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Evaluating Options to Integrate Energy Storage Systems in Albania

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Abstract: - The focus of the paper is to identify for the first time the most adequate energy storage systems (ESS) applicable in the central or bulk generation of the electricity sector in Albania. The application and integration of ESS is a smart way to overcome the problems of timely power supply volatility and minimizing energy losses, transmission congestion relief and upgrade deferral (top 10%), energy time shift (arbitrage), and many other services that reduce the cost of electricity and gain the security of energy supply. The presence of high-level rates of water discharges into the Hydropower Power Plants (HPP) and the problems of congestion in the transmission grid are the two main problems that require new methods for addressing and solving them. To select the right form and type of ESS that should be applied in our national energy system, E-select, a very flexible and internationally approved model is chosen. The results of this study are necessary for achieving a flexible, cheaper, and environmentally friendly energy system in Albania.

Key-words: ESS, E-select, Optimization, Efficiency, transmission congestion, PHES, and CAES-c

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1 Introduction

Energy is a very important source for the economic and social development of a country. Electric energy storage is poised to become an important element of the electricity infrastructure of the future. The storage opportunity is driven involving numerous stakeholders and interests and could involve potentially rich value cues. The increase in activity levels in different sectors of the national economy (residential, agricultural, industrial, transport, etc.) inflicts an increase in the final demand for energy resources. Energy storage is the capture of energy produced at one time for use later. Regardless of the technology, today, most regulatory frameworks do not reflect the role and value that energy storage can provide. In many markets, storage is classified as a load-modifying resource or, in some cases, it is classified both as a generation asset and as a load resource. This leads to energy storage systems often facing double charges, paying levies on both the consumption and production of electricity [1]. Electrical Energy Storage refers to a process of converting electrical energy from a power source into a form that can be easily stored at the desired period and converted back to electrical energy when needed. Such a process enables electricity to be stored during “off-peak” hours which results in low generation costs or from intermittent energy sources (RES). The storage techniques have been applied so far in many countries such as Germany (Huntorf Power Plant with a turbine capacity of 390 MW), the USA (110 MW of installed turbine capacity), China, Japan, Denmark, and in many other countries. In the study of [2] Compressed air energy storage (CAES) technologies can be used for leveling the electricity supply and are therefore often considered for future energy systems with a high share of fluctuating renewable energy sources, such as e.g., wind power. Such systems will create the clime to integrate large RES capacities and avoid congestion or investment in the transmission grid. In other words, the security of supply, rational use of energy resources in the country, diversification of the energy sector nationwide, increase competitiveness, energy market liberalization, as well as environmental protection, are some of the main benefits of integrating energy storage systems (ESS) into the national energy grid. The assessment and the possibility of ESS integration within the generation-transmission chain will be realized by considering a set of variables, policy, physical, technical, economic, and environmental constraints. The basic role of energy conservation is the same in all engineering applications and serves to absorb the energy generated at a certain point in time and manage it later when the benefit is greater. Understanding the role of energy storage systems (ESS), firstly, requires a complete global picture of installed capacities, forms, and types of various ESS and future trends which will help decision-makers in the country to develop clear ideas for the efficient and sustainable electricity sector.

2 An Overview of the Albanian Energy System

A balanced configuration of the energy system dominated by fossil fuel inflicts an energy system based on RES. Combining different technologies that support new fuel types in compliance with the main two objectives of the national energy strategy and sector strategic action plan is mandatory to attain 2030 goals. This analysis is very complex and may require the use of technologies that are still in the early stages of development. In 2018 the total final energy consumption in Albania was around 24 TWh (2081ktoe). In table 1 the distribution of energy consumption by sectors in Albania is given 1[3]. Indeed, the transport sector is by far the biggest consumer of energy sharing 40% of energy consumption in Albania.

Table 1. Distribution of primary energy supply by demand sector, 2018. [4-5]

Sector	%
Transport	40
Residential	24
Industry	20
Services	10
Other	6

According to in 2018, Albania's total primary energy supply (TPES) amounted to 2131(ktoe).

Table 2. Fuels going through Final Energy Consumption in Albania, 2018 [6-7].

	%
Crude, NGL and, Feedstock	57
Hydroelectricity	25
Solid fuels	9
Biomass (Fuelwood)	8
Solar energy	1
NG	Negligible
Derived heat	0

The distribution of energy by fuel type going to the final energy consumption in Albania is given in table 2. Crude oil covers around 57% of the final energy consumption in the country followed by hydroelectricity 25%, biomass as wood fuel type 8%, solid fuel 9%, and the rest (1%) derive from solar energy. Albania's electricity demand grew rapidly from 1995 to 2000 due to demographic, economic, and social trends, including rural-to-urban migration, increased use of electricity for space heating and cooling and, rising living standards [8]. The Albanian power system is dominated by hydropower, representing more than 95% of the country's installed capacity with a total of 2605 MW installed. Most of the installed capacity (1448MW) 56% is owned by the Albanian Power Corporation (KESH) and the rest belongs to the other producers [9]. The country has a 98MW fossil-fuel thermal power plant representing 3.76% of the total installed capacity which is not put into operation since its construction in 2011, due to a failure in its cooling system. The import of electricity in Albania is highly influenced by weather and climatic conditions and historically around 3TWh/year of electricity is imported into the regional market [9].

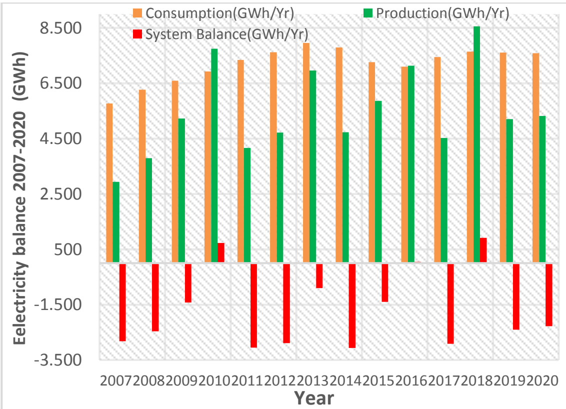

Fig. 1: Yearly electricity balance in Albania (GWh), 2007-2020 [10].

