

AN OVERVIEW ABOUT COSTS ANALYSIS OF BATTERIES IN ENERGY TRANSITION

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Abstract: Storage electricity in batteries is crucial for the integration of renewable energy sources into power grids and for maintaining grid stability. Battery storage plays a vital role in the transition toward a sustainable and reliable energy system, reducing dependence on fossil fuels and contributing to greenhouse gas emission reduction goals in energy transition processes. Battery energy storage is essential for a sustainable energy future and has favorable economic effects.

Key words: congestions, energy transition, battery, sustainable energy development.

1. INTRODUCTION

The global energy transition, although it seems to have entered another phase – with the United States leaving the Paris Agreement, OPEC countries increasing oil production, China building nearly 100 GW of coal-fired power generation capacity – cannot be stopped because the cost of renewable energy is competitive and will become even more competitive (even with storage units).

The integration of prosumers into the grid, both from a technical and commercial perspective, is associated with certain challenges in ensuring the safe and standard-compliant operation of the network, as well as in maintaining a financial balance between prosumers and other consumers connected to the grid, particularly at low voltage levels.[1] One possible solution could be the transition to value-based compensation, regardless of the prosumer's installed capacity, based on Day-Ahead Market prices during the hours when they inject energy into the grid.

It is necessary to set clear national objectives aimed at increasing renewable energy generation capacities, as well as storage capacities, by expanding programs and increasing funding to support energy storage. Romania needs 30 billion euros in network investments by 2050, of which about 15 billion should be needed by 2030.

Prosumers and other distributed energy sources have a substantial influence on the distribution network. Due to the unpredictable nature of energy flows, the grid must become more adaptable, while ensuring that voltage levels stay within acceptable limits remains the primary challenge.[2]

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2. SIGNIFICANCE OF BATTERIES IN ENERGY TRANSITION

To meet the ambitious decarbonization goals established by nations, it is essential to invest in grid expansion, improve the performance of existing renewable energy assets, and enhance the flexibility of the energy system. Enhancing the system's flexibility can be achieved through energy storage solutions for addressing the challenges posed by the intermittent and variable nature of renewable sources, as well as through the provision of subsidiary services. In this context, consumers are encouraged to take on a central role as prosumers within the energy system, being connected to the distribution grid, generating, consuming, and storing energy through various technologies, while actively participating in energy markets.

Battery energy storage systems are becoming crucial technologies for maintaining the stability and reliability of power grids. These systems enable the storage of excess energy generated during low-demand periods and its discharge during peak demand, while also helping to optimize energy resource utilization, decrease reliance on fossil fuels, and enhance the overall efficiency of energy systems.

The variability of renewable energy sources leads to nonlinear energy production, relying on elements like sunlight and wind speed, which fluctuate over time and across locations [1], [3]. This variation can result in discrepancies between energy supply and demand, potentially causing voltage and frequency fluctuations in the electricity grid, thereby impacting its performance and reliability [4]. In this scenario, battery energy storage systems are crucial, offering an effective method to handle intermittency and maintain a consistent energy supply.

2.1. Benefits

The energy mix in Romania is a diverse combination of hydropower, nuclear, natural gas, coal and growing renewable sources like wind and solar with a strong focus on expanding renewables and reducing coal dependence to meet EU decarbonization targets. Storing electricity in batteries offers numerous advantages. Advantages that enhance both economic effectiveness and the endurance of energy frameworks [5]. These advantages are varied and encompass decreasing energy expenses, steadying rates, enhancing the dependability and adaptability of power networks, advocating for the adoption of renewable energy sources, and generating employment.

3. COSTS OF BATTERY ENERGY STORAGE

Storing electrical energy in batteries involves a series of costs that can be divided into capital costs, operation and maintenance costs, and levelized cost of energy (LCOE). In this chapter, it is emphasizing these cost components and how they influence the economic viability of energy storage solutions.

Economic elements, like the prices of raw materials and market dynamics, can greatly affect the expenses related to battery energy storage. For instance, variations in lithium and cobalt prices, which are crucial elements of lithium-ion batteries, may

influence manufacturing expenses and thus impact battery pricing. Government regulations and subsidy programs are essential in lowering expenses and encouraging the adoption of energy storage technologies. Funds for research and development, tax breaks, and financial assistance programs are crucial for promoting investment and speeding up the widespread use of batteries [6]

3.1. Cost of Capital

Capital costs represent the initial expenditures necessary to buy and set up battery energy storage systems. These expenses are shaped by the kind of battery, energy storage capability, and the utilized technologies. Recently, expenses related to capital for lithium-ion batteries, the most commonly utilized ones today, have dropped considerably. As specified in market literature reported that the average price of lithium-ion batteries has fallen from around 1.100 \$/ kWh in 2010 to 200\$/kWh in 2025. This significant decline is ascribed to technological progress, economies of scale, along with advancements in manufacturing methods [7]

Residential storage systems generally cost more per unit of capacity compared to industrial or grid stabilization systems because of unique installation needs and the extra equipment needed [5]. Moreover, batteries utilizing alternative technologies, like solid-state or redox-flow, are still in the initial phases of commercialization and entail greater capital expenses, yet they hold the potential for considerable advancements down the line [5].

3.2. Operation and Maintenance Costs

Operation and Maintenance expenses are ongoing costs linked to the functioning and upkeep of energy storage systems. These expenses comprise overseeing the systems, substituting damaged parts, and the costs linked to handling and recycling batteries once they reach the end of their life cycle.

