EnTiCe

Energy. Timely. Certain.

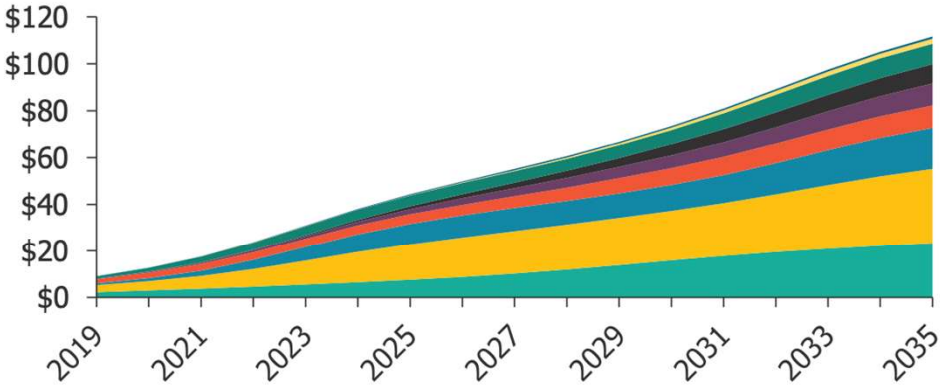
Low-cost battery for grid reliability

Market Opportunity

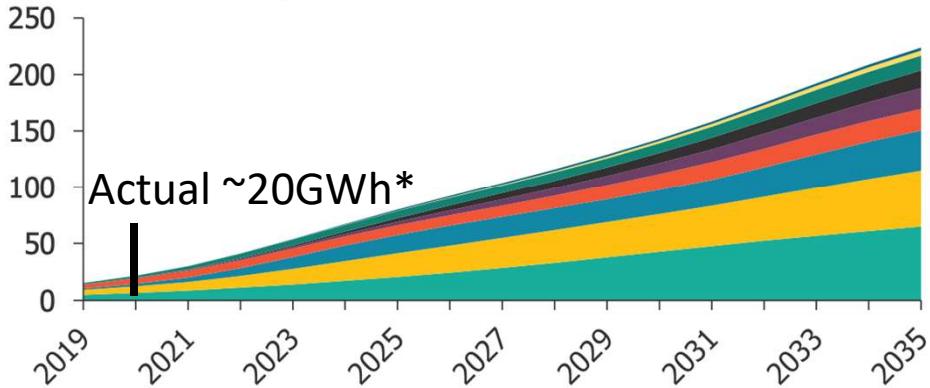
2019 projections

Global stationary storage market forecasts

Energy storage annual revenue ($ billions)



Annual installed energy capacity (GWh)

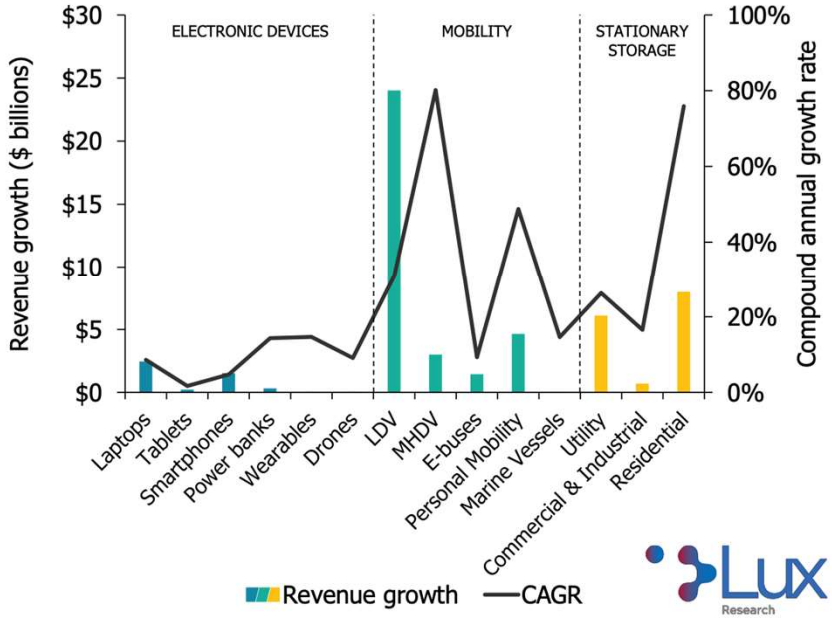


China | Europe | North America
Japan and Korea | India | Southeast Asia
Australia | Africa | South America