The net domestic production of electricity realized for 2020 is 5,313 GWh. As is shown in the graph in figure 1, the lowest electricity consumption was recorded in 2007 with 5,767 GWh and the highest electricity consumption is the one recorded in 2013 with 7855 GWh. By 2020, electricity consumption in our country is 7,588 GWh. Compared to 2019, there is a slight decrease in electricity consumption in the country by 23.4GWh. Technical and non-technical losses remain critical issues for the national power system accounting for around 21.7% of the total electricity consumption in 2019 [9]. Total electricity consumption in 2021 amounted to 8,415 GWh. Compared to 2020, there is a significant increase in electricity consumption in the country by 826 GWh, or about 11% greater. At the same time, the electricity consumption in 2021 was 20% greater than the average multi-year consumption period from 2004 up to 2021. This increase in electricity consumption was influenced by the changes in the structure of the economy and its revival after the pandemic of COVID-19, as it happened in the countries of the region and beyond [9].

2.1 Drin's River Cascade HPP

Referring to 2018, especially in the Drin River cascade, the installed Hydro Power Plant (HPP) capacity was 1350MW and the yearly level of discharges reaches the value of 4111 million m^3. The load (H) varies from 115.5 up to161.5m.

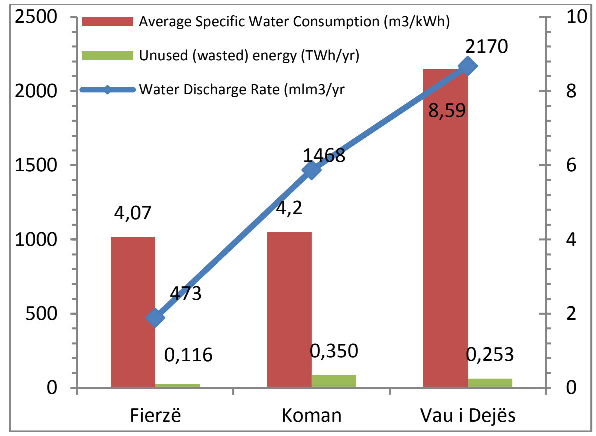

Fig. 2: The main characteristics of the HPP on Drini River Cascade, 2018 [9].

The historical level of water discharges from HPPs located in the Drin River cascade, from February up to April 2018 is given. The related non-utilization part of the potential energy available leads to significant energy losses and a negative impact on the environment, too. Other energy losses are also declared by other independent producers in the country, especially run-of-river HPPs types as they lack an ESS. The presence of such rates of energy losses and more expected due to the future RES integration, a criterion that supports the need to install an energy storage system is evidenced. However, from the historical data, the level of controlled discharges is realized in full compliance with the three basic principles: 1) "Safety Regulation" which are strictly related to safety issues, 2) optimal use of the hydropower reserve, and 3) minimizing the effects of floods in the lower part of the river.

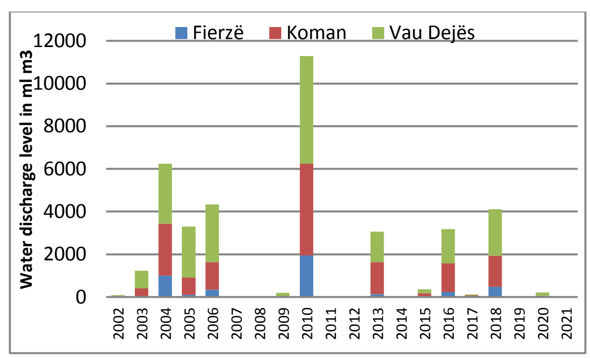

Fig. 3: Annual water discharges from HPP of Drini river cascade in million m^3, 2002-2021 [9].

The level of discharges of the Drin River cascade with an installed capacity of 1350 MW for the period

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2002-2021 is given in the graph in Figure 3. The level of discharges in 2010 resulted from 11.287 million m^3 of water, accounting for 30% of the total energy used during the year.

3 A Quick Overwiev of ESS

There are many benefits to choosing energy storage, depending on the application and the type of technology selected to meet that application's requirement. The importance and attractiveness of energy storage as an integral part of the electrical supply, transmission, and distribution systems are receiving increasing attention from a wide range of stakeholders including utilities, end-users, grid system operators, and regulators. The focus of this paper is to identify the form and type of storage that can be introduced at the generation-transmission level. Integration of ESS can serve as a generator with a limited amount of energy (during discharge time) and as a load (during charging time). Policies and initiatives to reduce losses from RES during off-peak periods, gain the security of supply and reduce greenhouse gas (GHG) emissions have certainly been the main drivers for the development of new power generation technologies. Increasing the degree of flexibility of the energy system at the national level or beyond necessarily requires an increased degree of utilization of stored energy sources. It can save consumers money, improve reliability and resilience, integrate generation sources, and help reduce environmental impacts. The benefits of the application of energy storage systems (ESS) in the national energy system are presented in figure 4.

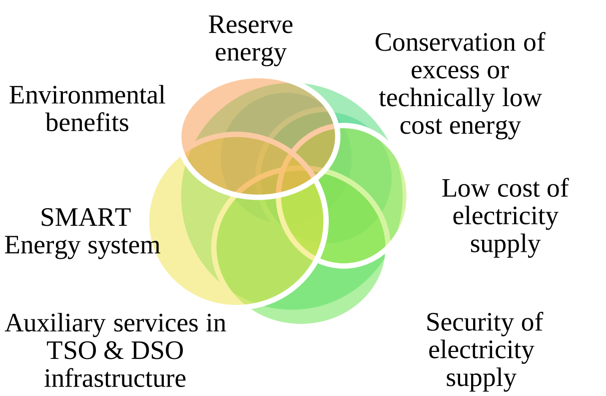

Fig. 4: The benefits of integration of ESS into the power system.

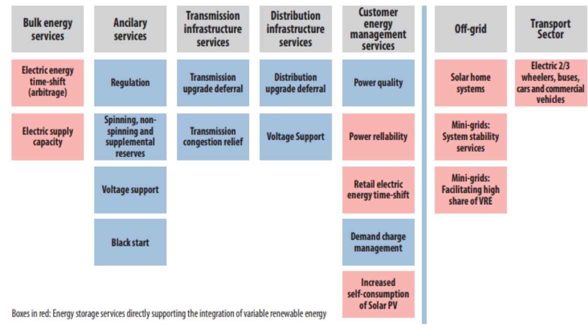

Fig. 5: The range of services that can be provided by electricity storage. [11]

Electricity storage will play a crucial role in enabling the next phase of the energy transition. Along with boosting solar and wind power generation, it will allow sharp decarbonization in key segments of the energy market.

