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Techno-economic analysis of Redox Flow Batteries: a methodological overview

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Objectives

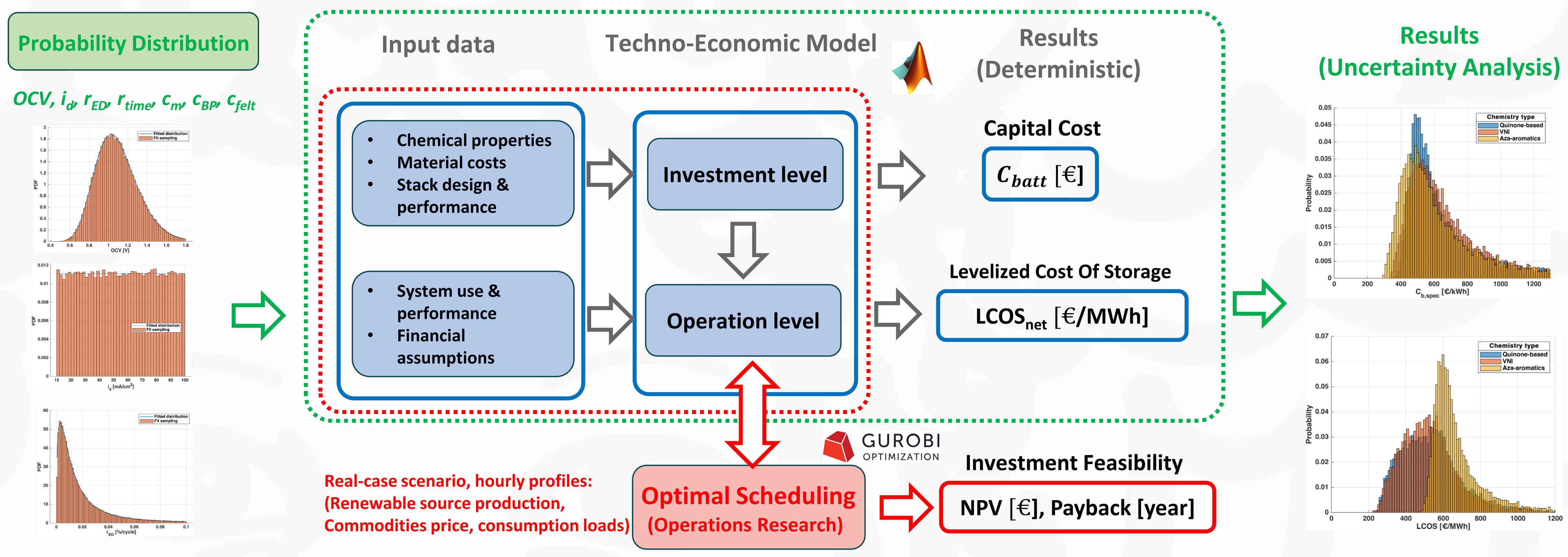
1. Comprehensive RFBs **techno-economic** framework development.
2. Key **technical** & **economic variables** identification.
3. **Storage solution profitability:** Consider both lumped (LCOS) & detailed (NPV, PBT) key performance indicators.

INTRODUCTION

Techno-economic profitability is essential to be commercially competitive, and this kind of analysis is especially relevant for Redox Flow Batteries (RFBs); RFBs have a large potential due to their intrinsic scalability and possibility of freeing from critical materials, e.g. developing environmentally friendly organic electrolytes based on widely available chemicals. Nevertheless, RFBs face substantial challenges, both vs. conventional electrochemical storage, such as Li-ion, due to their larger investment costs and lower roundtrip efficiency counterbalancing their larger operational life and capability to restore cyclic degradation. Furthermore, within RFBs, the organic ones are expected to have lower specific energy costs, due to the possibility of fabricating organic redox pairs at a low cost, but they are affected by higher degradation and will require a higher amount of electrolyte and larger membranes, to compensate for lower power and energy density compared to Vanadium RFBs. Several other solutions could be adopted to enhance their performance and those all need to be systematically assessed from a techno-economic viewpoint.

