Hybrid redox flow batteries:

Technology upscaling, opportunities and challenges

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Company presentation

GREEN ENERGY STORAGE

RESHAPING THE ENERGY TRANSITION

Green Energy Storage – GES:

SME located in Trento, north Italy, working on the developing of redox flow batteries

2015 - Harvard AQDS TECHNOLOGY PATENT License Agreement:

License Agreement with Harvard for exclusive rights in Europe for the AQDS patent, based on semi-organic Antraquinon/Bromine flow battery technology

2015 - 2019 – AQDS/Br RFB technology development:

GREENERNET (2018)– 2,5 kW/10 kWh RFB prototype

COMESTO (2018) – Application of GES RFB into a Nanogrid System development

PROVINCIA AUTONOMA di TRENTO (2019) – battery component engineering project

2020 – Hybrid RFB technology:

Based on market and supply chain restrictions for AQDS, GES moved to hybrid RFB technologies

2021 – IPCEI for the European Battery Innovation Program

GES is enlisted within the second IPCEI (Important Projects of Common European Interest) for the creation of a European battery value chain.

IPCEI FOR THE EUROPEAN BATTERY INNOVATION PROGRAM

IPCEI (Important Projects of Common European Interest)
GES was granted with a 62 M€ budget project to develop a new RFB battery technology.
The funding covers the activities of a 4-year R&D and a 2-year first industrial deployment (FID)

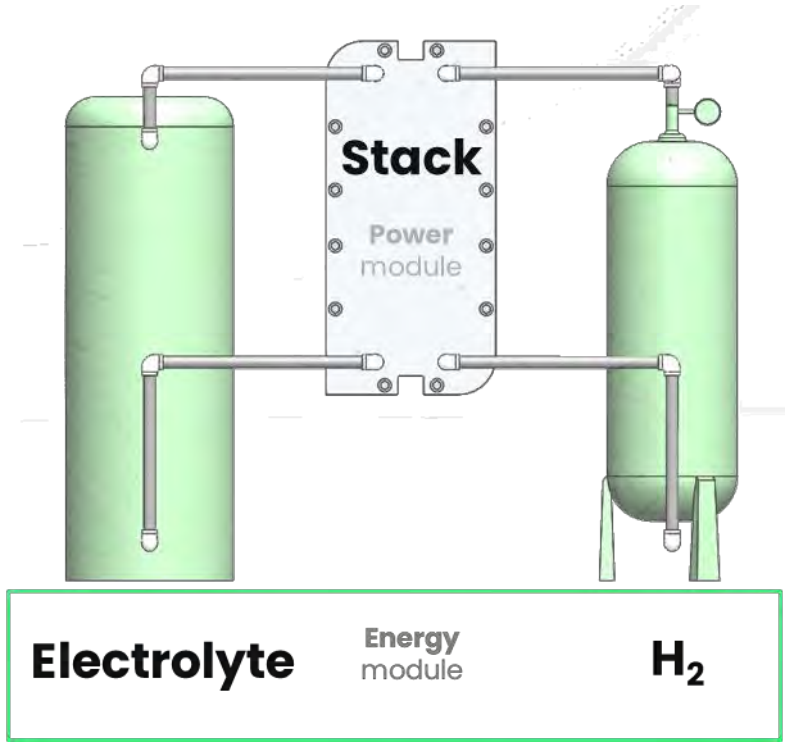
BUDGET: 62 M€ (GES)

DURATION: 6 years
(4 ys R&D + 2 ys FID)

PROJECT: new RFB technology from R&D to first industrial deployment (FID)

GES HYBRID RFB TECHNOLOGY

GES technology is based on a hybrid system: hydrogen as anolyte and an aqueous catholyte.
These active materials were selected because they own a potentially interesting electrochemical performance.



Hydrogen anolyte:

- Competitive electrochemical performances:
  - H_2 owns the lowest redox potential in aqueous electrolytes and the lowest overpotential in pH → Maximizes the cell voltage and efficiency
  - Current densities up to 1 A/cm^2 demonstrated in similar technologies → Maximizes the cell power density
- High worldwide investment to develop H_2 systems

GES acqueous catholyte:

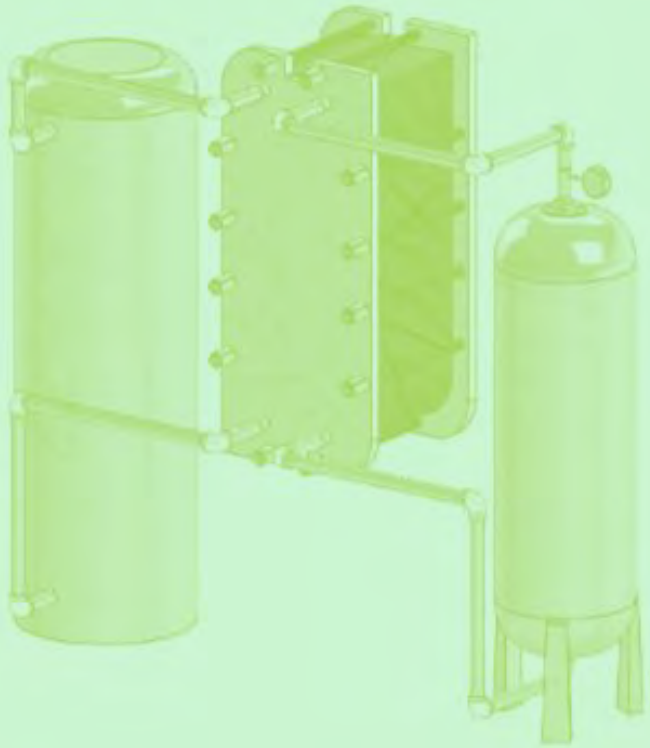
- Based on an abundant and economic active component (non-critical raw material)
- The electrolyte owns an acidic nature, it is non-toxic and non-corrosive
- Two PATENTS submitted on the catholyte chemistry

Theoretical values and KPIs:

- Theoretical energy density >120Wh/l
- Energy efficiency >85%
- LCOS of 0,02 Eur/kWh/cyc in mass production

02

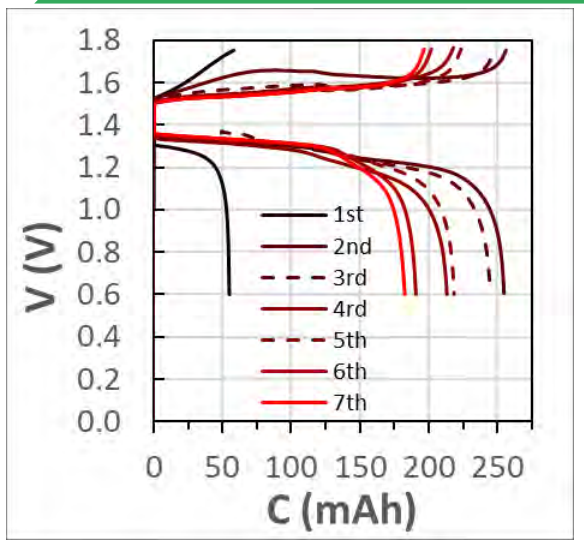
R&D activities



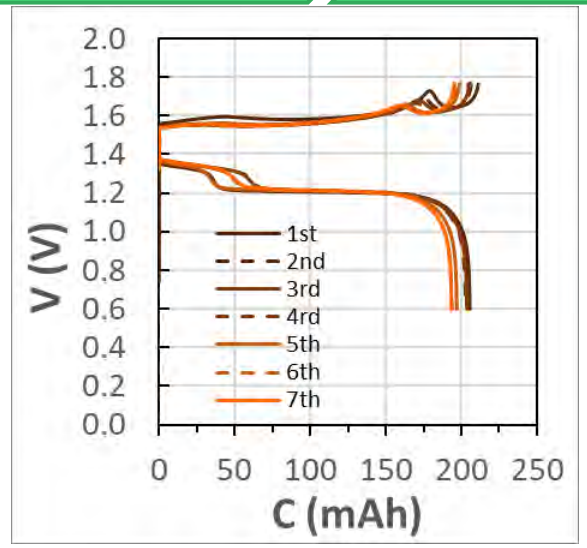
STABILIZATION OF H_2-GES SYSTEM

GES found a potentially interesting cathodic active material for redox flow batteries. The active material showed a very poor electrochemical behavior that was stabilized by optimizing the electrolyte formulation and electrode properties.