As variable renewables grow to substantial levels, electricity systems will require greater flexibility. At very high shares of RES, electricity will need to be stored over days, weeks, or months. By providing these essential services, electricity storage can drive serious electricity decarbonization and help transform the whole energy sector. Electricity systems already require a range of ancillary services to ensure smooth and reliable operation (Figure 5). Supply and demand need to be balanced in real-time to ensure the quality of supply (e.g., maintaining constant voltage and frequency), avoid damage to electrical appliances, and maintain supply to all users. The International Renewable Energy Agency analyzing the effects of the energy transition until 2050 in a recent study for the G20, found that over 80% of the world's electricity could derive from renewable sources by that date [11]. Electricity storage capacity can reduce constraints on the transmission network and can defer the need for major infrastructure investment. With the very high shares of wind and solar PV power expected beyond 2030 (e.g., 70-80% in some cases), the need for long-term energy storage becomes crucial to smooth supply fluctuations over days, weeks, or months. Research and Development (R&D) in the way to 2030 is therefore vital to ensure future solutions are available, have been demonstrated, and are ready to scale up when needed. Electricity storage can directly drive rapid decarbonization in key segments of energy use. In transport, the viability of battery electricity storage in electric vehicles is improving fast. Batteries in solar home systems and off-grid mini-grids, meanwhile, are decarbonizing systems that were heavily reliant on diesel fuel, while also providing the clear socio-economic benefit of the grand transition process.

Table 3. The benefits, features, and limitations of ESS integration [12].

#	Benefit Type	Discharge Duration*		Capacity (Power: kW, MW)		Benefit ($/kW)**		Potential (MW, 10 Years)		Economy ($Million)†	
		Low	High	Low	High	Low	High	CA	U.S.	CA	U.S.
1	Electric Energy Time-shift	2	8	1 MW	500 MW	400	700	1,445	18,417	795	10,129
2	Electric Supply Capacity	4	6	1 MW	500 MW	359	710	1,445	18,417	772	9,838
3	Load Following	2	4	1 MW	500 MW	600	1,000	2,889	36,834	2,312	29,467
4	Area Regulation	15 min.	30 min.	1 MW	40 MW	785	2,010	80	1,012	112	1,415
5	Electric Supply Reserve Capacity	1	2	1 MW	500 MW	57	225	636	5,986	90	844
6	Voltage Support	15 min.	1	1 MW	10 MW	400		722	9,209	433	5,525
7	Transmission Support	2 sec.	5 sec.	10 MW	100 MW	192		1,084	13,813	208	2,646
8	Transmission Congestion Relief	3	6	1 MW	100 MW	31	141	2,889	36,834	248	3,168
9.1	T&D Upgrade Deferral 50th percentile††	3	6	250 kW	5 MW	481	687	386	4,986	226	2,912
9.2	T&D Upgrade Deferral 90th percentile††	3	6	250 kW	2 MW	759	1,079	77	997	71	916
10	Substation On-site Power	8	16	1.5 kW	5 kW	1,800	3,000	20	250	47	600
11	Time-of-use Energy Cost Management	4	6	1 kW	1 MW	1,226		5,038	64,228	6,177	78,743
12	Demand Charge Management	5	11	50 kW	10 MW	582		2,519	32,111	1,466	18,695
13	Electric Service Reliability	5 min.	1	0.2 kW	10 MW	359	978	722	9,209	483	6,154
14	Electric Service Power Quality	10 sec.	1 min.	0.2 kW	10 MW	359	978	722	9,209	483	6,154
15	Renewables Energy Time-shift	3	5	1 kW	500 MW	233	389	2,889	36,834	899	11,455
16	Renewables Capacity Firming	2	4	1 kW	500 MW	709	915	2,889	36,834	2,346	29,909
17.1	Wind Generation Grid Integration, Short Duration	10 sec.	15 min.	0.2 kW	500 MW	500	1,000	181	2,302	135	1,727
17.2	Wind Generation Grid Integration, Long Duration	1	6	0.2 kW	500 MW	100	782	1,445	18,417	637	8,122

*Hours unless indicated otherwise. min. = minutes. sec. = seconds.
**Lifecycle, 10 years, 2.5% escalation, 10.0% discount rate.
†Based on potential (MW, 10 years) times average of low and high benefit ($/kW).
†† Benefit for *one year*. However, storage could be used at more than one location at different times for similar benefits.

The table above contains five criteria from the group of 17 primary benefits coming from ESS integration is given. Discharge duration indicates the amount of time that the storage must discharge at its rated output before charging. Capacity indicates the range of storage system power ratings that apply for a given benefit. The benefit indicates the present worth of the respective benefit type for a period over 10 years (2.5% inflation, 10% discount rate). Potential indicates the maximum market potential for the respective benefit over a period of 10 years. Current energy systems are moving toward the process of diversification and the growing role of energy storage systems (ESS) is considered an inevitable alternative to the path toward the process of decarbonization of the energy sector. Innovative energy conservation technologies are expected to make a significant contribution in the future, especially in the case of electrification of transport systems, increasing the contribution of RES and nuclear resources. According to long-term projections, they can be converted into promising electricity generators. Various energy storage technologies have been proposed to store excess or non-transmissible electricity in the form of mechanical, thermal, gravitational, electrochemical, and chemical energy. Energy conservation technologies are complex and difficult to understand compared to most low-carbon technologies. The storage value in an energy system depends on the portfolio of electricity generation, specifically on the relative amounts of inflexible and flexible generation. Existing power, dispatch, and grid models are either not broad enough to examine all alternative forms and options of energy conservation or have insufficient time solutions to realistically portray the need and performance of storage technologies. A clear interpretation of the possibility of integrating ESS within a national energy system can be mandatory as it can provide positive information that supports the new energy market model and rules.

Referring to data provided by the United States Department of Energy in the "Global Saved Energy Report", it is reported that 'PHES' hydro-electro-energy storage systems account for over 96% of all storage technologies worldwide, with an installed capacity of over 181 GW [13]. ESS can also be classified according to the form of electricity conservation presented in Figure 6 [12].