METHODS & DATA

The **capital cost** and the **Levelized Cost of Storage (LCOS) models** have been computed paying attention to the **whole battery system** performance, the **context** where it is going to be integrated, different **degradation** mechanisms, and the **energy considered** to compute LCOS (see methodology below).



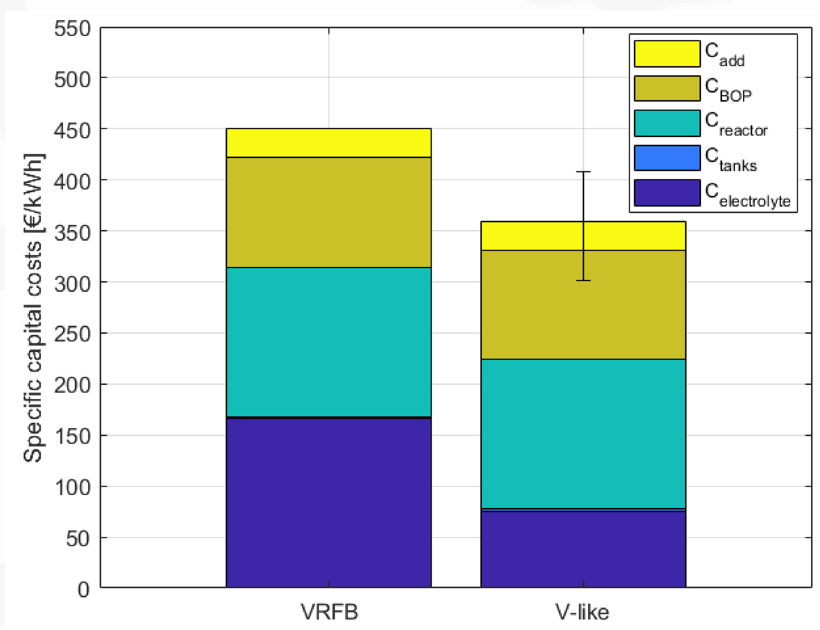
The main sources of uncertainty affecting the Cost and LCOS models were analysed and tackled in two ways:

1) detailed test cases that enabled to see the impact of battery optimal design & scheduling as per operations research state of-the-art, namely modeled as mixed integer linear program (MILP).

2) uncertainty of design parameters (performance & cost related) is measured by identifying a probability distribution, that is reflected in the results.