Lux Research

Near-term growth opportunities

2019-2022

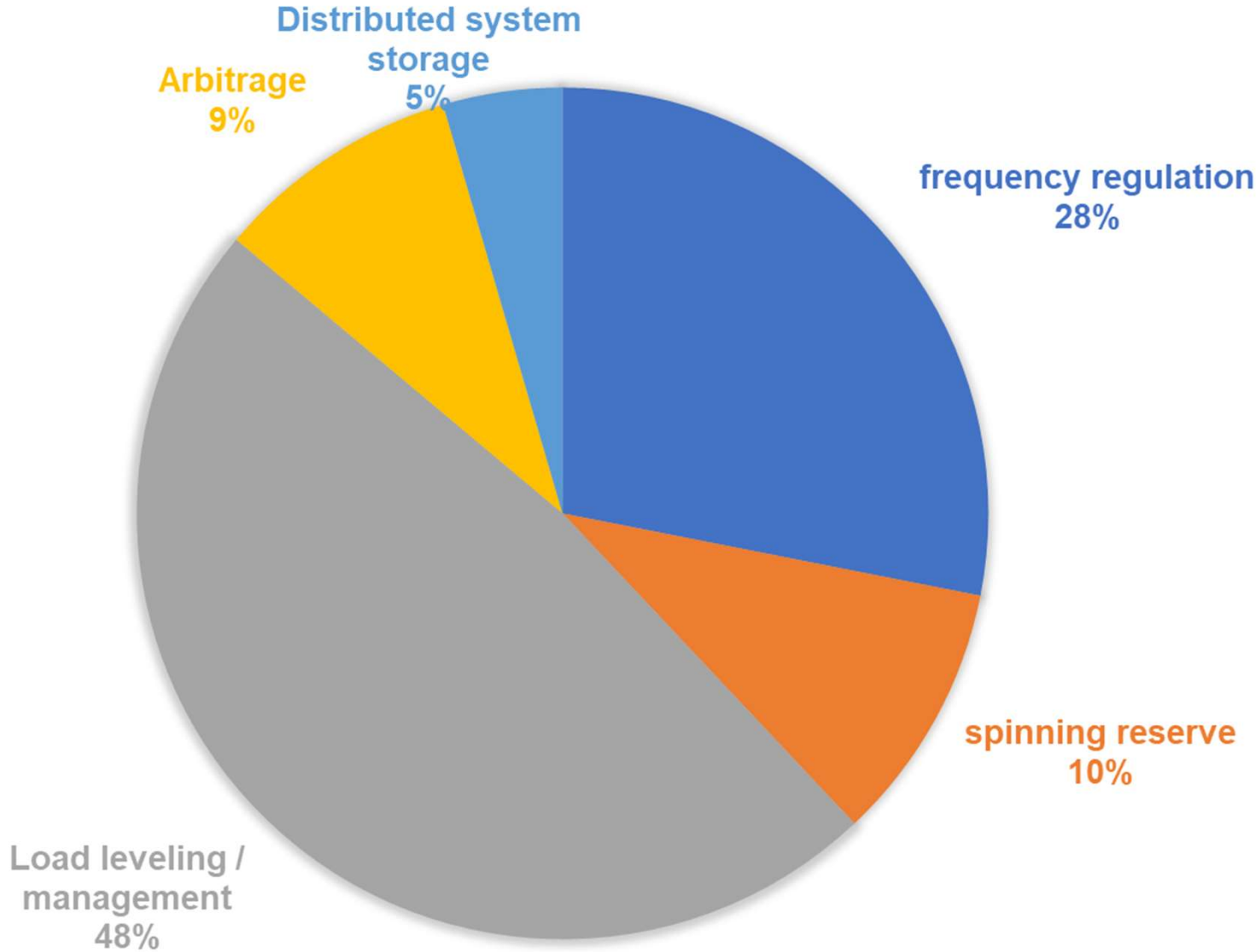


Lux Research

Utility scale storage expected to grow at 20% CAGR in the near-term with growth concentrated in China, EU and North America.

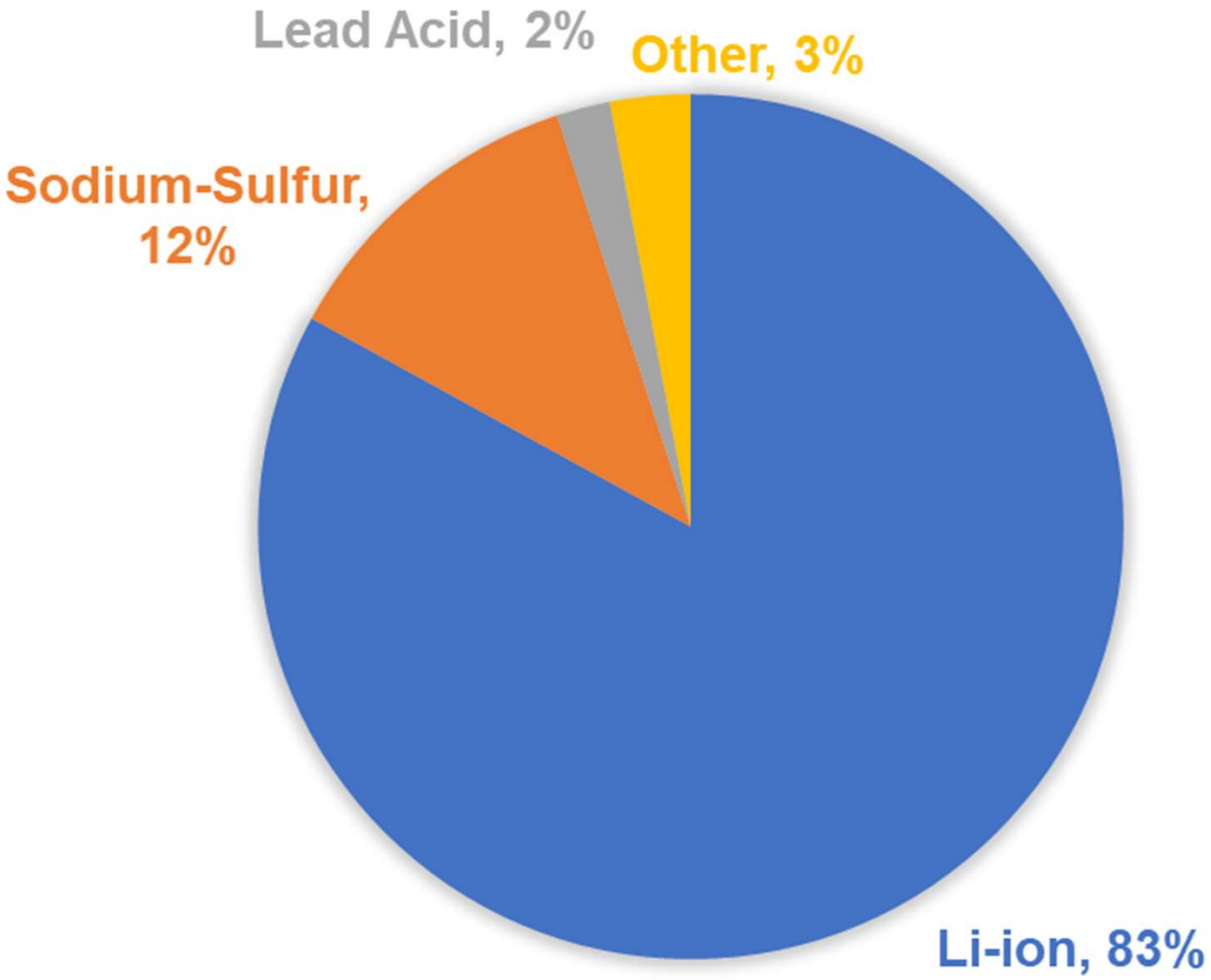
*https://www.iea.org/reports/energy-storage

Battery storage market distribution



1. http://www.sciencedirect.com/science/article/pii/S0958211811702026; 2. https://www.gasworld.com/hydrogen-market-forecast/2010268.article;
3. http://www.marketsandmarkets.com/Market-Reports/micro-grid-electronics-market-917.html; 4. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-new-economics-of-energy-storage 5.GTM US energy storage monitor – 2017

