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# Pitfalls of LCOS in Comparing Various Energy Storage Technologies

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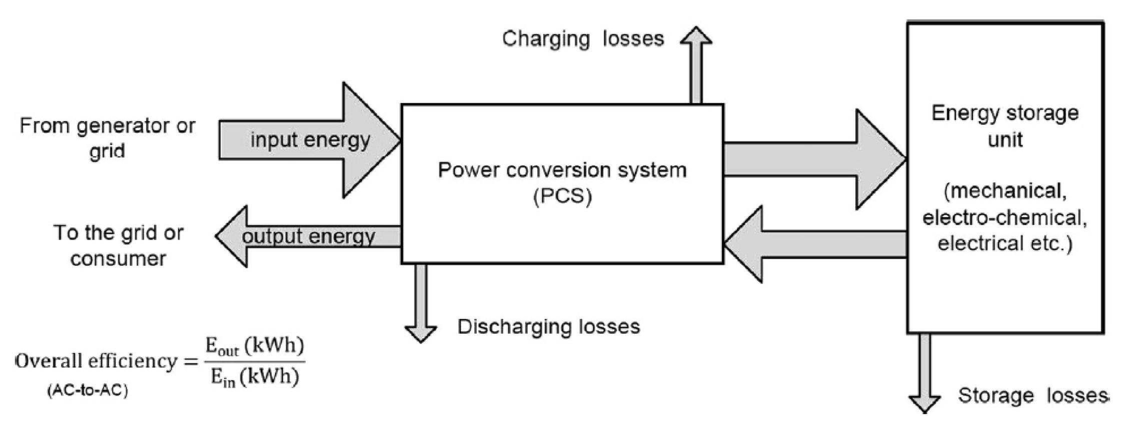
## Abstract

The objective of this study is to discuss the drawbacks of using Levelized Cost of Storage (LCOS) as a comparative metric for evaluating different energy storage technologies. The study aims to highlight the need for a better metric that captures the cost-competitiveness of these technologies. The global energy landscape is shifting towards renewable sources, necessitating the development of effective energy storage solutions. The energy storage market offers various technologies, categorized into mechanical, thermal, electrical, electro-chemical, and chemical forms. However, for this study, the focus is on technologies where both the inputs and outputs are electricity. The study begins by explaining the general procedure for calculating LCOS, which takes into account capital expenditures, operational and maintenance costs, and fuel expenses. This methodology is then applied to selected storage technologies to conduct a comparative analysis. LCOS is influenced by the technology itself, including capital expenditures and operational costs, as well as the cost of charging, which is directly related to electricity cost and inversely related to the round-trip efficiency (RTE) of the system. However, the cost of charging is market-specific, depending on factors such as source, time, location, season, and global events. Storage companies have limited control over electricity costs, and favorable conditions in one location may not guarantee economic viability elsewhere. Consequently, LCOS may not accurately reflect the actual cost of storage. The study concludes that a better metric is needed for a fair comparison of different storage technologies. This metric should be developed without incorporating the cost of electricity or, alternatively, explicitly include the cost of electricity alongside LCOS. It is recommended to present a range of LCOS values for low and high electricity costs. Furthermore, separate comparisons can be made for capital expenditures, operational and maintenance costs, and round-trip efficiency to provide a comprehensive analysis of the technologies.


## Levelized Cost of Storage (LCOS)

- Average cost of electricity ($/MWh or $/kWh) discharged from a storage device accounting all costs (Capital, O&M and fuel) throughout the lifetime of the device
- Two major units are power conversion system(PCS) and Energy Storage Unit (ESU)




Ref.: Zakeri and Syri, 2015, Electrical energy storage systems: A comparative life cycle cost analysis

- General formula for LCOS

$$LCOS\left(\frac{\$}{MWh}\right) = \frac{Investment\ cost + \sum(O\&M_t + Charging_t)\cdot(1+r)^{-t}}{\sum MWh_t \cdot (1+r)^{-t}}$$