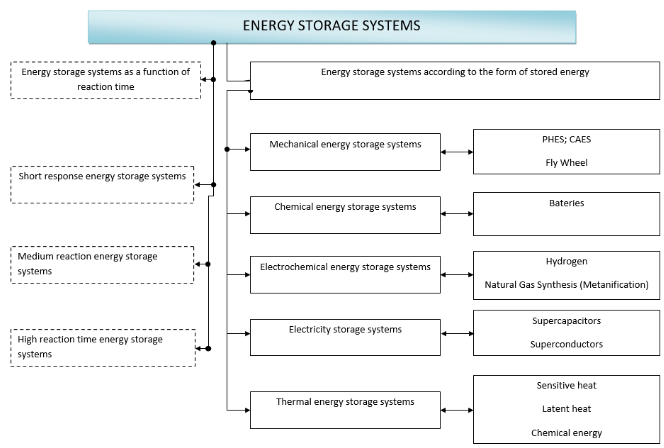

Fig. 6: Schematic representation of the classification of energy storage systems (ESS) [12].

According to [14], by the end of 2020, global operational energy storage project capacity totaled 191.1GW, an increase of 3.4% compared to the previous year.

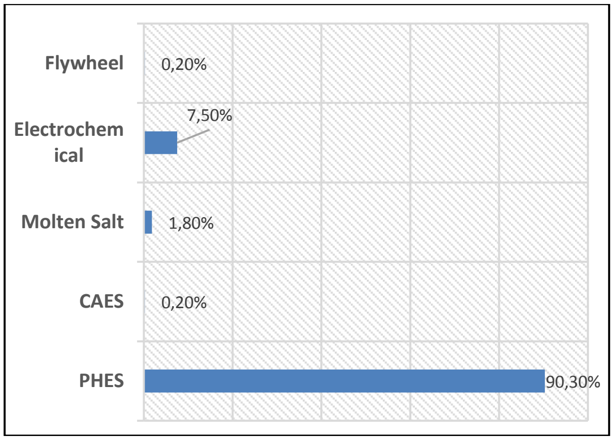

Fig. 7: Global Energy Storage Market by Total Installed Capacity (2020) [14].

Pumped hydro energy storage comprised the largest portion of global capacity at 172.5GW, an increase of 0.9%. Electrochemical energy storage reaches a total capacity of 14.1GW. Among the variety of electrochemical, lithium-ion batteries accounted for 13.1 GW, helping battery storage break 10 GW for the first time [14].
According to [15] Pumped Hydro Electricity Storage currently dominates total installed storage power capacity, with 96% of the total of 176 GW installed globally in mid-2017. The other electricity storage technologies already in significant use around the world include thermal storage, with 3.3GW (1.9%), batteries, with 1.9GW (1.1%), and other mechanical storage with 1.6GW (0.9%).

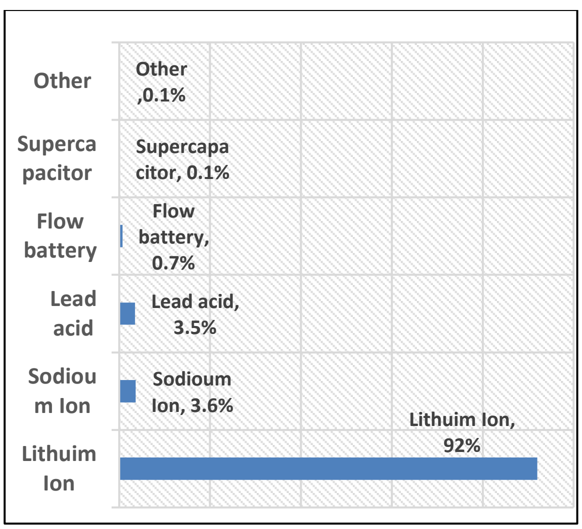

Fig. 8: Global Energy Storage Market share (%) by Total Installed Capacity (2020) [14].

According to a brief statistical study on the trend in ESS-related global mix (%), Lithium-Ion battery storage continued to be unchanged and the most widely used, making up most of all new capacity installed reaching a value of 93% (within the electrochemical forms) by the end of 2020 [16]. Referring to 2016, Lithium-Ion battery-based storage technologies share more than 95% of new energy storage systems installations (Excluding storage and storage systems PHES) [17].
Total installed battery storage capacity stood at around 17GW as of the end of 2020. Installations rose 50% in 2020 compared with a mediocre 2019, when the installation rate was flat for the first time in a decade. Globally China, the USA, and Japan are the countries that have the highest installed capacities of energy storage systems in the national energy system (Figure 9).

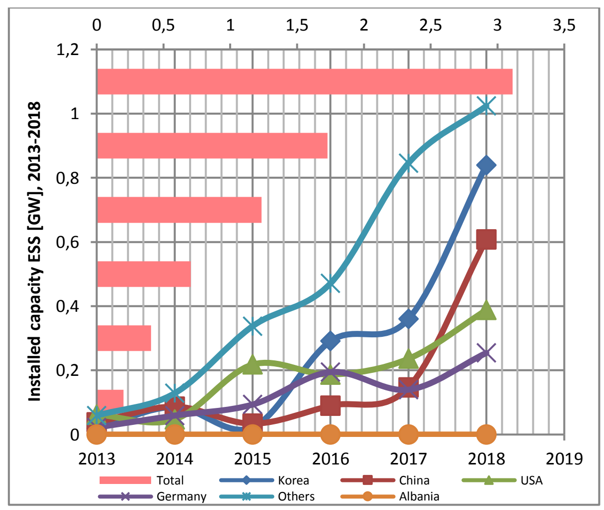

Fig. 9: The yearly development of ESS during 2013-2018 [18].

As it can be seen from figure 9, the yearly development of energy storage systems reached a record level in 2018, the newly installed capacities are two-fold more compared to 2017. Storage is one of a set of options that ensures power system flexibility and can generally be developed quickly and modularly whenever power system flexibility is needed [18]. As depicted in figure 9, Albania does not exist either expected to be performed any ESS soon, although the level of energy losses identified in the Drini River Cascade (refer to figures 2-3) are considerable.

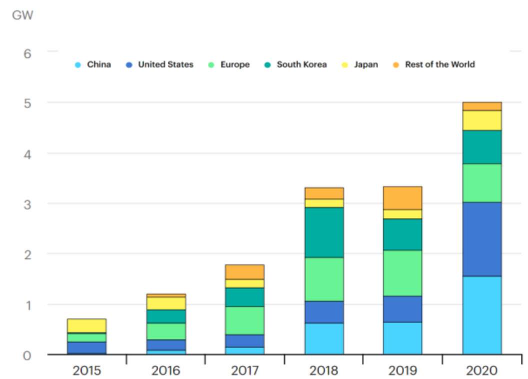

Fig. 10: Annual energy storage additions by country, 2015-2020 [19].