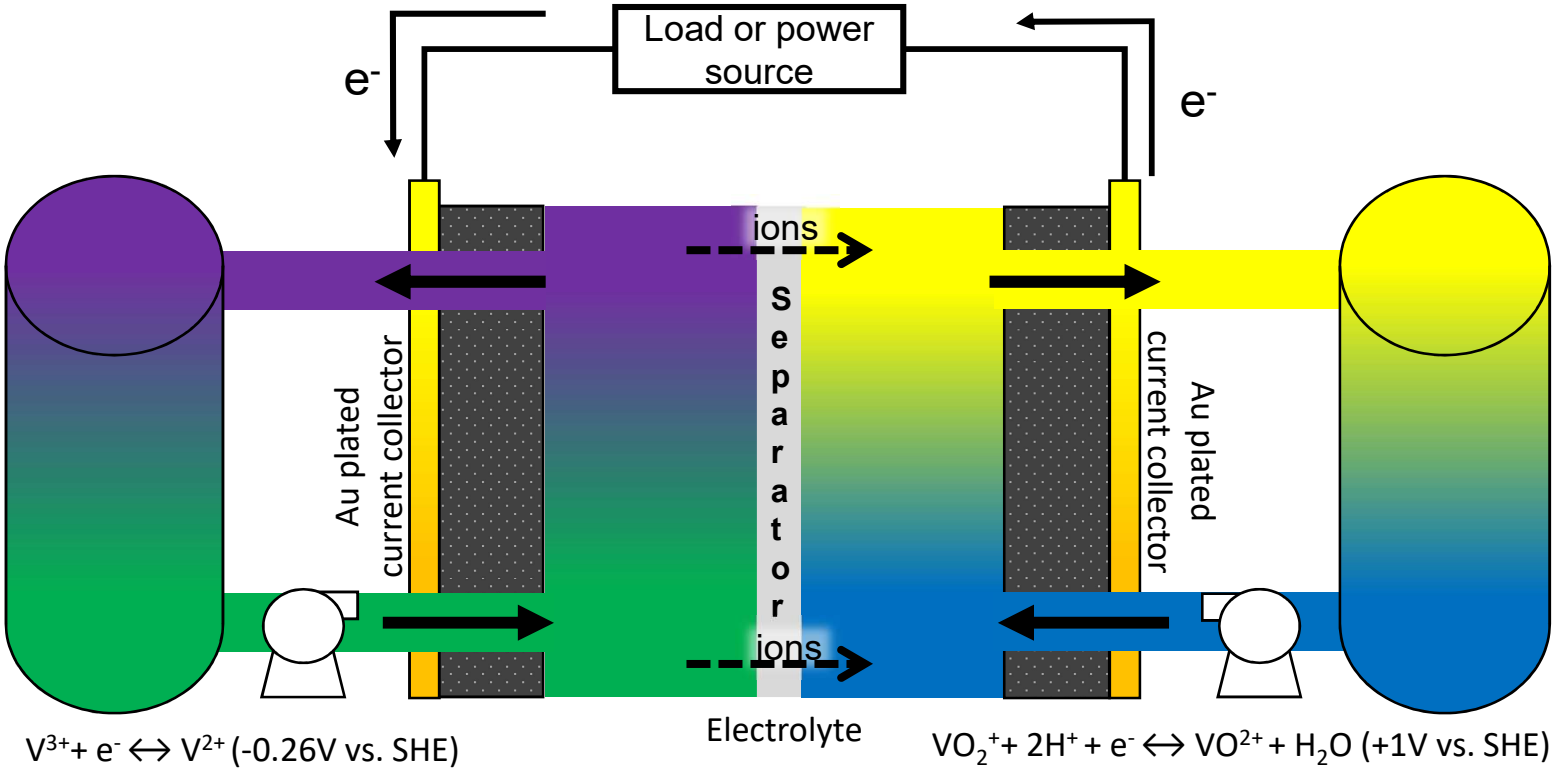
Battery storage technology distribution



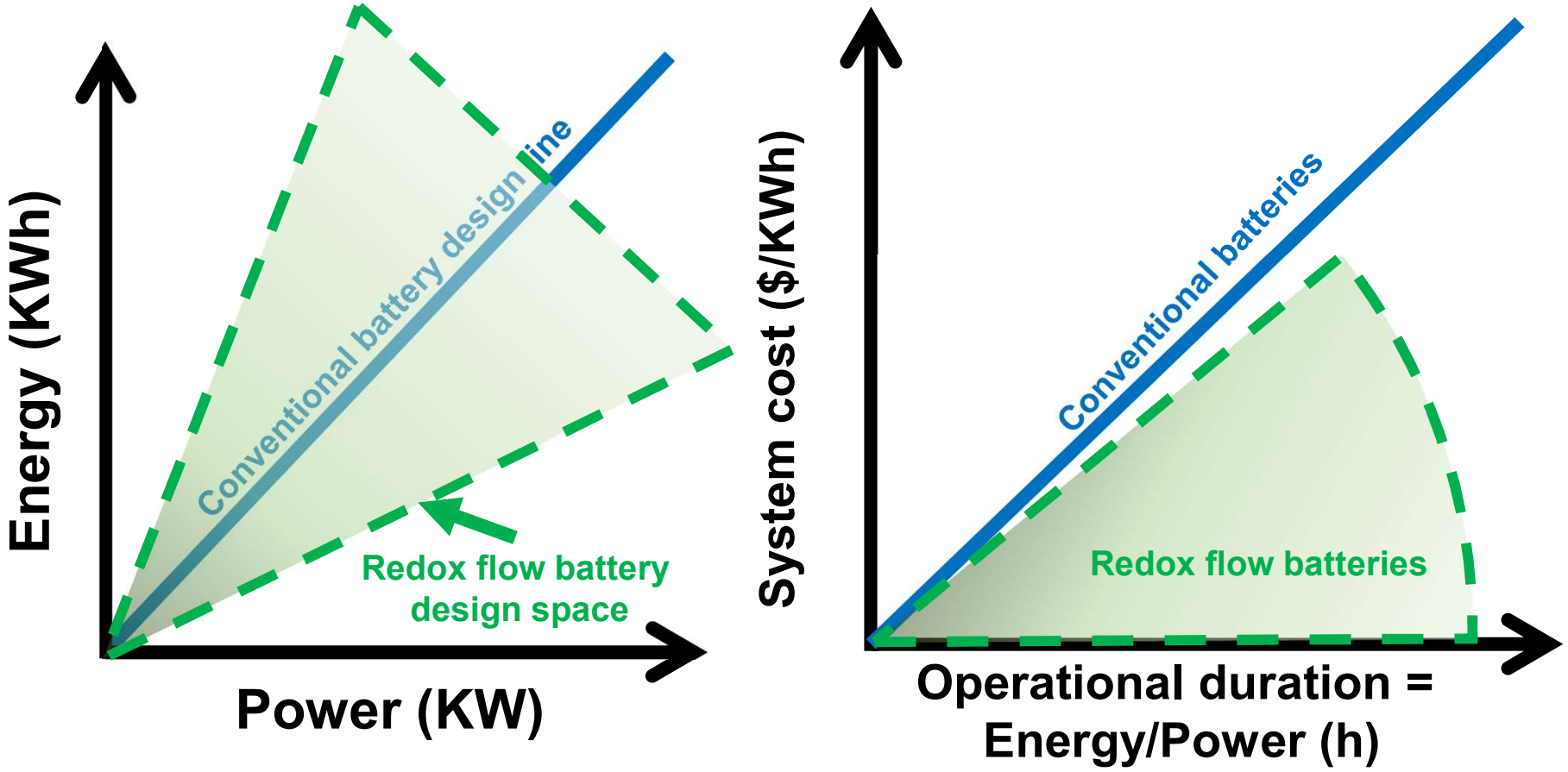
Other technologies include Flow batteries