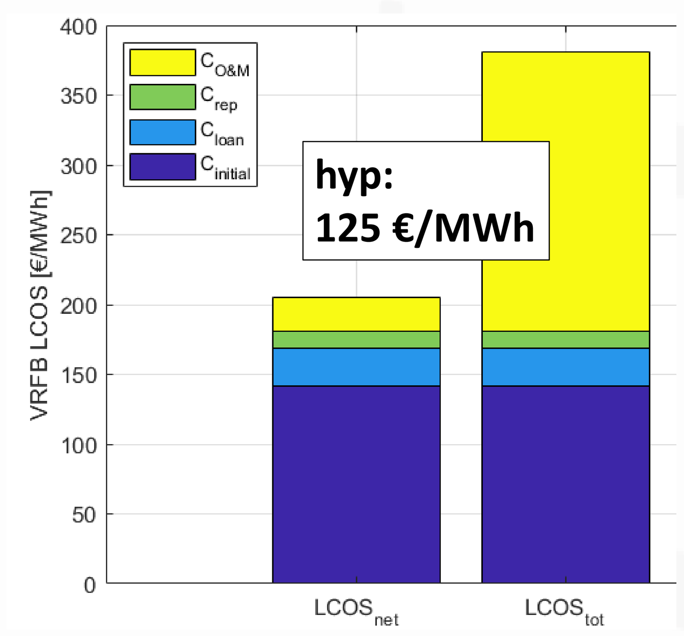
RESULTS

Capital costs breakdown VFB & V-like



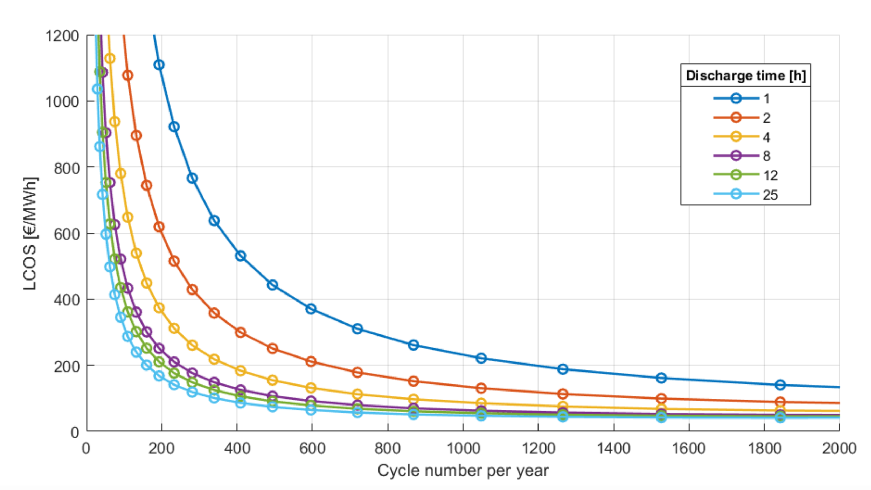
The presented methodology, validated against vanadium's current capital costs (left figure, 4h duration) could be utilized to measure the impact of technical and economic assumptions. E.g. considering that Aqueous Organic RFB are still not economically competitive, the cost of an ideal one was quantified to see what happen if it performs as a vanadium one (V-like), but keeps low cost of active material (3.5 vs. 30$/kg), density (1044 vs 1400 kg/l) and degradation (0.1 capacity %/day of cyclic and temporal degradation with 10 $/kWh of replacement cost vs 0.4% /cycle for V due to crossover) like organic one. The **error bar** is based on main components costs (membrane, bipolar plate, electrode felt) literature data and gives a **confidence interval** ranging from 5th to 95th percentile. On the right-hand side the impact of stored electricity purchase cost is considered showing how it increases the value of LCOS by more than 30% (assuming 125 €/MWh vs. 0), which is why we distinguished between LCOS$_{net}$ and LCOS$_{tot}$.

Cost of electricity, impact on LCOS



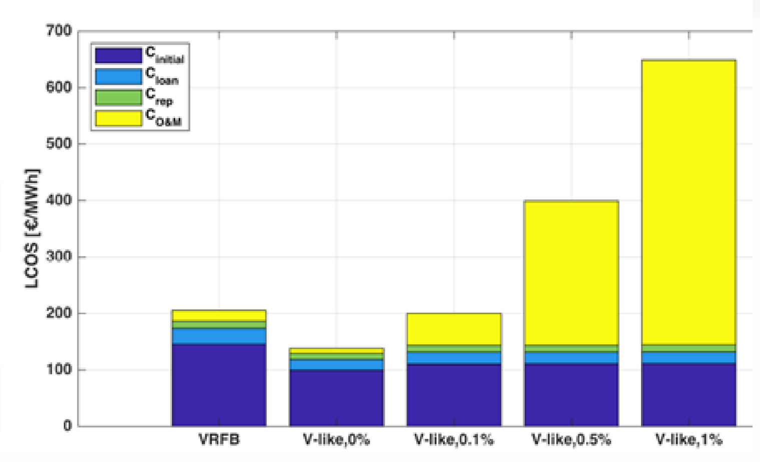
N cycles/day & discharge time

Sensitivity highlighting the **number of charge-discharge cycles per day** impact on LCOS; it strongly depends on the actual battery's optimal usage calculated via **optimal scheduling model (MILP)**. Same figure shows the **energy/power ratio (discharge time)** impact on LCOS.