Emerging markets are paying attention to the application of ESS forms, engaging seriously through the establishment of support mechanisms, as storage as technology continues to need policy approaches that facilitate and enable and favor their application in different regions of the world as is clearly shown in the graph in figure 10. Globally, 5 GW of storage capacity was added in 2020, led by China and the United States, each registering gigawatt-scale addition. Utility-scale installations continue to dominate the market, accounting for around two-thirds of total added capacity [18]. In the IEA's Net-Zero Scenario by 2050, the total installed capacity expands 35-fold between 2020 and 2030 to 585 GW. Over 120 GW of battery storage capacity is added in 2030, up from 5 GW in 2020, implying an average annual growth rate of 38% [18]. Key speculation for the future of energy storage is the extent to which EV technology developments can "spill over" into grid-scale batteries. Given that the market for EV batteries is already ten times larger than for grid-scale batteries, the indirect effects of innovation and cost reductions in mobility applications could provide a significant boost.

After significant investments and increased use by the electronics and transportation sectors, the average price of a Lithium-ion battery pack in 2018 decreased significantly by 85% less than in 2010 [17]. Production capacity for lithium-ion batteries is expected to triple by 2022, driven by large-scale application in the EV market.

Total electricity storage capacity appears set to triple in energy terms by 2030 if countries proceed to double the share of renewables in the world's energy system. With the growing demand for electricity storage from stationary and mobile applications, the total stock of electricity storage capacities in terms of energy will require to grow from 4.67TWh in 2017 to around 15.72TWh (155-227% higher referring to 2017) if the RES share into the energy system is going to be doubled by 2030. The future storage capacity in (GWh) will be dominated by PHES. By 2030, pumped PHES capacity will increase by 1560 to 2340 GWh above 2017 levels in the REmap Doubling case. The more rapid growth of other sources of electricity storage will see its share fall to 45-51% by 2030 in the REmap Doubling case [15].

4 Methodology

4.1 Energy Storage Model Identification

The chosen methodologies of exploiting ESS using computational tools for representing the incorporation of ESS within the selected section location of the power system to where it can be connected, and the bulk generation, transmission, and distribution, commercial and industry, and residential users as it is given in figure 12. The current study also addresses the commercial availability, benefits, realistic requirements, barriers, and limitations of these technologies in the important two sections namely bulk generation, transmission, and distribution under the current and future Albanian energy system. This method allows the evaluation various of ESSs concerning their applications, characteristics, costs, and benefits within the power system. The obtained results of the analysis were all combined to verify the appropriateness of different ESS and prioritize them for meeting the application list given in table 4. It also enables determining the best possible use and physical placement within the grid. The best storage system is the one that fits the application's list, at the cheapest possible cost.

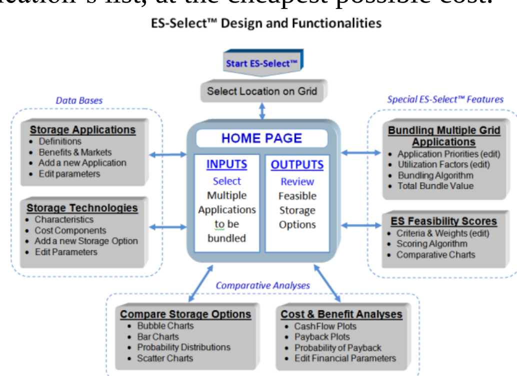

Fig. 11: Overview of ES-Select™ design and functionalities [20].

Comparing energy storage systems is complicated as it is closely related to a wide variety of operational and business factors such as differences in deliverable power, efficiency, discharge time, life cycle, the number of applications that the systems can be applied to, financial parameters and the ability to monetize multi-applications benefits. As shown in figure 11, ES-Select™ is a very sophisticated, highly interactive model that offers a means to conduct a careful analysis of the many interrelated factors that influence the overall feasibility scores given in the graphical presentation and ranks them for the selected application(s) list required (see table 4). The model uses a Monte Carlo-based analysis to handle uncertainties in cost, benefit, life cycle, efficiency, discharge duration, and other influenced parameters.

4.2 Energy Storage System Location And Priorities Chosen In The Study

The chosen methodologies of exploiting ESS using computational tools for representing the incorporation of ESS in the selected section location of the power system where it can be connected to bulk generation, transmission, and distribution, commercial and industry, and residential users. This method allows the evaluation of various ESS regarding their applications, characteristics, costs, and benefits within the power system. The obtained results of the analysis were all combined to verify the appropriateness of different ESS and prioritize them for the electric power system suitable to the region.

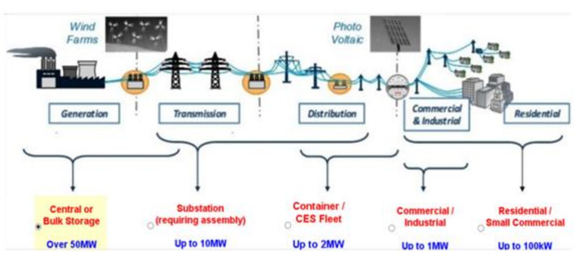

Fig. 12. Five possible locations for ESS integration. The central or bulk storage (>50MW) is selected [20].

Figure 12 shows five possible locations for the application of energy storage systems (ESS) connected to the national energy system. The selection of a location on the network is of particular importance as it directly affects three critical factors also evaluated by many studies in the field of energy storage and storage such as:

- ***a. Installation cost;***
- ***b. Availability/applicability of integration of energy storage and storage systems and;***
- ***c. Expected storage capacity.***

Based on features and the current situation of the power system in the country, studies [16-20], objectives highlighted in [21], the 6 main applications' priorities, and the importance that each application can bring to Albanian power system were carefully chosen and ranked as it is given in table 4.

Table 4. List of application's services and priorities selected for the proposed ESS.

Application list	
App#1	Trans. Congestion Relief
App#2	Trans Upgrade Deferral at 10%
App#3	Energy Time Shift (Arbitrage)
App#4	Solar Energy Time Shift
App#5	Wind Energy Time Shift
App#6	Solar Energy Smoothing

As the 6 basic applications that will be performed by ESS are selected in the model and updating the techno-economic features of various Energy Storage Technologies in the model, then the appropriate forms and types of energy storage are carried out.