1. http://www.sciencedirect.com/science/article/pii/S0958211811702026; 2. https://www.gasworld.com/hydrogen-market-forecast/2010268.article; 3. http://www.marketsandmarkets.com/Market-Reports/micro-grid-electronics-market-917.html; 4. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-new-economics-of-energy-storage 5.GTM US energy storage monitor – 2017

The answer is (always) flow batteries

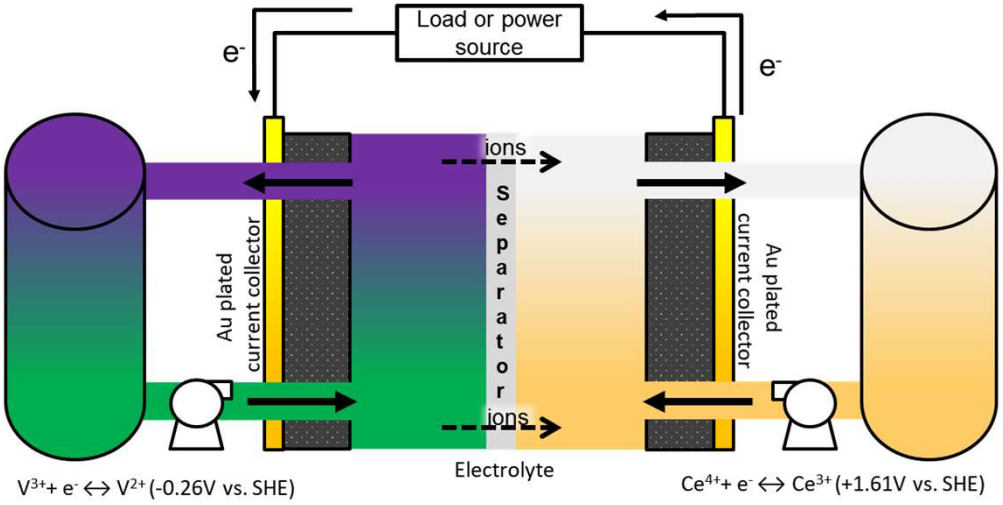


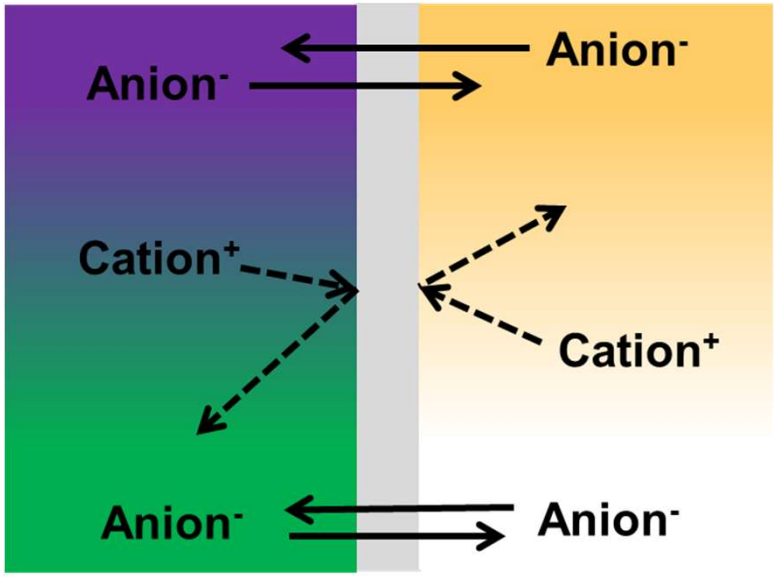
Why *EnTiCe* redox flow batteries?



Bigger the system - lower the marginal cost

Electrode-decoupled flow batteries





- ✓ **Far less expensive compared to all-V RFB (~$400/KWh at scale)**
- ✓ Design flexibility – greater variety of actives
- ✓ Tunable cell voltage
- X Can lead to capacity fade due to mixing
- X Some designs require phase change (deposition/dissolution) of one or more actives

