CONDENSED-PHASE AQUEOUS REDOX-FLOW BATTERY (CARB) SYSTEM FOR LARGE-SCALE ENERGY STORAGE

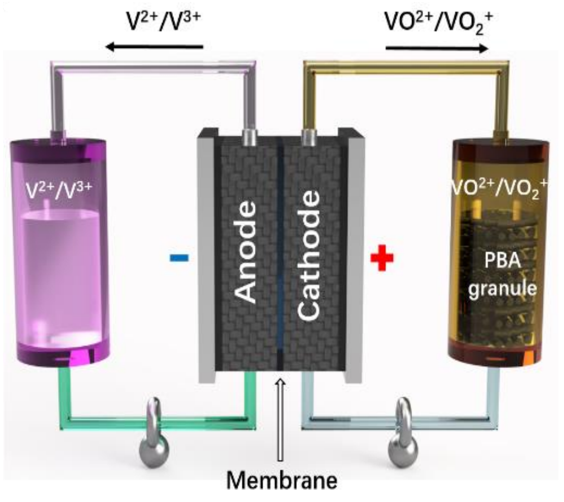
PROJECT SUMMARY

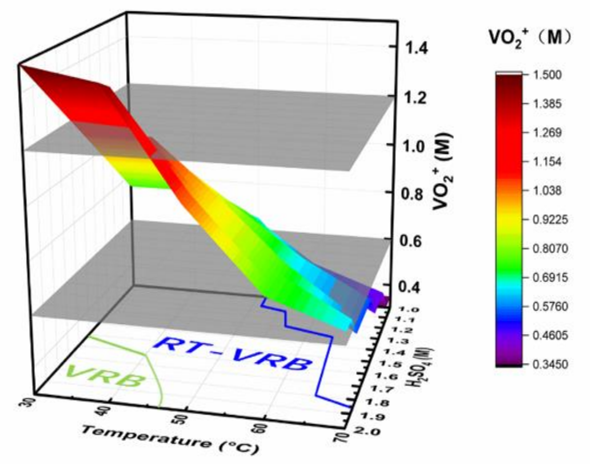
- Among various energy storage technologies, redox flow batteries (RFBs) with excellent operation flexibility and scalability are promising for grid electricity storage. However, the large-scale deployment of redox flow is limited by the low energy density and entailed high material cost.

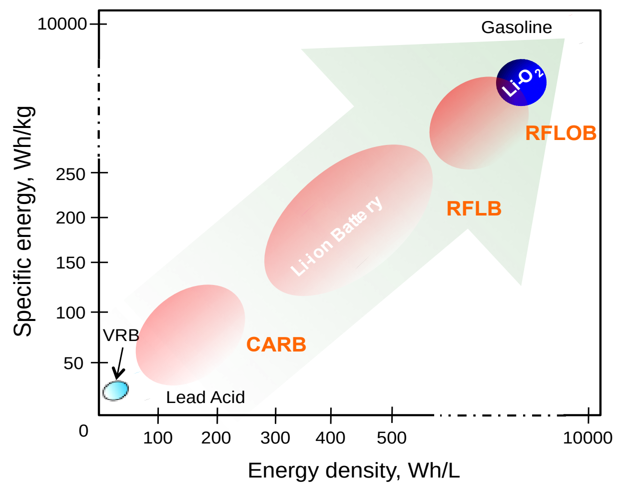
- With the support of EMA, we have developed a few novel redox flow battery chemistries based on the redox-targeting concept. These new electrolyte systems utilise low-cost condensed-phase materials and present considerably enhanced capacity.

- We have judiciously paired different electrolyte systems and demonstrated the operation of full cells at different scales. These condensed-phase aqueous redox-flow battery (CARB) systems revealed superior performance to the vanadium redox-flow battery (VRB) in terms of materials cost, energy density and durability (especially at elevated temperatures) and showed great promise for large-scale stationary energy storage. In conjunction with low-concentration VO^{2+}/VO_2^+ catholyte, a CARB system was developed in which a Prussian blue analogue, is employed as a capacity booster to address the above issues.

- The concentration of catholyte is reduced to 0.6 M without sacrificing the capacity. This provides ample room to broaden the operating temperature window of CARB to 70ºC. The theoretical volumetric capacity of the PBA could reach 135 Ah/ L, which is more than 3 times that of VRB. The CARB system demonstrated is expected to give credible impetus for VRB chemistry for robust and high-density energy storage applications.







