



# New directions in Long Duration Energy Storage Research & Development

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**Revolutionary Energy Storage Systems**  
Future Science Platform

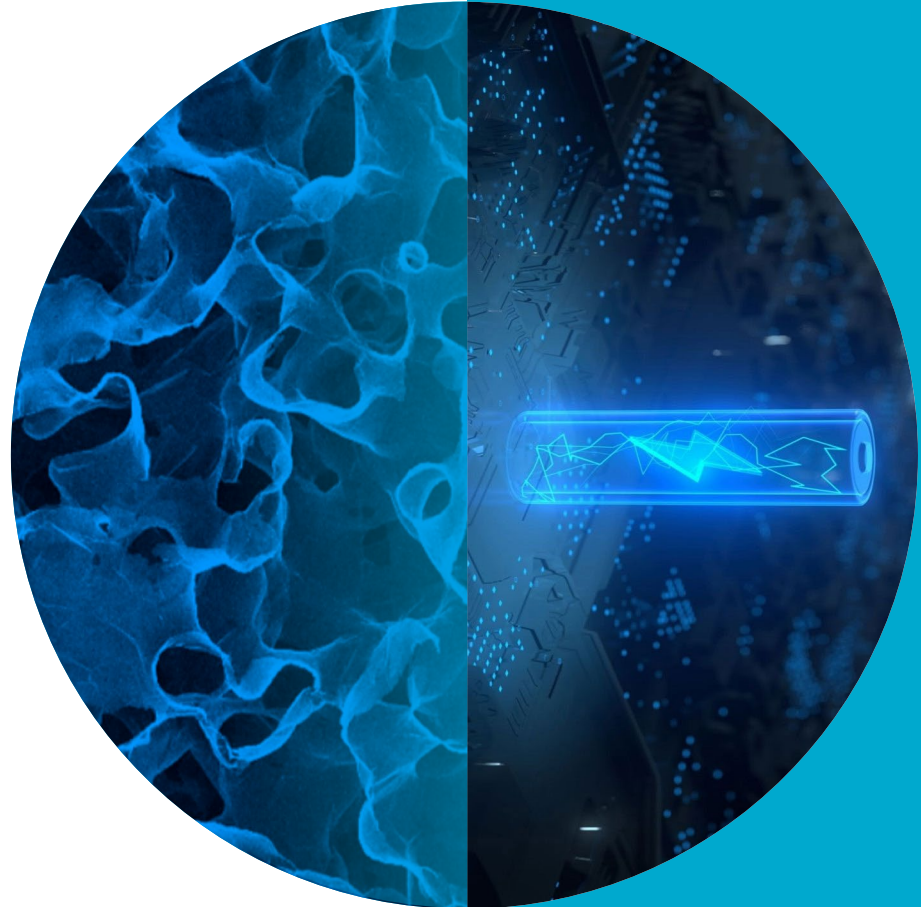
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Flow Battery Symposium

15 Oct 2024

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Australia's National Science Agency





We acknowledge the Whadjuk Noongar people as the Traditional Owners of the land that we live and work on, and pay our respects to their Elders past and present.



## REFLECTIONS

- **The Journey so far...**
  - Introduced in 1997
  - Worked on enhancing stability of supersaturated V(II) and V(III) solutions
  - Using Raman spectroscopy to determine sulfate/bisulfate ratio
  - Investigated Photocatalytic regeneration of V(IV) solution



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A  
BIG  
THANK  
YOU!