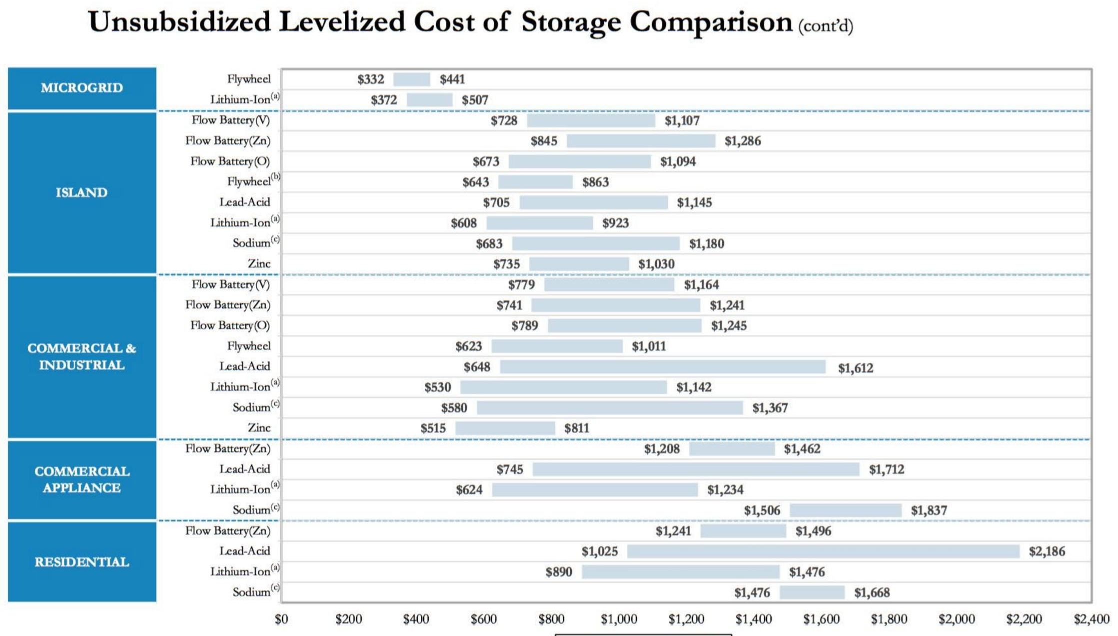
Capital = Total capital expenditures
$O\&M_t$ = Fixed operation and maintenance costs in year t
$Charging_t$ = Charging cost in year t
MWh = The amount of electricity discharged in MWh in year t, measure for the capacity factor
$(1+r)^{-t}$ = The discount factor for year t

- Considering the price of electricity ($/MWh) into charging cost and the overall efficiency or roundtrip efficiency (RTE)

$$LCOS\left(\frac{\$}{MWh}\right) = \frac{Investment\ cost + \sum O\&M_t \cdot (1+r)^{-t}}{\sum MWh_t \cdot (1+r)^{-t}} + \frac{P_{el}}{\eta_{RTE}}$$

## Diverse Energy Storage Market

**Unsubsidized Levelized Cost of Storage Comparison** (cont'd)




Ref.: Lazard

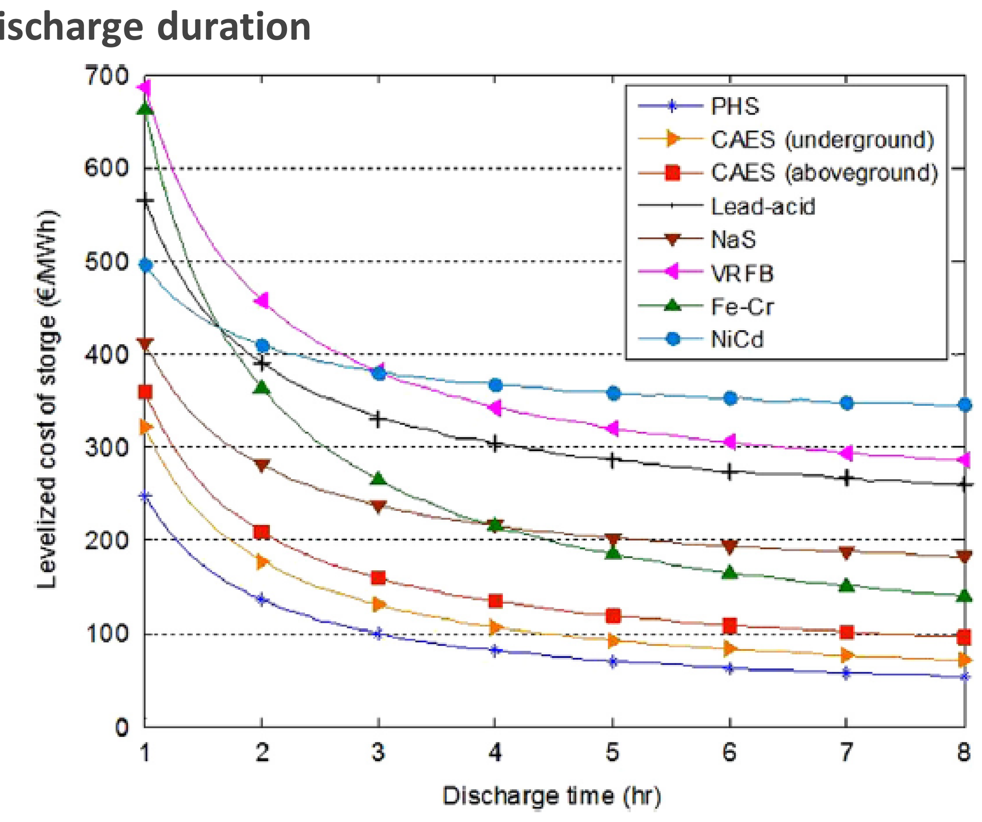
When the cost of electricity is included in the Levelized Cost of Storage (LCOS) calculation, it can introduce a potential problem or limitation:

- **Varying electricity prices:** Electricity prices can vary significantly over time and across different regions. Including these fluctuating electricity prices in the LCOS calculation might lead to inconsistent results, making it difficult to compare storage technologies accurately.
- **Unrealistic assumptions:** The LCOS calculation typically assumes a constant cost of electricity over the entire lifetime of the storage system. In reality, electricity prices are subject to market forces and policy changes, which might not align with the assumptions made in the LCOS model.
- **Ambiguity in application:** The inclusion of electricity costs in LCOS might not always be appropriate or practical, especially in cases where the energy storage system is deployed for specific purposes, such as backup power or grid stabilization, rather than optimizing electricity consumption.
- **Lack of granularity:** Including the cost of electricity in LCOS might oversimplify the analysis and fail to account for the different price structures (e.g., time-of-use rates) and usage patterns, which can significantly impact the financial viability of an energy storage project.
- **Difficulty in isolating storage benefits:** By factoring in the cost of electricity, it becomes challenging to isolate the specific benefits and cost-effectiveness of the storage system alone, as it gets intertwined with electricity pricing dynamics.

## Sensitivity analysis

The LCOS is dependent on many factors such as discharge duration, short-term vs. long-term, and technologies.

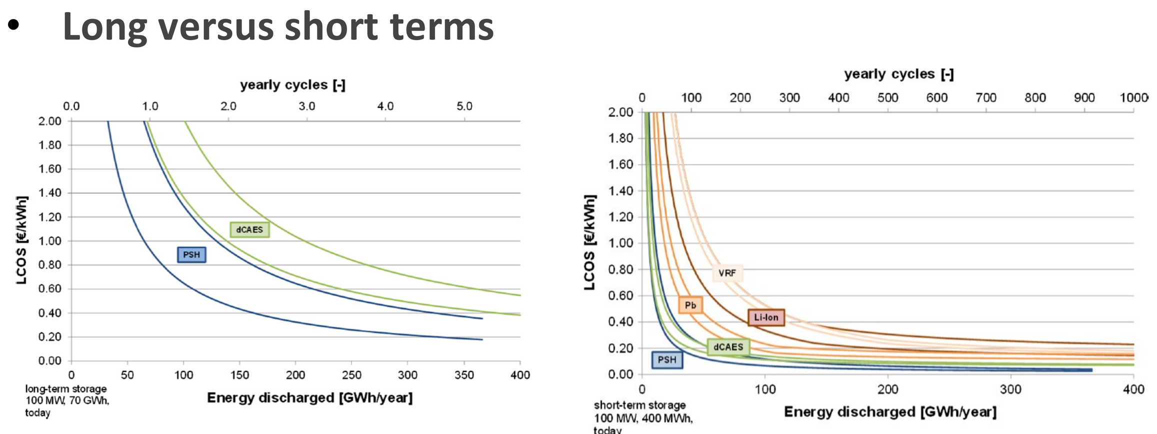
- **Discharge duration**




Ref.: Zakeri and Syri, 2015, Electrical energy storage systems: A comparative life cycle cost analysis

- The batteries' rank order varies depending on the discharge time.