Left: Configuration of CARB battery with PBA loaded in the catholyte tank; Middle: Operation temperature, electrolyte VO_2^+ and acid concentration of VRB and CARB batteries; Right: Roadmap of various redox-targeting-based RFBs and comparison with other battery technologies.

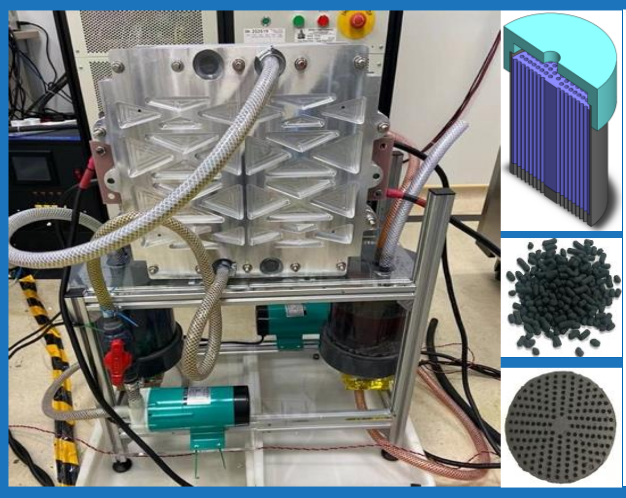
PROJECT OUTCOMES

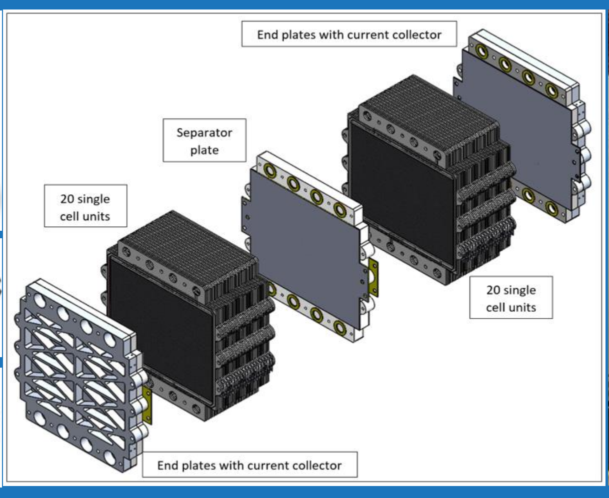
- The CARB system design features:
  - 4 CARB stacks (each stack's output power at 2.5 kW up to a maximum of 5 kW) connected to the electrolyte pumps and tanks via a series of PVC manifold piping and acid resistant soft tubing, with 16 inlets and outlets coupled to the stacks.
  - Housed in 3 separate enclosures, which take several safety factors into account: chemical leakage/spillage containment; weight tolerance and distribution; system containment from human interference.
  - Main system houses the display panel, electrolyte tanks, pumps, and the bulk of the manifold and piping sub system.
  - Optimised frame design through fabricating and testing cell stack of different size (from 100 W, 300 W, 1 kW, to 2.5 kW).
  - Multiple manifold inlet/outlet with extended flow channels to resolve the shunt current issue.

- The prototype 10 kW CARB battery system was successfully integrated into a microgrid network installed in Temasek Polytechnic (TP) campus, which consists of a 4.08 kWp Solar PV system, DC-to-AC inverter, microgrid central controller and the DC-DC converter. Managed by TP-Clean Energy Research Centre (CERC), the system will continue to operate and collect more data for performance comparison with other BESS such as lithium-ion batteries.

- This project led to the generation of several intellectual properties including 3 PCT patent applications on battery chemistries, and 2 patent applications on frames and bipolar plates design.

- In line with the ambition of pursuing low-carbon economy and electrified transportation by 2040 in Singapore, we anticipated that a safe and low-cost stationary energy storage adapted to local climate conditions would be critical to the national energy infrastructure. The CARB battery technology developed from this project would provide an implementable solution to enhance the stability and resilience of the power grid. We seek close collaborations with industry to bring the technology to the next level of commercialisation and deployment, and address the national grand challenges in energy resilience.





Left: A 500 W lab testing CARB battery system with PBA materials made into granules or honeycomb structures and loaded in the catholyte tank; Middle: 5 kW cell stack design with 20 single cell units connected by internal manifold and endplates; Right: Two sets of 10 kW CARB battery system integrated with the control units and connected to the microgrid.

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