The operation and maintenance expenses for lithium-ion batteries are quite minimal in comparison to other energy storage technologies, owing to their dependability and longevity. The longevity of the battery significantly impacts operation and maintenance expenses. Lithium-ion batteries generally last between 10 to 15 years, influenced by the number of charge and discharge cycles and the conditions in which they operate. Alternative battery technologies like nickel-metal hydride (NiMH) or lithium iron phosphate (LiFePO₄) may have varying lifespans, thereby affecting maintenance and replacement expenses.

3.3 Levelized cost of energy (LCOE)

Levelized cost of energy (LCOE) is an essential economic metric that represents the overall cost of energy generation per unit of energy produced throughout a battery's lifespan. LCOE considers all expenses, such as capital, operational and maintenance, and financing costs.

The ongoing decline in LCOE for battery energy storage systems is making them more competitive with conventional energy generation and storage options.

A recent study from speciality literature indicates that the LCOE for lithium-ion batteries has significantly declined in recent years, attaining values about 131-232 \$/ MWh, based on the application and system scale. This indicates a decrease of about 70% relative to 2015, underscoring the swift advancement of this technology. In comparison, the LCOE for alternative storage technologies, like hydrogen or pumped hydro, is usually greater, but they can provide benefits in particular situations [5], [6].

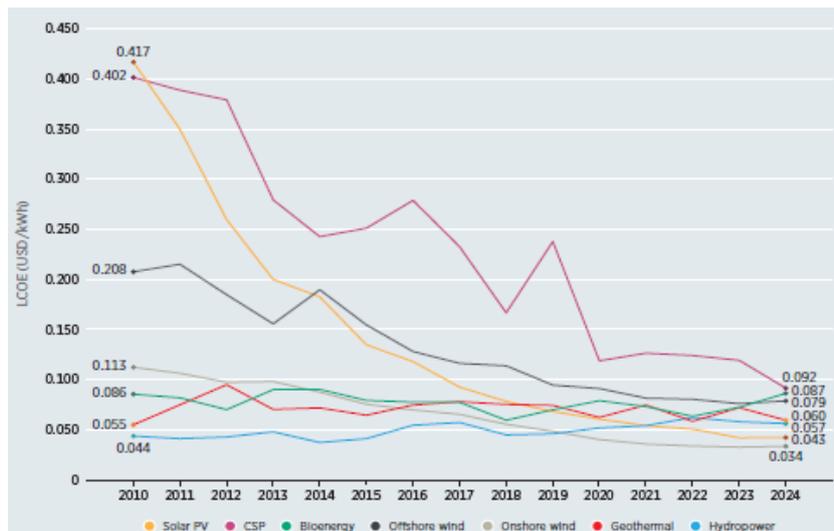


Fig.1. Renewable energy LCOE decline

Source: IRENA (RENEWABLE POWER GENERATION COSTS IN 2024)

4. ADVANTAGES USING BATTERIES

4.1. Reducing energy costs

A primary economic advantage of using batteries for energy storage is the optimization of energy expenses. Batteries enable the accumulation of energy generated during times of low demand and excess, releasing it when demand is high, thereby minimizing the reliance on fossil fuel generators to address peak demands [8]. This results in substantial savings for users and power grid managers.

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4.2. Stabilizing energy prices

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4.3. Improving the reliability and flexibility of electricity grids

Battery energy storage enhances the dependability and adaptability of electricity networks by supplying crucial ancillary services, including frequency and voltage stabilization, load balancing, and management of grid congestion [1],[4]. Batteries can swiftly respond to fluctuations in energy supply and demand, offering a prompt reaction ability that is essential for ensuring grid stability. This minimizes the chances of power failures and guarantees a steady and dependable energy supply.

4.4. Promoting the use of renewable energy sources

A major advantage of battery energy storage systems is to enable the extensive adoption of renewable energy sources. The inconsistency of renewable energy sources, like solar and wind, poses a significant challenge to their broad adoption [5],[9]. Batteries enable the accumulation of energy produced from renewable sources when production is high and its availability in times of increased demand or minimal output, thereby optimizing the utilization of renewable energy and decreasing reliance on fossil fuel energy sources.

4.5. Jobs and Economic Development

The advancement and implementation of battery energy storage technologies generate considerable employment prospects across multiple sectors, such as research and development, production, installation, and maintenance. The energy storage sector knows economic development by investing in infrastructure and technological advancements, thus fostering economic growth and enhancing global competitiveness. The rising demand for lithium-ion batteries has resulted in substantial investments in production facilities and research, generating employment and fostering regional growth [10].

5.CONCLUSIONS

Battery storage, hybrid power systems, and digitalisation are vital for advancing the energy transition and integrating variable sources such as solar PV and wind. Large-scale battery deployment is essential to build a renewable-based power system, with storage expected to deliver most short-duration flexibility needs. Energy storage in batteries plays a crucial role in the shift towards a sustainable and dependable energy system. This technology presents various economic advantages, such as lowering energy expenses, stabilizing prices, and enhancing the reliability and adaptability of electricity grids. Additionally, battery energy storage supports the widespread incorporation of renewable energy sources, lessening reliance on fossil

fuels and helping to achieve goals for reducing greenhouse gas emissions. Although the initial capital investment is substantial, it has significantly decreased due to advancements in technology and economies of scale, making storage technologies increasingly financially feasible. Operating and maintenance costs remain relatively low, and the ongoing decline in the levelized cost of energy (LCOE) highlights the growing competitiveness of batteries in comparison to traditional options.

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