5 Simulation Results and Discussion

This scientific paper describes a high-level, technology-neutral framework for assessing potential benefits from and economic market potential for energy storage used for electric-utility-related applications in Albania. The overarching theme addressed is the concept of combining applications/benefits into attractive value propositions that include the use of energy storage, possibly including distributed and/or modular systems. Other topics addressed include high-level estimates of application-specific lifecycle benefit (10 years) in ($/kW) and maximum market potential (10 years) in MW. Combined, these criteria indicate the economic potential (in $Millions) for a given energy storage application/benefit. The combination of the value of an individual benefit ($/kW) and the corresponding maximum market potential (MW) indicates the possible impact that storage could have on the Albanian economy.

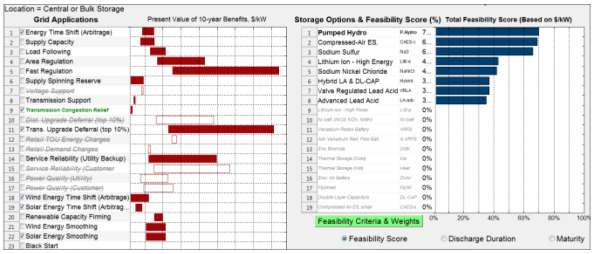

Fig. 13: The result of the feasibility scores analysis based on ($/kW).

The analysis of the feasibility scores for the selection of the right form and type of ESS, meeting the services listed in table 4, it results in 8 different types of storage recommended as the most suitable by the ES-Select model. The ESS that has the highest feasibility scores result in the form of mechanical storage, respectively PHES and CAES-c (compressed air energy storage-cavern). Energy shifting is one of the issues always supported by the application of PHES and CAES conservation schemes. Currently, on a global scale, mechanical storage systems such as PHES and CAES serve as systems to store excess energy (overproduction), especially from renewable energy sources (RES) or energy delivered from generators at off-peak demand and low-cost intervals. Other storage alternatives carried out to support chosen application's list can be Na-S batteries, Li-Ion batteries, etc. These batteries have a long-life cycle, and high capacity and can be used in practical cases when short or long discharge time is required.

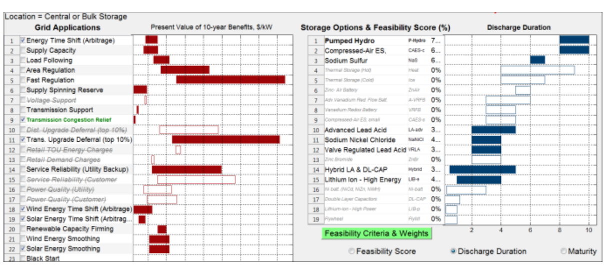

Fig. 14: Result of the discharge duration analysis for various ESS for the chosen application services.

From the results in the simulation (Figure 14), PHES and CAES-c types can provide long discharge times from 8 up to10 hours, while NaS batteries offer a discharge duration of around (6÷7) hours while other types offer discharge duration (1÷5) hours. The longer the discharge duration the more flexible and stable the power system can be. PHES and CAES-c are usually used for applications with an installed power capacity (10÷1000) MW and E/P ratio greater than 5 (energy displacement) as well as (5÷100) MW with E/P ratio varying from 3 up to 6 (load levelling). The amount of energy stored from CAES-c and PHES is limited only by the volume of the air and water reservoir.

These technical characteristics make Na-S batteries perfect for practical applications such as: responding to frequency changes, and energy shifting from renewable sources in time. However, Na-S batteries require high temperature to operate efficiently hence it can bring uncertainty and risk that's why it is excluded as a valuable option.

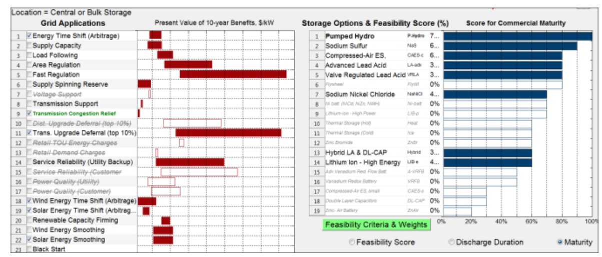

Fig. 15: Scores for commercial maturity for various ESS meeting the application's list.

In figure 15 the result of the simulation regarding technology maturity is applied per the chosen application given in table 4. The results rank first PHES, Sodium Sulfur, and third CAES-c. More evaluation of the selection process of appropriate ESS is needed.

In figure 16 the results from simulation-based on total installation cost for various ESS meeting the application's list (table 4) is given.

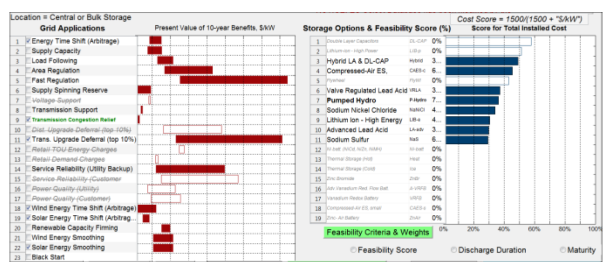

Fig. 16: The results from the simulation-based on total installation cost for various ESS meeting the application's list.

The cost score for each storage option is inversely proportional to the installed cost and is normalized concerning the expected final target values of $X/kW or $Y/kWh, depending upon whichever applies to an application, where X and Y are the expected costs of the ESS (eq.1 and 2 below):

$$COST\ SCORE = (\mathbf{X}/(\mathbf{X} + \mathbf{INSTALLED\ COST\ IN\ \$/kW})) \quad (1)$$

$$\boldsymbol{COST\ SCORE} = (\mathbf{Y}/(\mathbf{Y} + \mathbf{INSTALLED\ COST\ IN\ \$/kWh})) \qquad \mathbf{(2)}$$

The results rank first Hybrid LA&DL-CAP and second CAES-c.

6 Financial Analyses of ESS

The money available to the business serves as the "raw material" that enables the business to function smoothly just as it serves the fat ("material") that makes a machine work smoothly and increases longevity. By creating a cash flow budget, one can design fund applications for future time periods, which are needed for various maintenance services, replacement of plant parts or the need to replace aggregates at the end of the characteristic life cycle for energy conservation systems (ESS).
So, it is necessary to identify each period of money deficit in advance in such a way that the designer/developer gives recommendations or corrective actions today, to alleviate a possible deficit tomorrow.
In the ES-Select model, cash flow (Cash Flow) and payback period (Payback Period) are two interfaces in the Benefit/Cost group that enable full financial analysis for each storage option. The "Cash Flow" interface shows the costs, benefits and net cash flow accumulated by the selected ESS option during operation. The estimated cost of "replacement or renewal" for each storage option as well as the year in which the renewal will be required have been considered in the cash flow analysis. Annual costs are the sum of the maintenance or warranty cost plus the expected operating costs for each application selected in our study (refer table 4).
The "**simple payback period**" analysis module provides and compares the ROI (Return on investment), for all possible storage options calculated and ranked according to the total feasibility points. The simple payback period (SPP) of the investment can be given graphically or as a statistical distribution generated by the ES-Select model considering financial parameters in table 5.