Our system is all-soluble, electrode-decoupled and long lasting

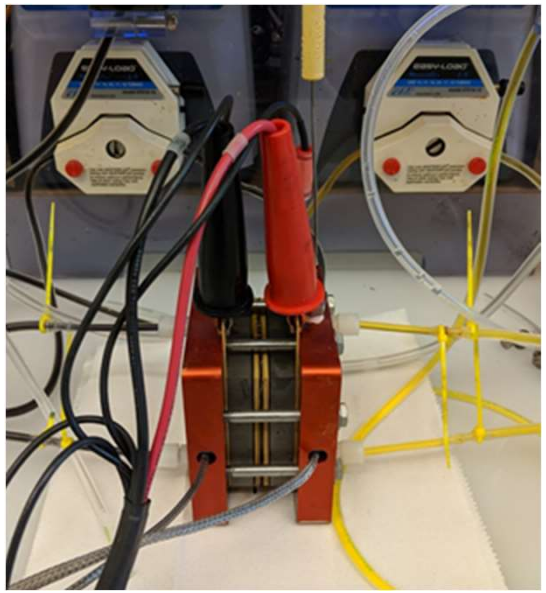
The *EnTiCe* battery

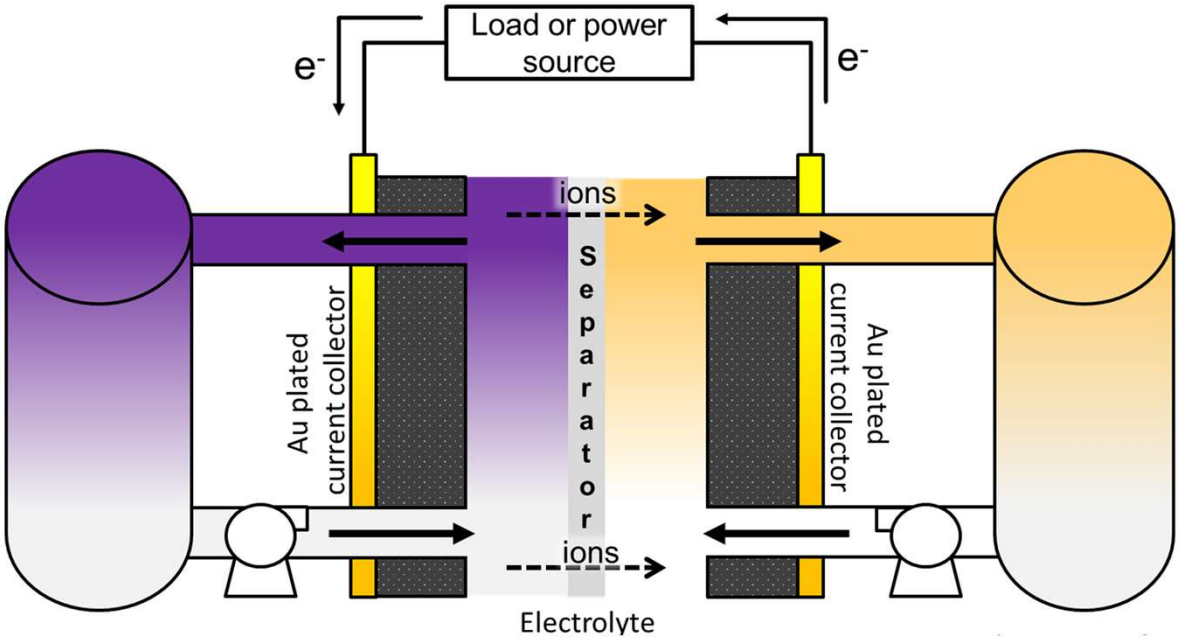
Patented redox flow battery (RFB) chemistry

United States Patent
Sankarasubramanian et al.

(10) **Patent No.:** **US 11,177,497 B2**
(45) **Date of Patent:** **Nov. 16, 2021**

- Sub-linear scaling of cost with scale
- Pathway to meet DoE battery cost targets of <$50/KWh - We use rock forming minerals as actives





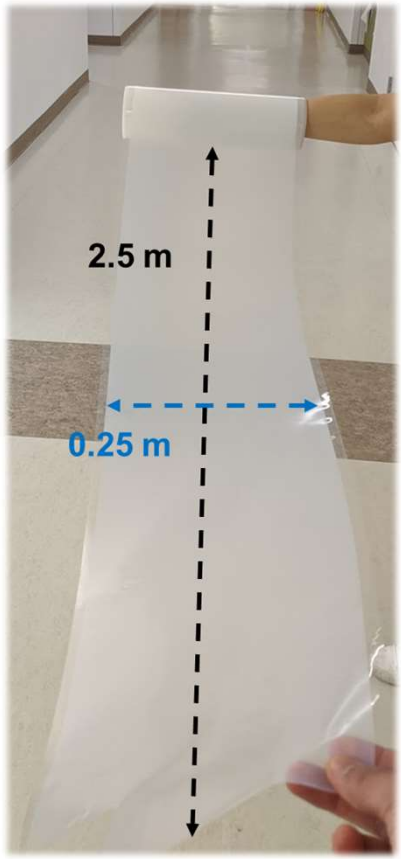
The *EnTiCe* battery

Patented membrane technology

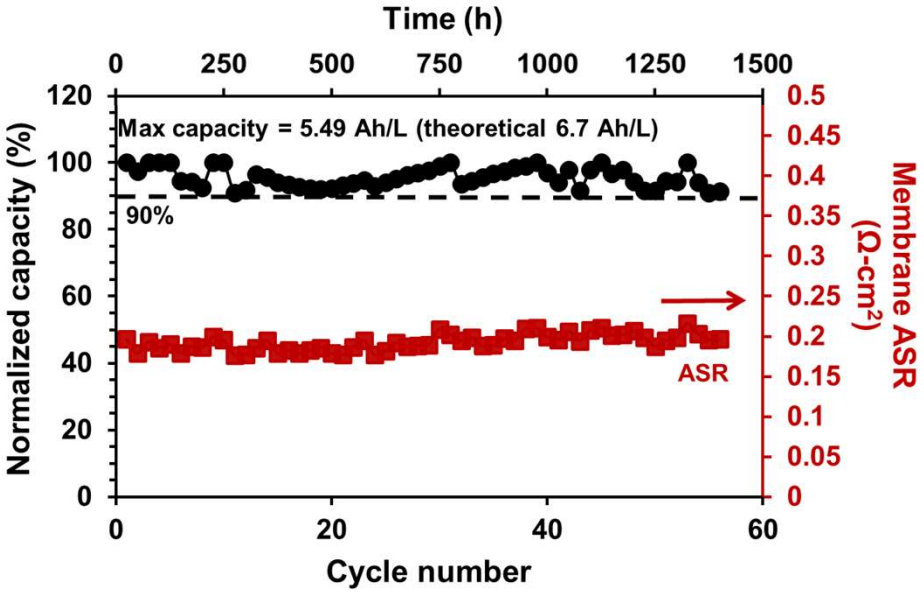
- Enables our unique RFB architecture
- In advance stage of scale-up and possible commercialization

United States Patent
Wang et al.