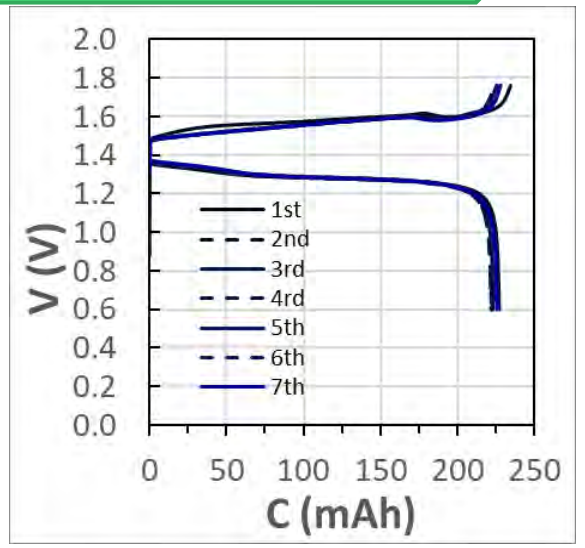
Optimized electrolyte solutions → Advanced electrodes



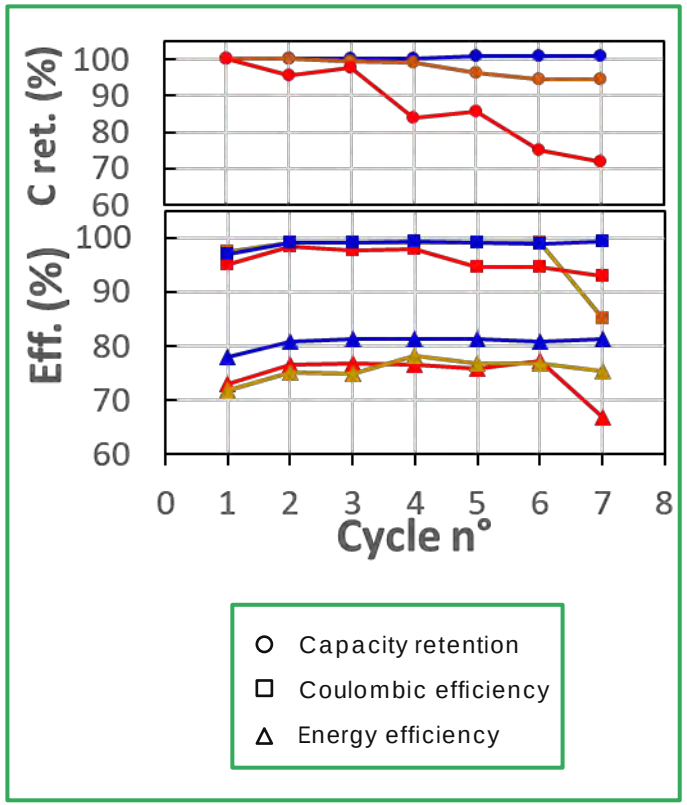
Base system



Optimized electrolyte system



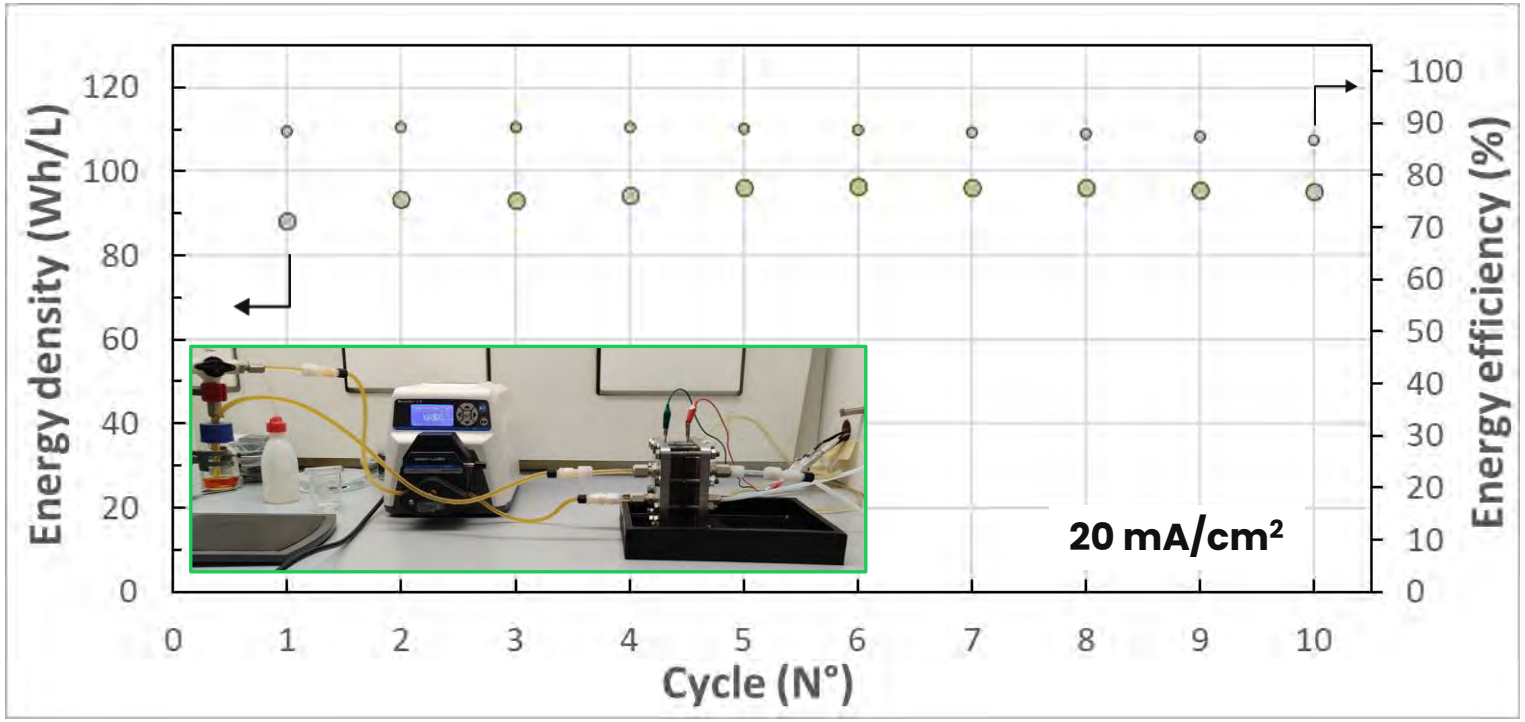
