PRE-COMMERCIALISATION DEVELOPMENT OF COPPER REDOX FLOW BATTERIES

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ABSTRACT

Copper redox flow batteries (CuRFB) provide a desired middle ground between the high raw material cost of VRFB and lower energy efficiency of iron flow batteries. Recent electrolyte and system design reserach has significantly improved CuRFB power & energy density, resulting in a highly scalable and low-cost ownership battery technology for adopters with a levelized cost of storage of 75 €/MWh over the projected lifespan of 20 years. During the CuRen project system size has increased dramatically, from 0.5 W to 200 W, with a planned 1 kW system soon to be completed.

COPPER RFB CHEMISTRY

CuRFB uses a symetrical electrolyte, cycling via disproportionation & comproportionation reactions, with deposition occuring at the cathode. Halides are added to solution to stabalise the copper active species, forming copper complexes. Lower cell voltages enables the use of a acidic environment, increasing conductivity.

$$Cu^{0} \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Cu^{+} \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Cu^{2+}$$

0.68 V

Cycling is uneffected by impurities in the electrolyte, with the use of 97% pure copper sources demonstrating no loss in performance. This allows for the future use of second-life copper in a single-step electrolyte production process.

Dendrite growth is non-apparent, with no risk of precipitation and cell death. Despite the lack of a highly oxidative species, the high acidity necessitates specific materials choice. High cycling stability and cell performance have enabled CuRFB as a competive 4-12 hour storage alternative.

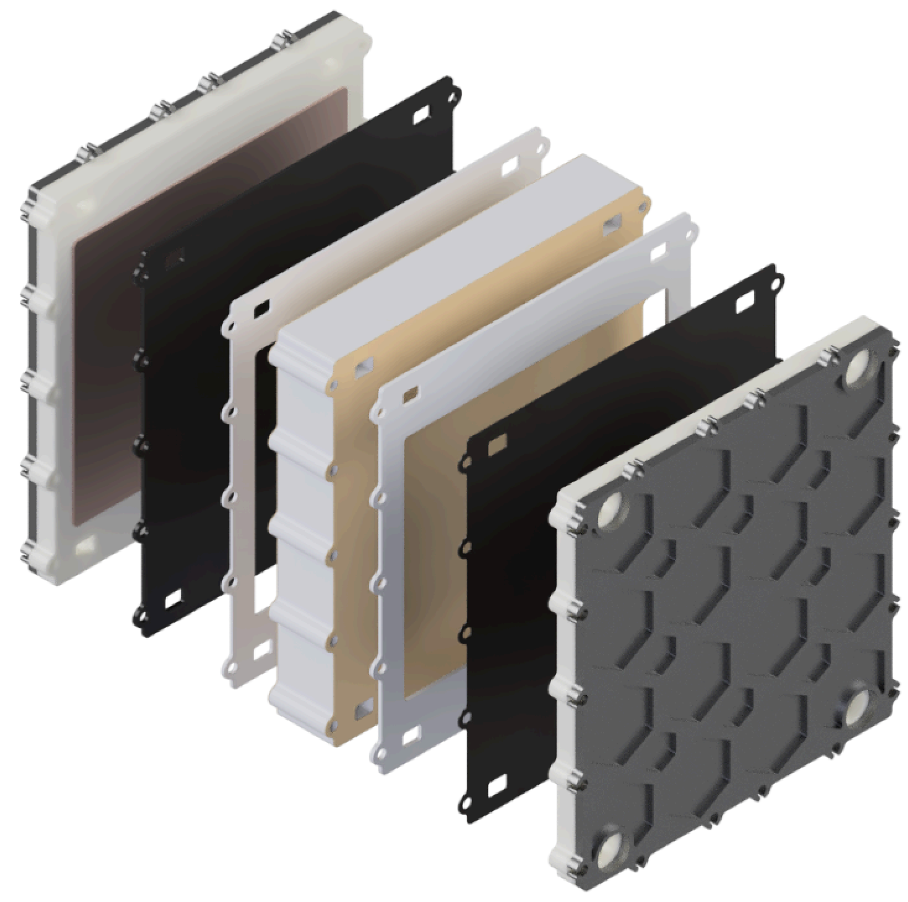
CE (%)	>98	EE (%)	75
Power density (mW cm^{-2})	32	Energy density (W L^{-1})	31

Values provided are based on average performance of different custom systems.

OPERATIONAL ADVANTAGES

Simple chemistry enables simple design with several all-round improvements to operation.

