource for the assessment and development of policies and regulations aimed at unlocking the potential of demand-side.

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