Optimized electrolyte system & advanced electrodes



- Implementation new electrolyte solution to stabilize the redox reaction
- Implementation of advanced electrodes to maximize the electrochemical performance
- Results of first optimization: Battery system with 99.3% coulombic and >81% energy efficiency

DEMONSTRATING THE COMPETITIVENESS OF H_2-GES SYSTEM

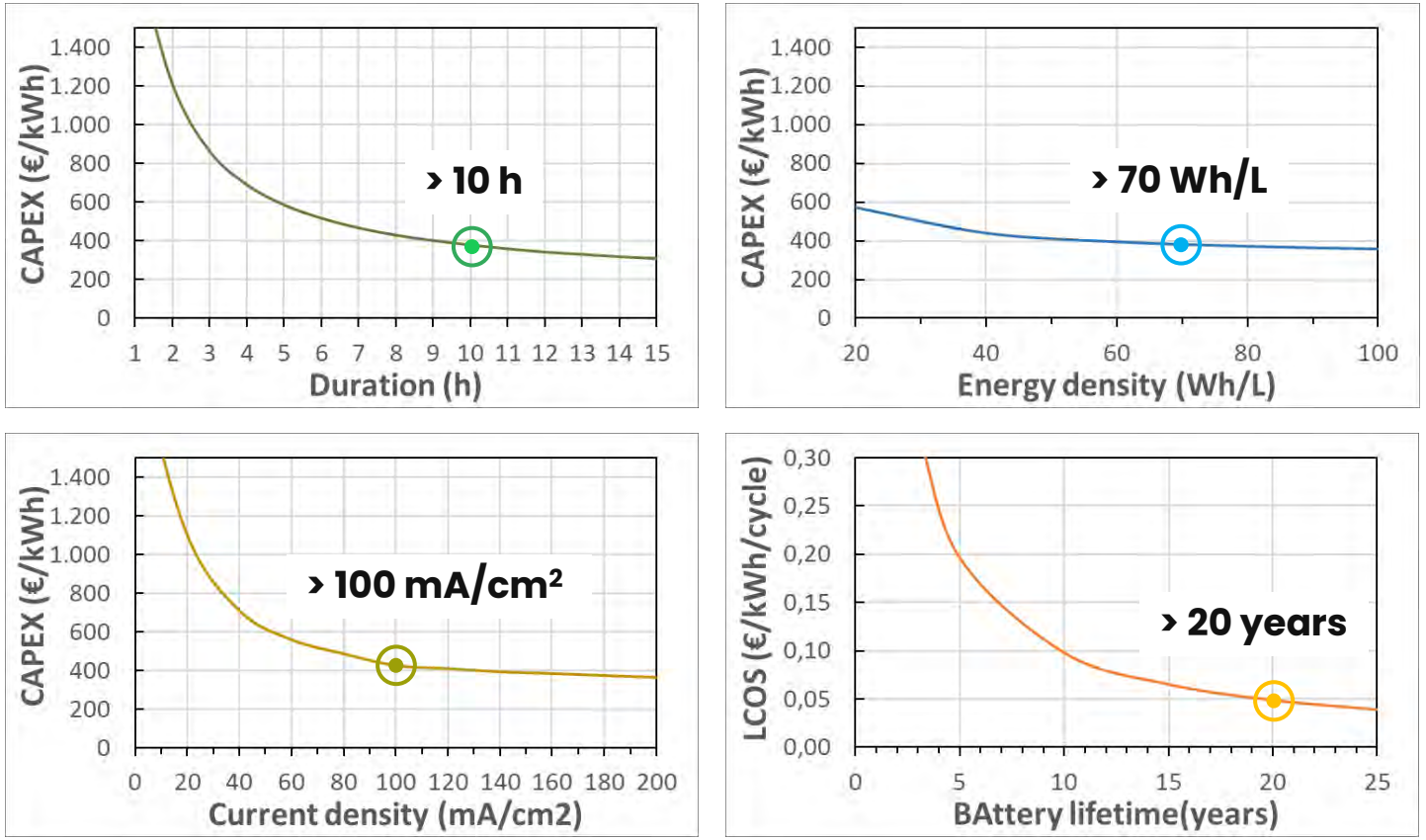
The electrochemical performance of an 80 Ah/L electrolyte was monitored in a lab scale redox flow cell (25 cm^2 active area).