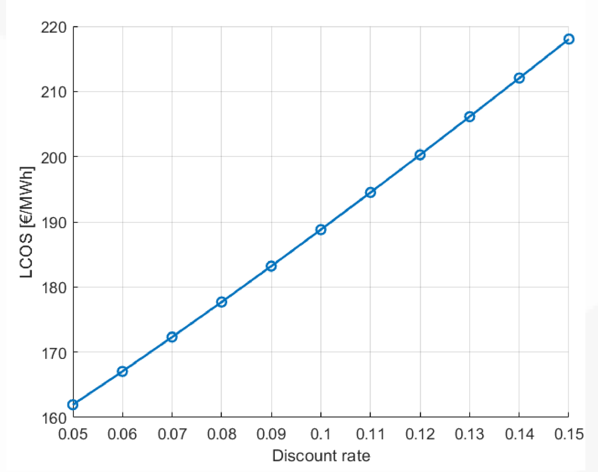
Total degradation

AORFB degradation could vary extensively, here we measure its impact on LCOS considering the total, **cyclic + calendar**, assuming one cycle per day. It shows how it **should not exceed 0.1% per day.**



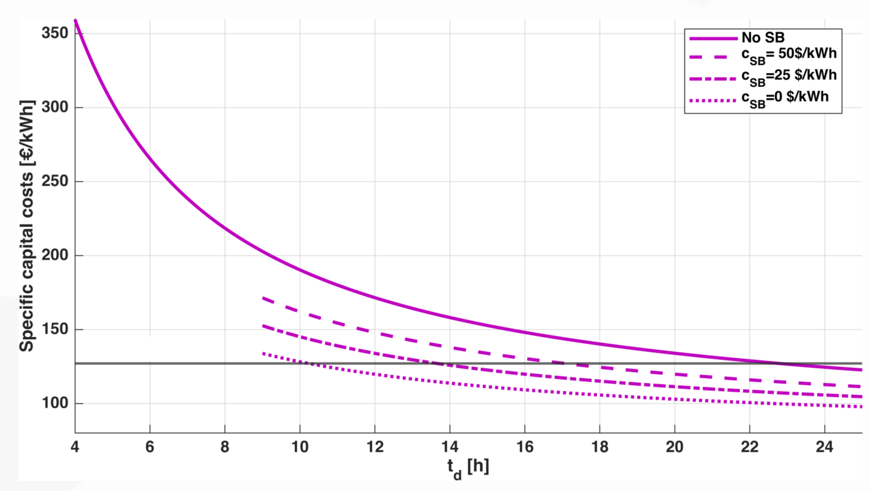
Discount rate

Financial assumptions, often neglected, have large impact. **Discount rate** ranging from small to large investors, from stable to unstable economies have an **impact that could exceed 30% of LCOS.**



Solid Boosters (SB)

Redox solid storage materials are under development to be used into the tanks (solid boosters) to **increase energy capacity and, thus density**.
V-like AORFB, with SB of above 16h capacity & 50 $/kWh cost, could reach the target of 150$/kWh (130€/kWh).



CONCLUSIONS

- The study identifies a comprehensive methodology for RFB techno-economic analysis.
- The importance of optimal scheduling and design of batteries as per state-of-the-art operations research has been highlighted.
- A comprehensive methodology to deal with uncertainty in energy storage system assessment is defined and presented.
- A set of key features for future Flow Batteries development towards competitiveness is identified.

References

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[3] D. Cremoncini, G. Di Lorenzo, A. Baccioli, A. Bertei, A. Bischi, "D3.5 Report on techno-economic modelling",Computer aided desing for next generation flow batteries (CompBat), Grant agreement ID: 875565, doi:10.3030/875565.

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