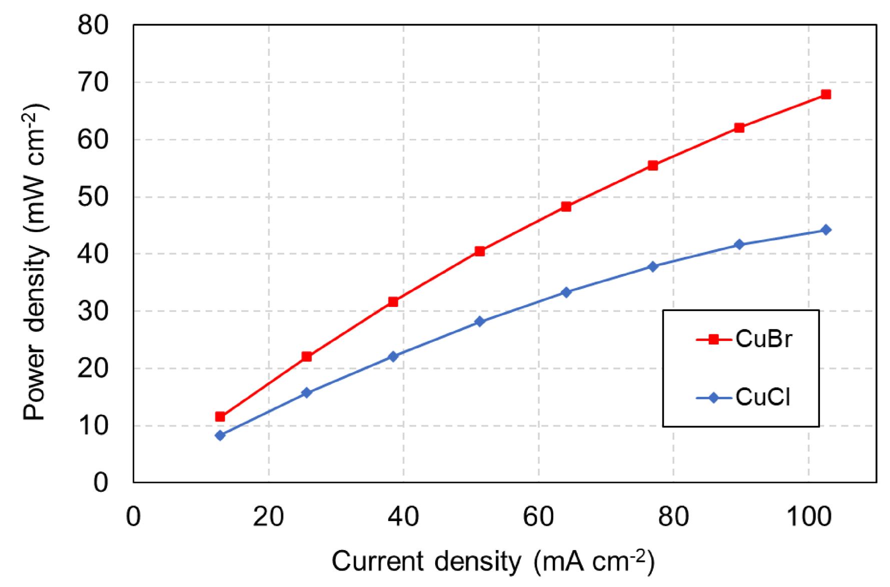
- **High stability:** 100% Depth of charge and fully recoverable capacity.[2]
- **Improved safety:** No H2/O2 evolution, large ambient operating window.
- **Sustainable:** Zero PGM usage, > 99% Copper recovery end of life, majority recyclable system.[3]



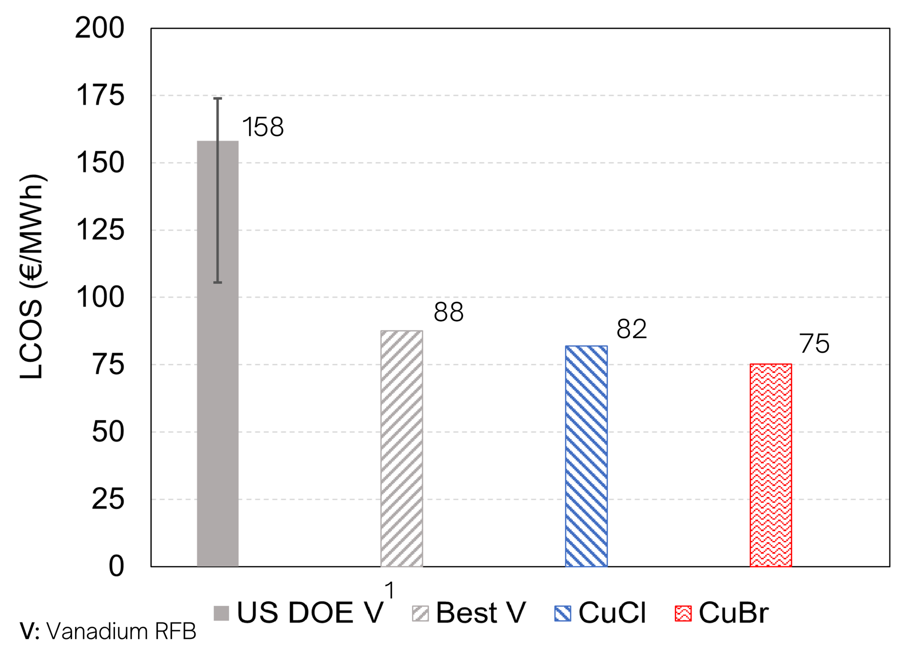
Expanded view of a CuRen V3 stack.

CU-HALIDE ELECTROLYTES

The stabalisation of copper by bromide increases power density by 45%, significantly reducing the required system size.