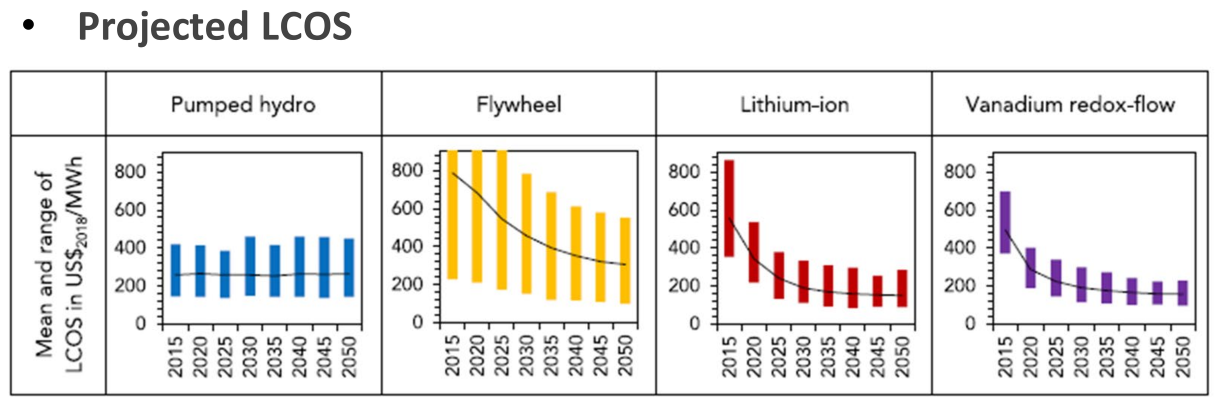
- **Long versus short terms**




Ref.: Jülch,2016, Comparison of electricity storage options using levelized cost of storage (LCOS) method

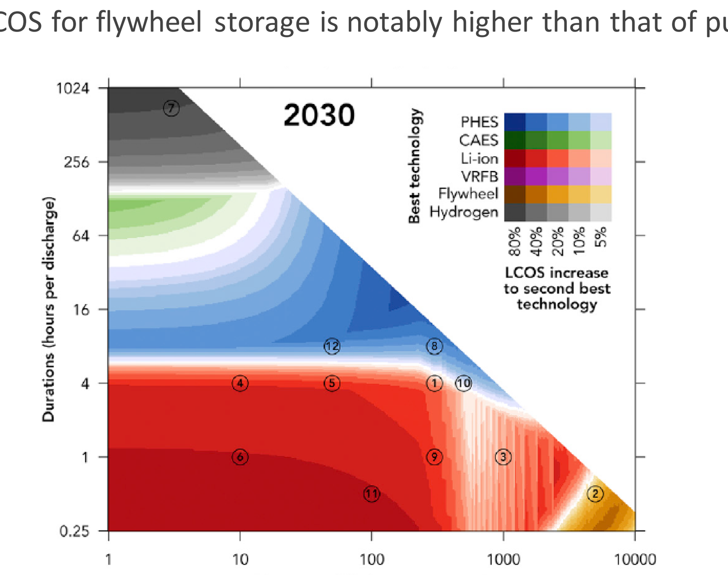
- As the yearly discharged energy decreases, the LCOS experiences a significant increase. This is attributed to the fact that the same CAPEX and OPEX costs are distributed among a smaller amount of discharged energy.
- PSH stands out as the most cost-efficient technology.

- **Projected LCOS**




Ref.: Schmidt et al.,2019, Projecting the Future Levelized Cost of Electricity Storage Technologies

- Pumped hydro demonstrates the lowest LCOS in 2015, ranging from 150 to 400 US$/MWh, primarily attributed to its long lifetime of 1,000 annual cycles, despite having relatively high initial investment costs.
- The mean LCOS for flywheel storage is notably higher than that of pumped hydro.