(10) Patent No.: US 10,910,656 B2
(45) Date of Patent: Feb. 2, 2021

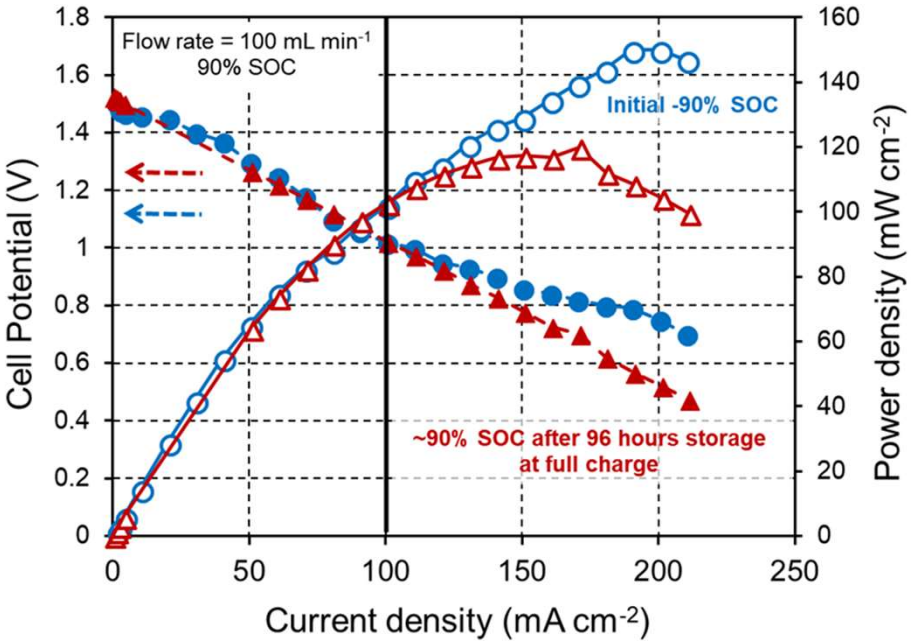


The *EnTiCe* advantage

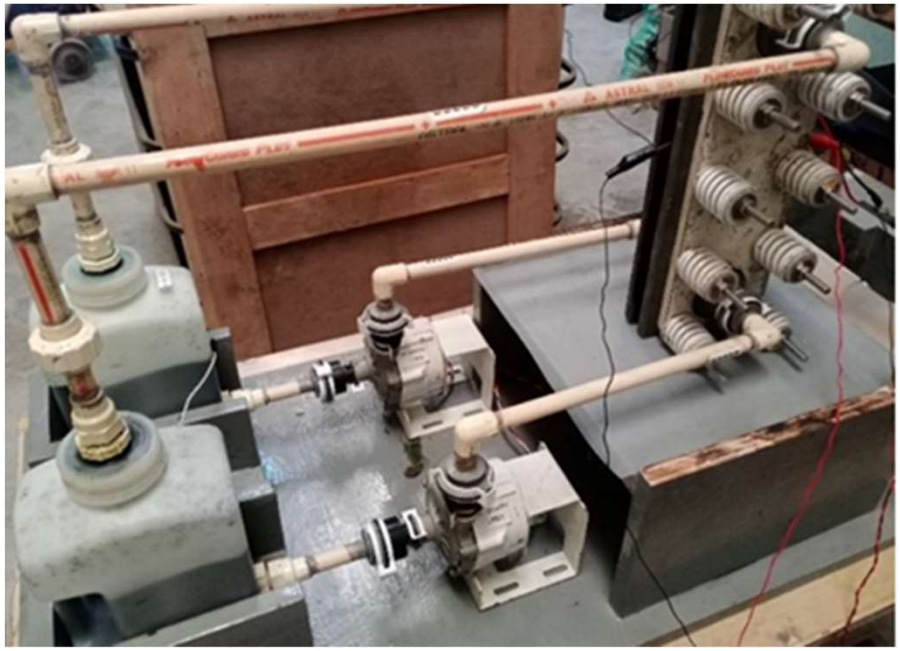


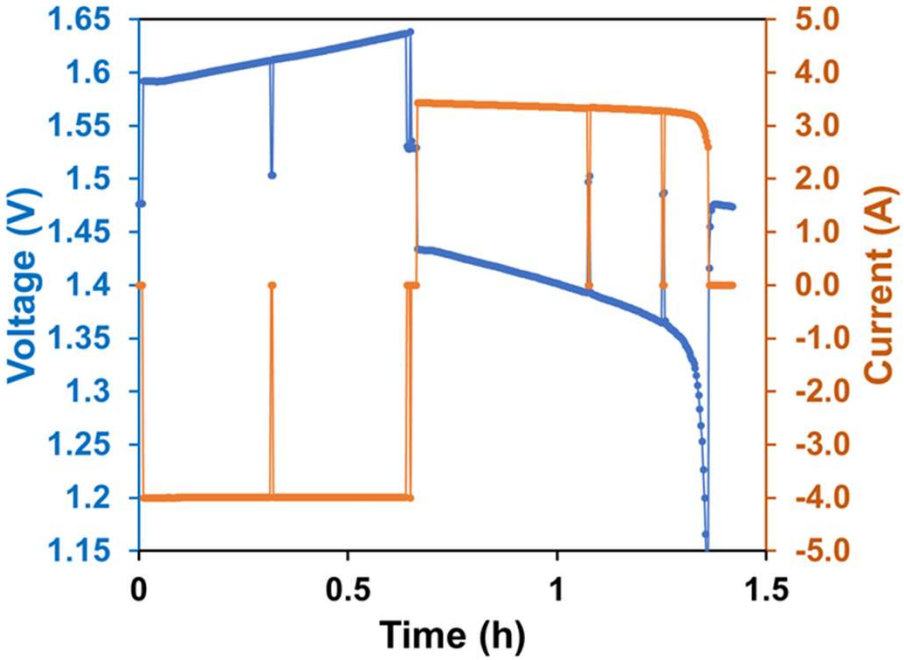
Long-term cycling performance demonstrated in the lab