The improved electrolyte decreases Deployed System LCOS to 74 €/MWh, where battery LCOS is 45 €/MWh

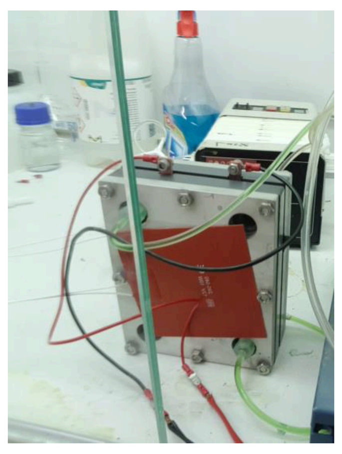


TOWARDS A 1 KW STACK

Alongside increasing stack size, other material and electrolyte improvements have been pursued. These are to be exploited in a 1 kW stack by Q3 2024.

- Custom fabricated SPEEK-biochar composite membranes enable minimal capacity decay at low cost.
- Novel stack sealing methods removes traditional gaskets, decreasing cell width.
- The higher solubility of copper bromide complexes in low pH enables a simple 3 molar copper electrolyte.

Project system development:



0.5 W - Q3 2023
8 Wh L^{-1}

→

200 W - Q1 2024
21 Wh L^{-1}

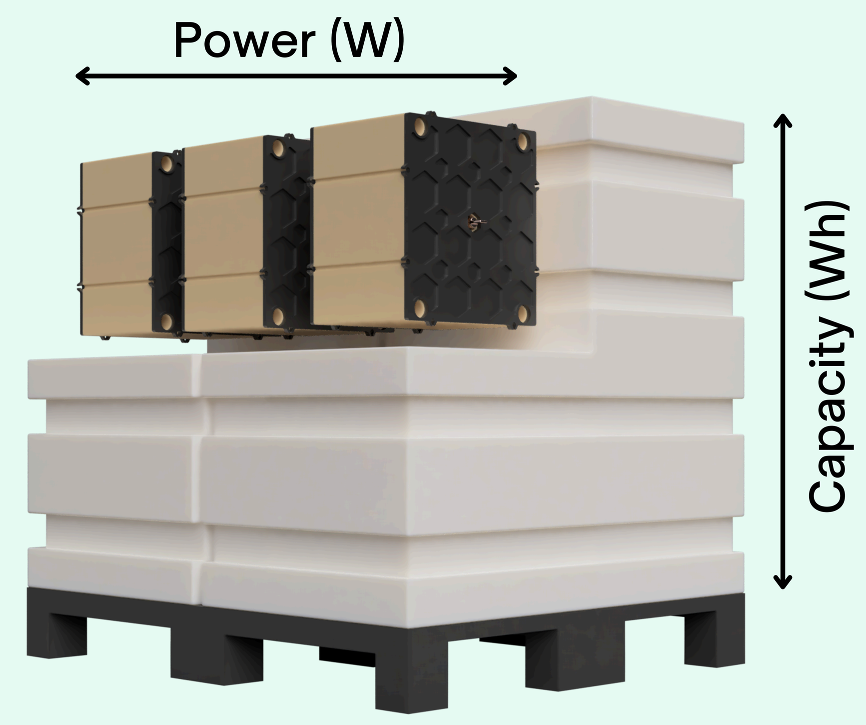
→

COMMERCIAL DEVELOPMENT

CuRen aims to spin-out by Q4 2024 as a CuRFB manufacturer and supplier based in Finland with a complete EU supply chain. System plans include containerised battery systems (120 kW, 960 kWh) delivered with an integrated battery management system, and continuous operation & maintenance services.

Current IP includes:

- Copper halide systems
- CuRFB integrated rebalancing system
- Novel low cost stack & system manufacturing



Modular CuRFB unit (3 kW, 24 kWh), 40 units in a containerised system for 120 kW, 960 kWh.

CONCLUSION

Research into CuRFBs has yielded significant increases in the systems' energy density drastically reducing battery LCOS to well below the DOE target of < €50/MWh and that of existing redox flow battery chemistries. The high energy and low environmental impact system provideds an all-round high performance energy storage solution, which has enabled steady progress towards commercialisation. However, there is yet much interest in both further engineering and reserach work towards a more sustainable, cost-effective and power dense system.

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BUSINESS FINLAND

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1) US Department of Energy: Grid Energy Storage Technology Cost and Performance Assessment (2022), PNNL-33283
2) Badenhorst, Wouter Dirk, et al., "Performance improvements for the all-copper redox flow battery: Membranes, electrodes, and electrolytes." Energy Reports 8 (2022): pp. 8690-8700.
3) Lloyd, David, et al. "Preparation of a cost-effective, scalable and energy efficient all-copper redox flow battery." Journal of Power Sources 292 (2015): 87-94.