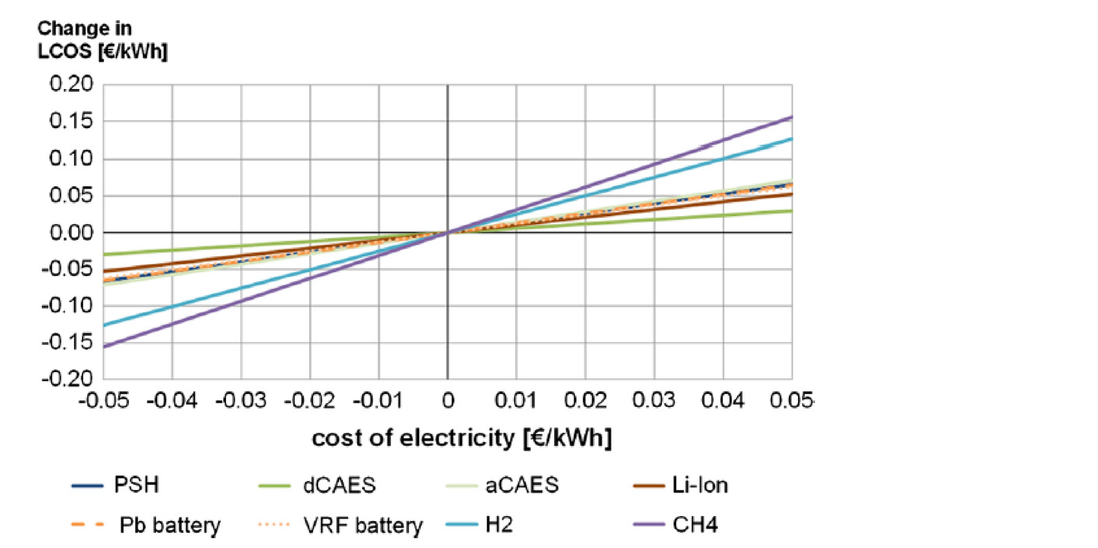



Ref.: Schmidt et al.,2019, Projecting the Future Levelized Cost of Electricity Storage Technologies

- On average, across various technologies and discharge and frequency combinations, the LCOS share attributed to charging cost is 4%, while it increases to 9% across the 12 modeled applications.
- When electricity prices experience a ten-fold increase, rising from 50 to 500 US$/MWh, the relative importance of round-trip efficiency also increases.

## Pitfalls of LCOS

- Power block vs energy block: Different for different technology. Keeping the power output the same, the duration can be increased by partially retrofitting the energy block. However, for battery technology or others, entire system will be set up. Therefore, LCOS i.e., $/MWh depends on power, duration, and technology
- Pitfall 2: Varies with location due to electricity costs. In some places cost may be negative




Ref.: Jülch,2016, Comparison of electricity storage options using levelized cost of storage (LCOS) method

- The costs are oversimplified by LCOS, as it fails to account for all expenses related to a real financial decision.
- The project context is oversimplified, disregarding project risks and oversimplifying interest rates within the capital recovery factor and other capital costs.
- When used as an average across different countries, LCOS masks regional variability, as costs, LCOS values, revenue, and renewables availability differ significantly among countries.
- While including the cost of electricity in LCOS can provide some insights into the economic viability of energy storage projects, it's crucial to carefully consider the specific context and purpose of the analysis. In many cases, it may be more appropriate to evaluate LCOS independently without directly factoring in the cost of electricity or to conduct sensitivity analyses to understand how changes in electricity prices impact the overall results.

## Conclusions

The levelized cost of storage (LCOS) is a useful metric for comparing the cost of different energy storage technologies over time. However, it also has some pitfalls that need to be considered:

- Simplistic approach: LCOS calculates the average cost of energy storage over the system's lifetime, assuming constant utilization. This approach may overlook dynamic operational characteristics and complexities associated with certain technologies.
- Lack of real-time factors: LCOS does not consider real-time factors such as market price fluctuations, demand patterns, or grid conditions. It may not accurately reflect the economic value of storage in a dynamically changing energy landscape.
- Inadequate cost components: LCOS may not account for all relevant costs involved in storage projects. For example, it might not include grid integration costs, maintenance expenses, or decommissioning costs, leading to an incomplete cost estimation.
- Ignores performance variations: LCOS assumes a constant performance level over the storage system's lifetime. However, actual performance may degrade over time, impacting the economics and long-term viability of the storage technology.
- Limited technology scope: Different energy storage technologies have varying characteristics, and LCOS might not adequately capture the nuances of each technology, leading to potential misjudgment of their cost-effectiveness.
- Geographical limitations: LCOS calculations may not consider regional variations in factors such as energy prices, policies, and resource availability, making it less suitable for cross-regional comparisons.
- Future uncertainties: LCOS projections rely on assumptions about future energy prices, technology advancements, and policy changes. Unexpected shifts in these variables can render LCOS predictions inaccurate.
- Comparison bias: When comparing energy storage technologies, LCOS alone might not provide a complete picture. It is essential to consider other factors like the response time, grid services provided, and environmental impacts to make informed decisions.

To overcome these pitfalls, it is advisable to use LCOS as one of several evaluation tools alongside other complementary metrics to obtain a comprehensive understanding of the true costs and benefits of energy storage technologies.

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