Long term storage with no performance degradation



The *EnTiCe* advantage





Third-party validation ongoing

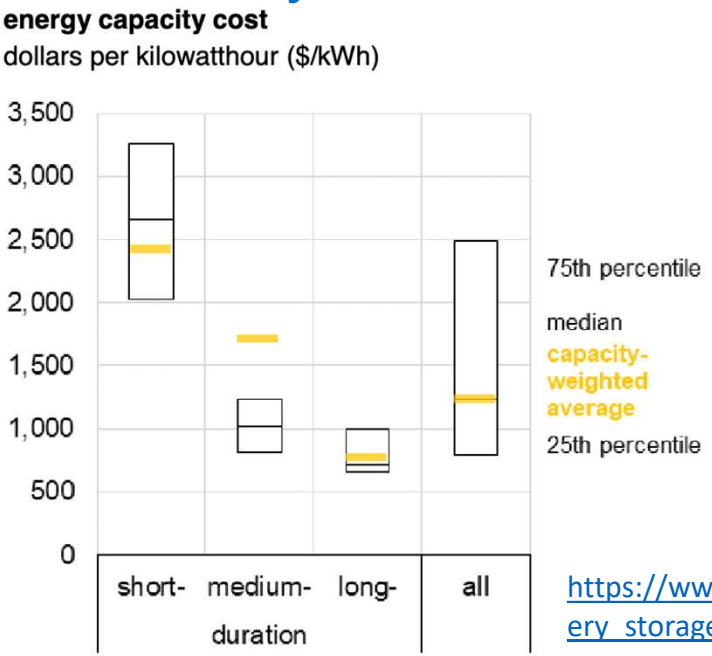
The *EnTiCe* advantage

2020 all-V RFB cost estimates from US DOE (supplier cost)

	1 MW/4 MWh System		10 MW/40 MWh System	
Estimate Year	2020	2030	2020	2030
DC system (with SB and container costs) ($/kWh)	$367	$299	$341	$278
PCS ($/kWh)	$22	$17	$17	$13
PCS markup ($/kW)	$2.2	$1.7	$2	$1
ESS equipment total ($/kWh)	**$391**	**$318**	**$360**	**$292**
Integrator margin ($/kWh)	$58	$48	$36	$29
Complete ESS equipment total ($/kWh)	**$449**	**$365**	**$396**	**$321**
EPC ($/kWh)	$101	$82	$79	$64
AC Installed Cost ($/kWh)	**$551**	**$447**	**$475**	**$386**

https://www.pnnl.gov/sites/default/files/media/file/RedoxFlow_Methodology.pdf

2020 Utility installed energy storage costs from EIA



Most utility scale systems are <4-h duration LIBs and utilities are willing to pay >>$600/kWh

https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf

Present costs of the EnTiCe system

- Present costs of Ti-Ce RFB estimated by Mr. Thomas Gregory of Borealis Technology Solutions LLC. He has over 30 years of process modeling, design and costing experience with Dow chemicals. He has worked on Dow's battery efforts.
- Our model matches DOE's all-V RFB model –
  - Power – 1MW; Duration – 4h; 1 molar electrolyte solution concentration; 100 mW/cm^2 power density.
  - Same PCS, ESS and integrator margins assumed.

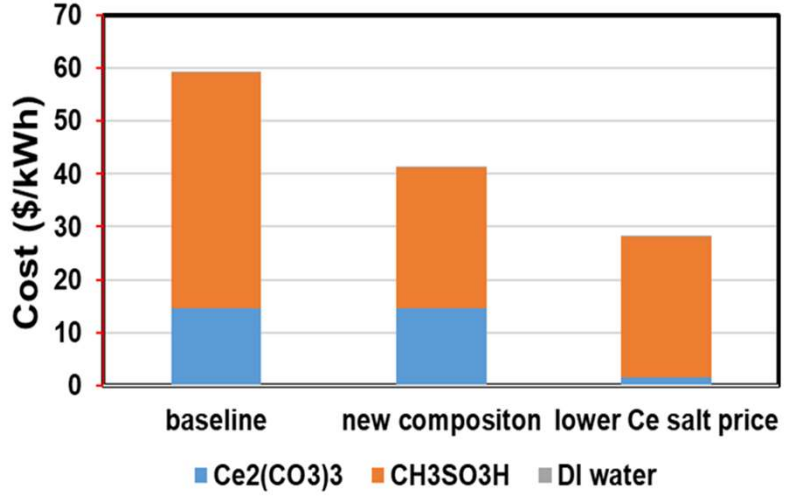
WUSTL Ti-Ce RFB cost estimates (supplier cost) – no optimizing assumptions

	1MW/4MWh	10MW/40MWh
DC system ($/kWh)	267	248
AC installed cost ($/kWh)	401	345

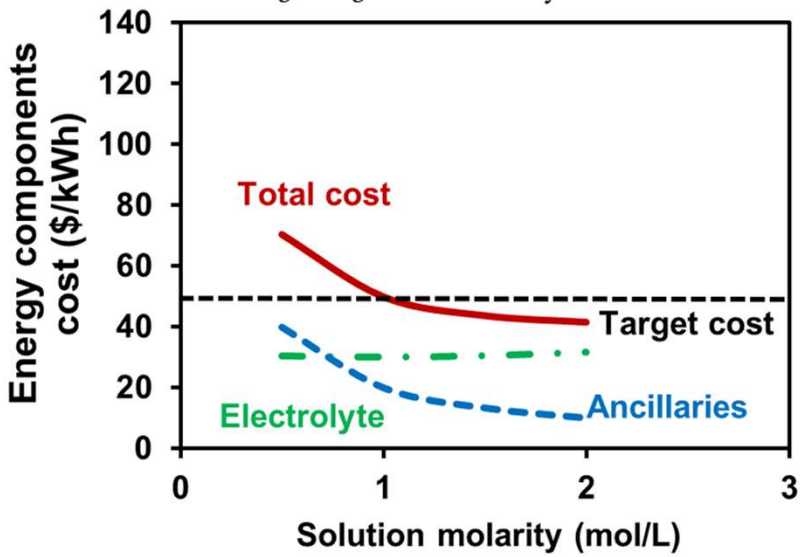
>$100/kWh difference compared to all-V RFB