The system showed very promising electrochemical performance: >90 Wh/L and >85% energy efficiency.
The system needs to be optimized in several aspects: current density, cycle life, etc.
To guide the R&D activities, the techno-economic analysis of the system was carried out.

THECNO-ECONOMIC ANALYSIS –> GUIDING THE R&D ACTIVITIES

The techno-economic analysis: cost calculation of a 10 kW RFB battery.
The effect of different parameters on battery cost were studied in order to set the priorities for the research.

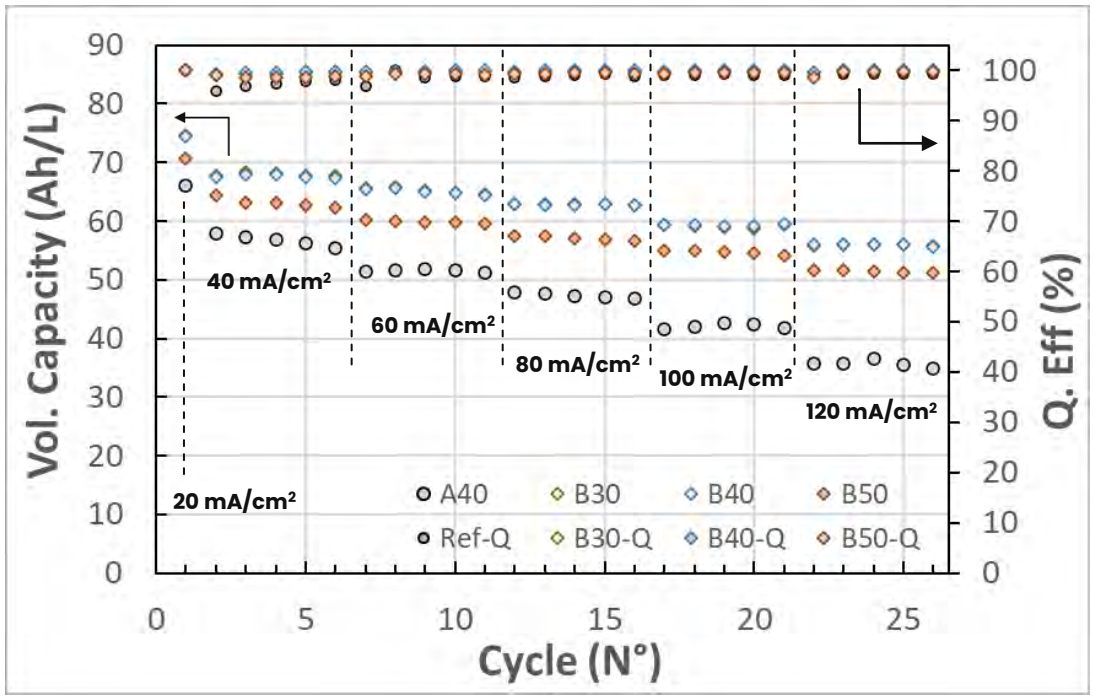


The techno-economic analysis sets the threshold values to reach an initial value of the levelized cost of storage (LCOS) below 0,04 €/kWh/cycle: 10 h discharge; 70 Wh/L; 100 mA/cm²; 20 year of lifetime. Based on these results, the R&D activities were oriented to reach them.
This conservative LCOS value assumes that experimental parameters are still under optimization and does not consider an economy of scale. The final KPI for LCOS is 0,02 €/kWh/cycle.

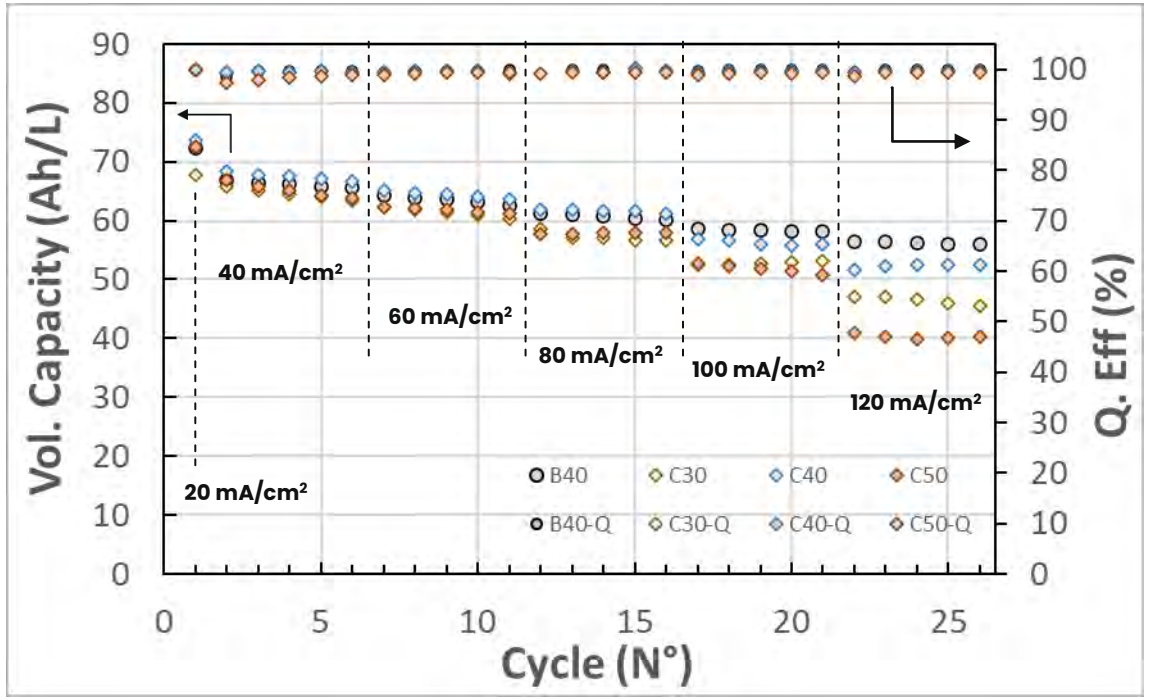
EXPLORING THE LIMITS OF THE CURRENT DENSITY

Electrode benchmarking studies were carried out on an 80 Ah/L lab cell: the effect of the different electrodes (type and supplier) and compression grades (30, 40 and 50%) at different current densities was studied.