Table 5. Financial parameters used for cash flow analysis: Base case scenario.

Profit growth rate	2%
Discount rate	(5-11)%
Electricity price growth rate	2.5%
Purchasing Cost of electricity (min)	$30/MWh
Purchasing Cost of electricity (max)	$50/MWh
Investment period	20years

In conclusion, the cost-benefit analysis process for the selected applications given in table 4 (App1→App6) gives answers to two main problems:

1. **To determine if the project is economically feasible and;**
2. **compare a concrete investment with other competing projects by defining the most feasible storage option.**

Considering the financial parameters presented in Table 5, a cash flow analysis for each ESS is performed and given in figure 17. The analysis of the cash flow and the SPP is carried out considering the project life of 20 years, the discount rate of 11%, the growth rate profit of 2.5%, the rate of increase of the electricity price 2.5%, and the purchasing energy min/max range ($30÷50/MWh) is accepted.

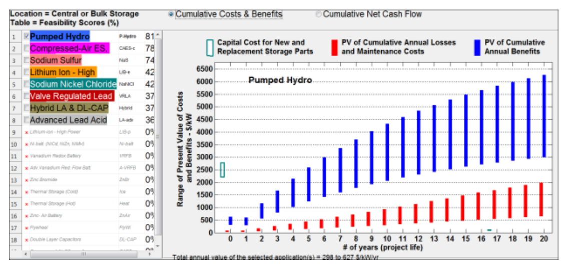

Fig. 17: Cumulative benefits and costs for the case of PHES type.

Figure 17 shows the result of the cash flow analysis which ranked first the PHES. The related spare parts costs are estimated to occur in the first year and in the 17-th year having values of $(2200-2750)/kW and less than $200/kW. While the PV (present value) of cumulative annual losses and maintenance costs increase progressively over the years ranging from $50 in year 1 up to $2000/kW at the end year of the system's lifetime. The actual value of benefits varies from $750 up to 6250/kW.

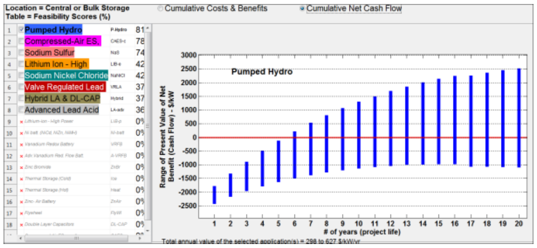

Fig. 18: Cumulative net cash flow for the case of PHES type.

Figure 18 shows the interval of the present value of the net benefit during the lifespan of the PHES plant. As it can be seen from the graph in figure 18, the PHES option ranges both in negative and positive regions, hence it requires a more detailed and extended analysis including different influencing factors.

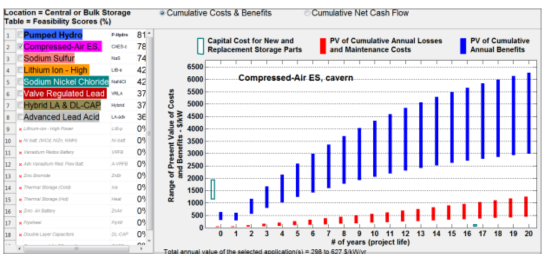

Fig. 19: Cumulative benefits and costs for the case of CAES-c type.

Figure 19 shows the result of the cash flow analysis for the case of ESS of the CAES-c type. From the simulation results, it is clearly shown that the costs for spare parts are estimated to occur in the first year and in the 17th year with respective values ranging from \$(1100-1900)/kW and less than \$150/kW. While the PV of cumulative annual losses and maintenance costs increase progressively over the years ranging from \$50 in year 1 to \$1250/kW at the end year of the plant lifetime. The present value of the benefit varies from \$750-6250/kW. Compared to PHES, CAES-c system has lower O&M costs.

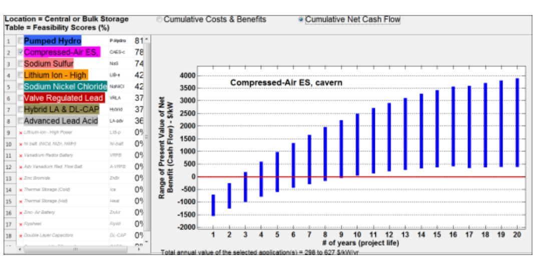

Fig. 20: Cumulative net cash flow for the case of CAES-c type.

The interval of net present value (\$/kW) calculated for 20 years of plant operation is given in Figure 20. As can be seen from the graph in Figure 20, CAES-c storage system provides positive revenue after the second year of its operation. The behavior of the system in respect of the initial techo-economimc parameters will be given in detail calculated in the section of risk analysis.

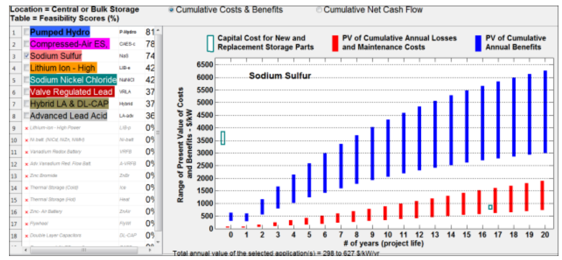

Fig. 21: Cumulative benefits and costs for the case of Na-S type.

In the graph in figure 21 the case of ESS of Na-S type is given. This system is represented with high capital costs for new spare parts ranging on average mids values \$(3300-3800)/kW in the first year of its operation.

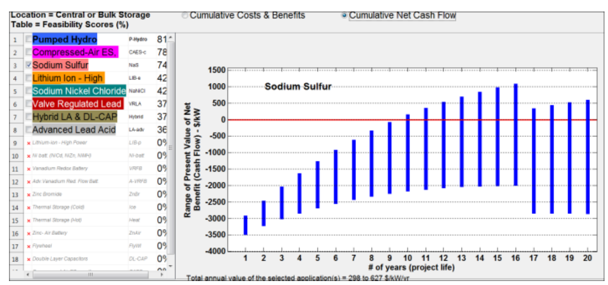

Fig. 22: Cumulative net cash flow for the case of Na-S type.