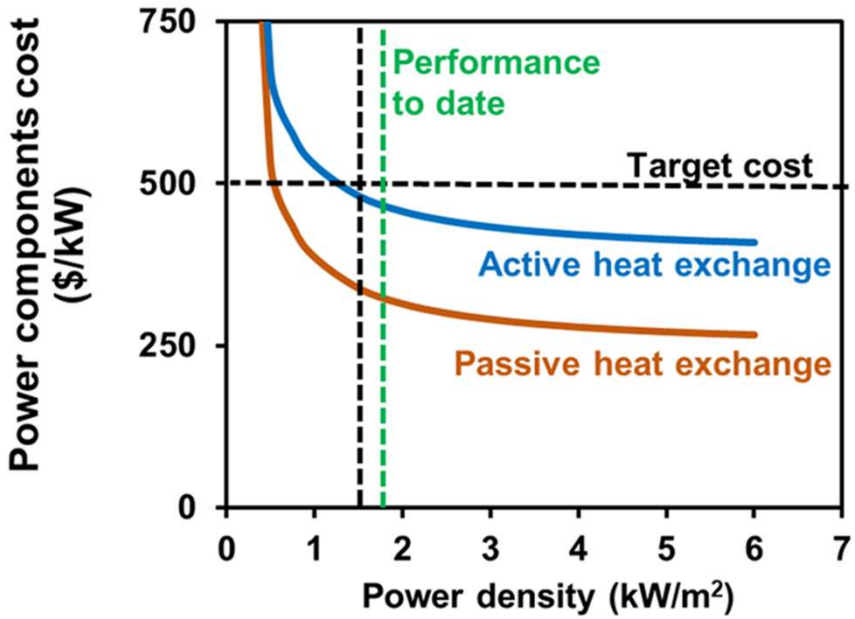
Future state costs of EnTiCe system

Projections are for GW-scale production with optimizing assumptions



CH_3SO_3H based system





Pathways exist to reach <$50/KWh and <$500/KW – accepted by ARPA-E

End users


Ameren


GE POWER


MITSUBISHI
ELECTRIC


SIEMENS


AES
the power of being global

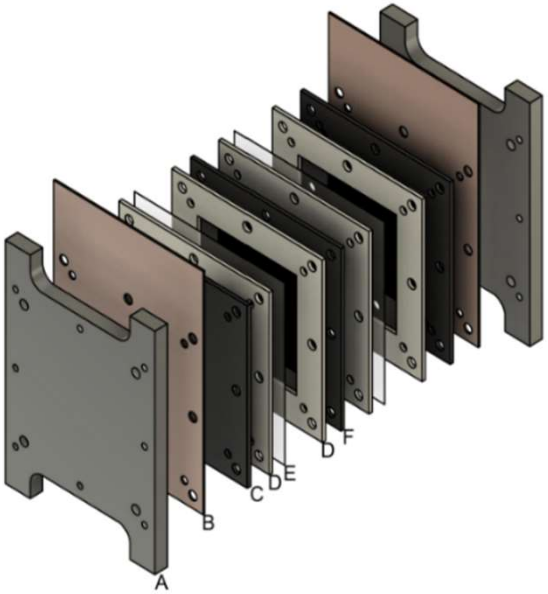

ABB

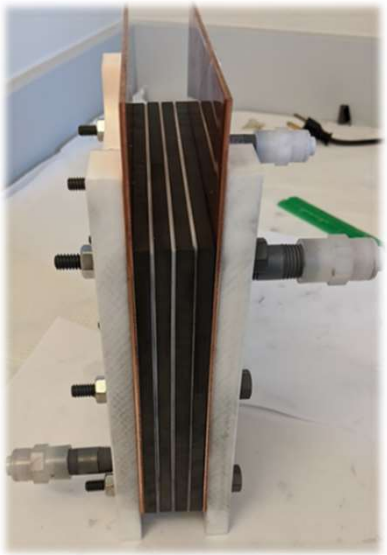
The competition

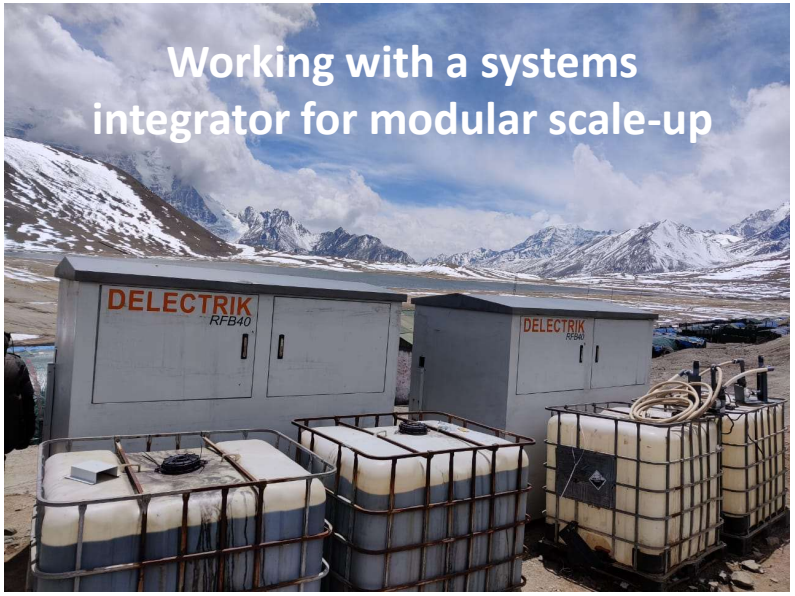
- **Lithium ion batteries**
  - Proven tech that is available now
  - Lithium and Cobalt supply are limited and not assured

- **Natural gas**
  - **EnTiCe Batteries are cheaper at scale (>100GWh/year)**

The Future







Short stack built – testing ongoing

Future steps :

- Scale-up membrane production to a minimum 20cm wide roll to enable RFB scale-up.

- Develop, build and test a 40KW RFB module.

The Future

Team building

- **Business development –** experience with utilities interactions and B2B sales.

- **Systems engineering –** experienced systems engineer with RFB, filtration or fuel cells background.

Company formation

- Need to determine vehicle – start-up vs. JV

Funding needs

- Pursuing non-dilutive options (SBIR/STTR)

The Team

Vijay Ramani

- 20+ years of electrochemical engineering experience
- SBIR phase 2B Co-PI
- Sought after consultant on energy storage tech

Shrihari Sankarasubramanian

- 12 years of electrochemical engineering experience
- 2 patent awarded, 5 pending
- Worked with GE, Toyota, Nissan, HydroQuebec