Electrodes A and B from SUPPLIER I



Best electrode from SUPPLIER I vs SUPPLIER II



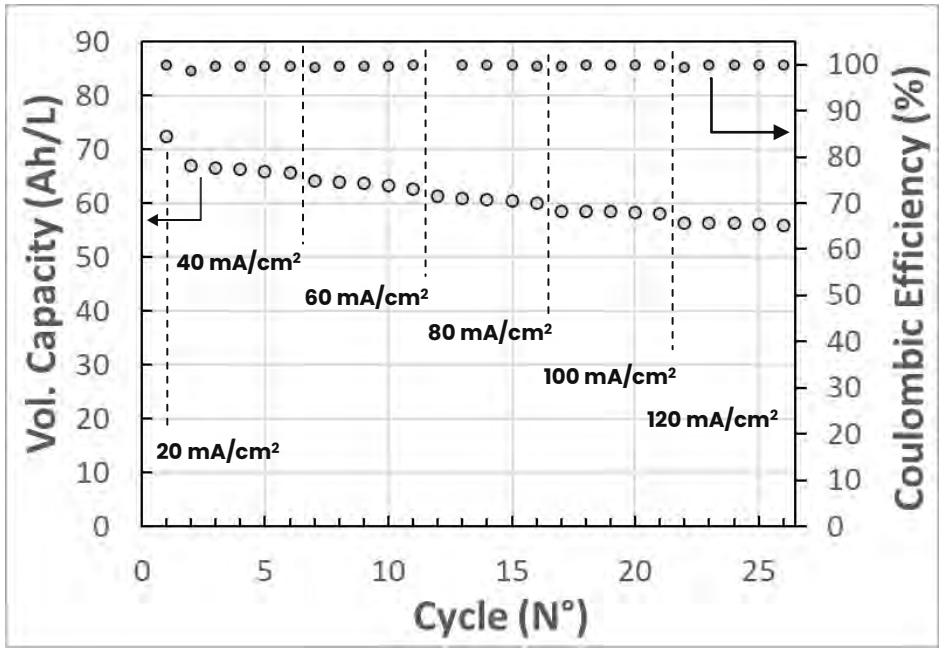
The results demonstrate that current densities above 100 mA/cm² are feasible by a proper selection of the electrode. Further studies are needed to maximize the delivered volumetric capacity.

A higher current density brings to a lower battery cost and a lower LCOS.

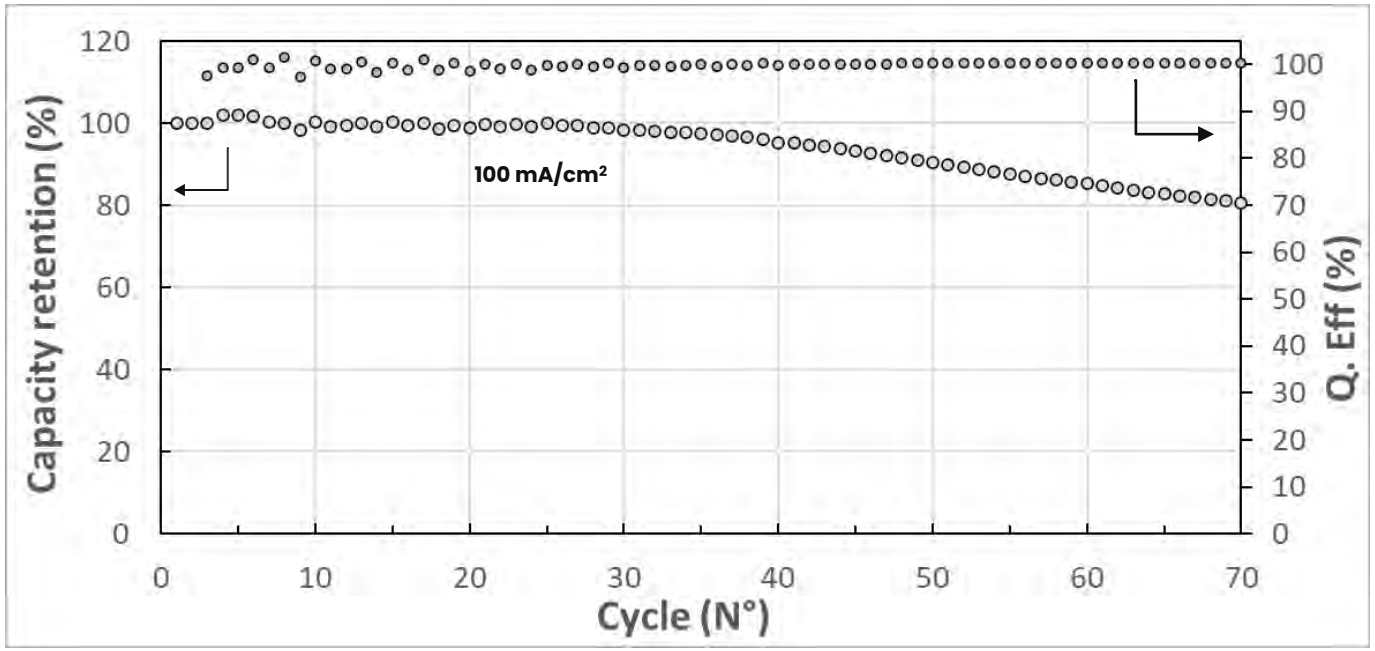
FIRST APPROACH TO CYCLE LIFE

The cycle life assessment of the best performing electrode was carried out in an 80 Ah/L lab cell.