As depicted in the graph in Figure 22 the Na-S battery storage system provides revenue after the 10-th year of its operation where the actual value of the net benefit is many folds lower, due to the high cost of spare parts and system depreciation over the years. Considering the total combined feasibility scores gathered from Na-S for the application's list given in table 4 it is ranked third, hence it can't be applied. Compared to Na-S batteries, high-energy Li-Ion batteries are characterized by high installation costs (up to \$4,000/kW) and associated costs for spare parts. As a result, Li-Ion batteries are not feasible, and it is excluded from our case study.

7 Simple Payback Period Calculation (SPP)

SPP is one of the methods for evaluating the economic efficiency of different studies and various engineering projects. This is the time required by an investment where the total discounted costs of a project are exceeded by the total discounted benefits. In our analysis, the lifespan of each ESS plant is considered 20 years. The ESS and technologies which result in a longer payback period than the manufacturer-recommended lifespan and literature are excluded.

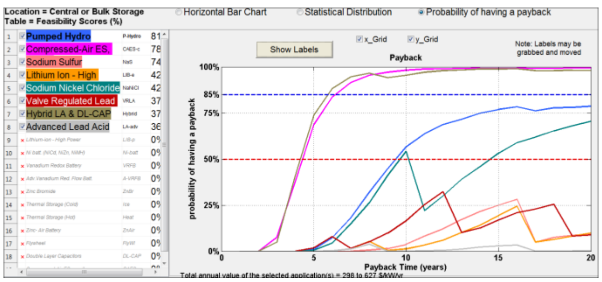

Fig. 23: Probability of having Payback (in years) of different proposed ESS at a discount rate of (r)11%.

The graph in figure 23 gives the probability of payback for each possible ESS that meet the application's list given in the table 4. In this graph it is clearly seen that for the initial preconditions of the financial parameters, referred to as the baseline scenario, given in Table 5 it results that the storage type of CAES-c and Hybrid batteries have a high probability of having a payback period in in the first 5-6 years of plant operation. PHES plants and Na-S batteries have a lower probability of reaching the payback period as a result and both technologies are excluded as a selection option for the case of our study. Based on the technical analysis and "cash flow" for each of the above systems, it results that: the CAES-c system meets the conditions to perform the list services of the national power system. Also, the CAES-c storage system has a higher lifespan and lower maintenance costs compared to Hybrid type batteries, which reach a maximum lifespan of up to 10 years or equivalent cycles. Choosing a discount rate of 5%, and considering other parameters unchanged, it is shown that the CAES-c storage system can have a payback within the first 3-4 years of its operation.

From the graph in Figure 24, a specific weight factor of 1 that calculates the total feasibility scores meeting the application's list, commercial maturity, location requirement, and total installation cost ($/kW) at the chosen location is accepted.

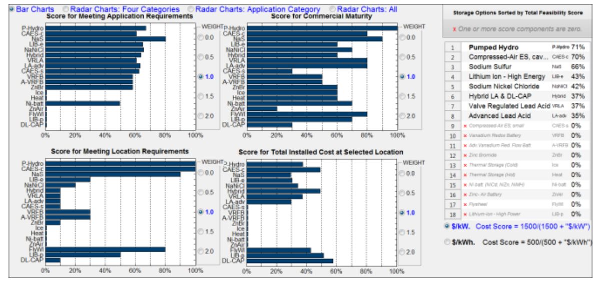
Fig. 24: Analysis of storage options sorted by total feasibility scores meeting the application's list, commercial maturity, location requirement, and total installation cost at the chosen location.

As it can be seen from the results of the analysis, the PHES storage system ranks first with 71% followed by the CAES-c with 70% and Na-S batteries at 66%. The other types are battery types having the same level of total feasibility points with (35-43)%. This assessment does not consider the physical aspect related to the real installation availability, which needs the designer to analyze step by step considering first the country context, associated costs, and other limiting factors in the site.

8 Conclusions

In Albania, the use of energy storage systems (ESS) systems has been limited due to the lack of research initiatives and cooperation between key actors in the energy sector in the country. The distinctive and profoundly important feature of energy storage systems (ESS) is to provide multiple benefits from a single device. The use of ESS, with the aim to solve multiple services in the transmission sector will be a key strategy to foster the upcoming RES capacities in Albania.

The high level of seasonal losses of potential energy in the Hydropower Power Plants (HPP) and the problems of congestion in transmission grid are the two main problems that require new methods for addressing and solving them. The purpose of this study was fully met by conducting a comparative technical and economic analysis of different types of energy storage systems at the central or bulk generation. The study confirms the status, capabilities and restrictions, costs, and benefits of the main storage technologies available: PHES, CAES, various batteries (NaS, Li-Ions, ZEBRA, etc.). The economic analysis focused on estimating the cost of installation, the payback period (SPP), profitability over a 10-year period, NPV as well as a detailed sensitivity analysis. Therefore, in the absence of the above-mentioned features, it is extremely difficult to tackle the challenges of the energy sector alone on the road to 2030 or 2050. PHES and Compressed air energy storage (CAES) is suitable for large-scale energy storage and can help to increase the penetration of intermittent sources such as wind and solar power into the Albanian power systems.

9 Recommendations

Risk assessment and acceptance should be considered for a project that has a significant cost, hence analyzing which factors create the greatest risk carefully and accurately and redesigning the actual energy strategy is needed. Deferral of investments in the transmission network involves partial or total diversions in investments for the renovation of the transmission system, using relatively small amounts of storage. To defer a possible upgrade within a period, the generating capacity of the (ESS) must be equal to the expected load increase during the following period. In these conditions, the presence of ESS in the transmission network could avoid unnecessary investment.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

-Ilirian KONOMI: Conceptualization of the publishedwork, formulation, and evolution of overarching research goals and aims. Data curation and scrubbing data and maintaining research data (including software code and validation.

Application of statistical, mathematical, computational, and simulation in ES-select model.

-Valma PRIFTI: Formal analysis and Preparation, creation, and presentation of the published work.

--Andrin KERPACI: Development or design of methodology; creation of models, preparation, creation, and presentation of the published work. Application of statistical, mathematical, computational, or other formal techniques to analyze or synthesize study data.

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