Current density study



Capacity retention



Current densities above 100 mA/cm² are feasible by a proper selection of the electrode and compression grade.
The system shows a coulombic efficiency of >99% but the capacity retention diminishes gradually.
Currently, further experiments are needed to improve the stability over time.

CONCLUSIONS FROM R&D ACTIVITY

We demonstrated the potential interest of GES technology

Good electrochemical performance: 60Ah/L, >99% CE @100 mA/cm^2,
Technical challenges to be solved: cycle life

We set the objectives to make the technology competitive

Technoeconomic analysis to set the objectives to reach
an initial LCOS of 0,04€/kWh/cycle

Next step: the technology needs to be optimized in lab scaled and validated in medium scale porotype

Cycle life and stability optimization
Preparatory activities for technology upscaling

03 Technology Upscaling

BATTERY UPSCALING ACTIVITIES:

Currently GES is working in parallel in three fields to speed up the upscaling of the H_2-GES technology

R&D in LAB SCALE CELL: electrochemical performance optimization

TRL 4 (end of 2023)

- GES aims to reach TRL 4 by the end of 2023.
- To speed up the process, GES is investing into incrementing the lab facilities

LAB CONDITIONING: hosting upscaling activities

Ready for July 2023

- A dedicated emplacement is been conditioned to host:
  - Medium scale instruments (e.g., battery cycler) and other facilities
  - Machine shop and fast prototyping

DEVELOPMENT AND FABRICATION OF MEDIUM SCALE MINISTACK TEST-BENCHS

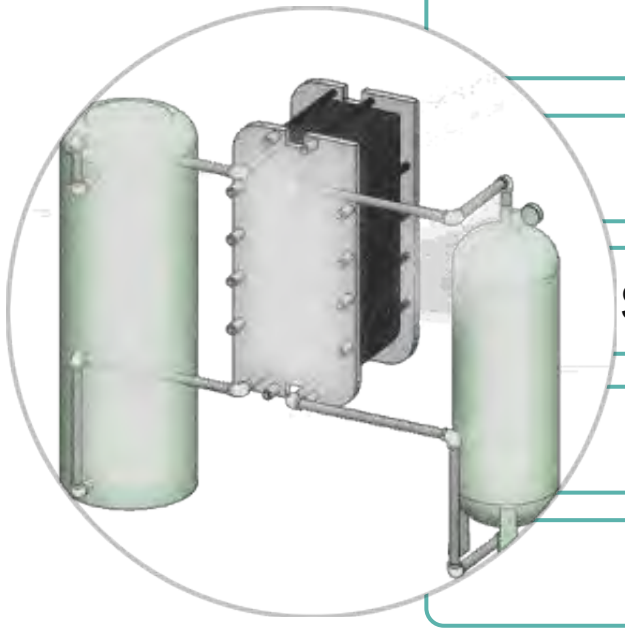
Delivery of 2 TB by the end of 2023

Medium scale technology demonstration by the end of 2024

- Design of medium scale ministack characterization test bench:
  - Power unit: up to 6 cell ministack (15x15 cm2/cell)
  - Balance of plant (included hydrogen storage) with sensors to monitor the physical parameters
  - Gradual fabrication of 8 test benches

DESIGN AND FABRICATION OF MEDIUM SCALE MINISTACK:

Due to the complexity of the test bench design, GES is collaborating with experts in the field



- Test-bench and power unit design
- Test-bench fabrication
- Software and control development (BMS)
- Electronic system development
- Metrology

GES IS RECRUITING EXPERTS IN DIFFERENT FIELDS like the above ones and others

OPEN POSITIONS (info@greenenergystorage.eu)

CONCLUSIONS FROM UPSACALING ACTIVITY

Setting up the path for technology upscaling

Optimize the electrochemical performance in lab scale
Lab conditioning for fast prototyping (medium scale ministack development)

Design and fabrication of medium scale test benches

The delivery of the first 2 test benches by the end of 2023

The technology needs to be tested in medium scale porotype

Activities to be carried out in parallel
Medium scale validation estimated in 2024

THANKS FOR YOUR ATTENTION

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