# MY CRYSTAL BALL





# MY CRYSTAL BALL

CSIRO Australia's National Science Agency

## Renewable Energy Storage Roadmap

March 2023

AEMO AUSTRALIAN ENERGY MARKET OPERATOR

## 2024 Integrated System Plan

For the National Electricity Market

### A roadmap for the energy transition

## The future of long duration energy storage

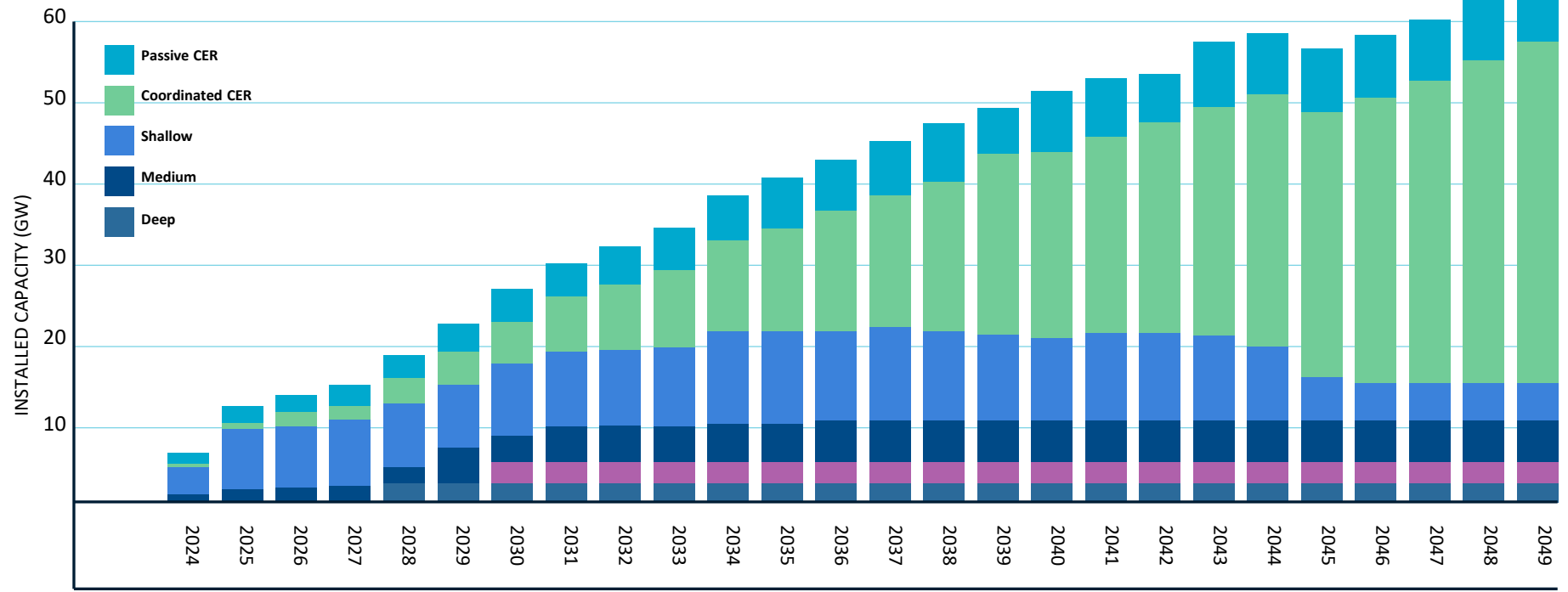
Keeping the lights on in a carbon constrained world

June 2024



# HIGHLIGHTS

## Fast shift to distributed power generation



## Alternative LDES are needed to fill the gap

Li-ion Batteries

The Missing Middle

Pumped Hydro



They typically have energy duration capabilities in the range of 12 hours and above and able to carry stored energy through long periods of time



Most have the capability to repeatedly cycle, with low rates of degradation



They can provide key system stability services, including synchronous services



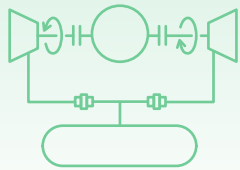
Alternative LDES are needed to fill the gap

Li-ion Batteries

The Missing Middle

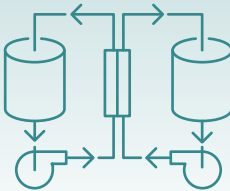
Pumped Hydro

COMPRESSED AIR



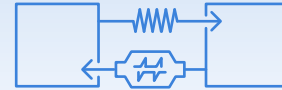
Diabatic  
Adiabatic  
Isothermal  
Liquid Air

REDOX FLOW



Vanadium Flow  
Zinc Bromide Flow  
Iron Flow

THERMAL

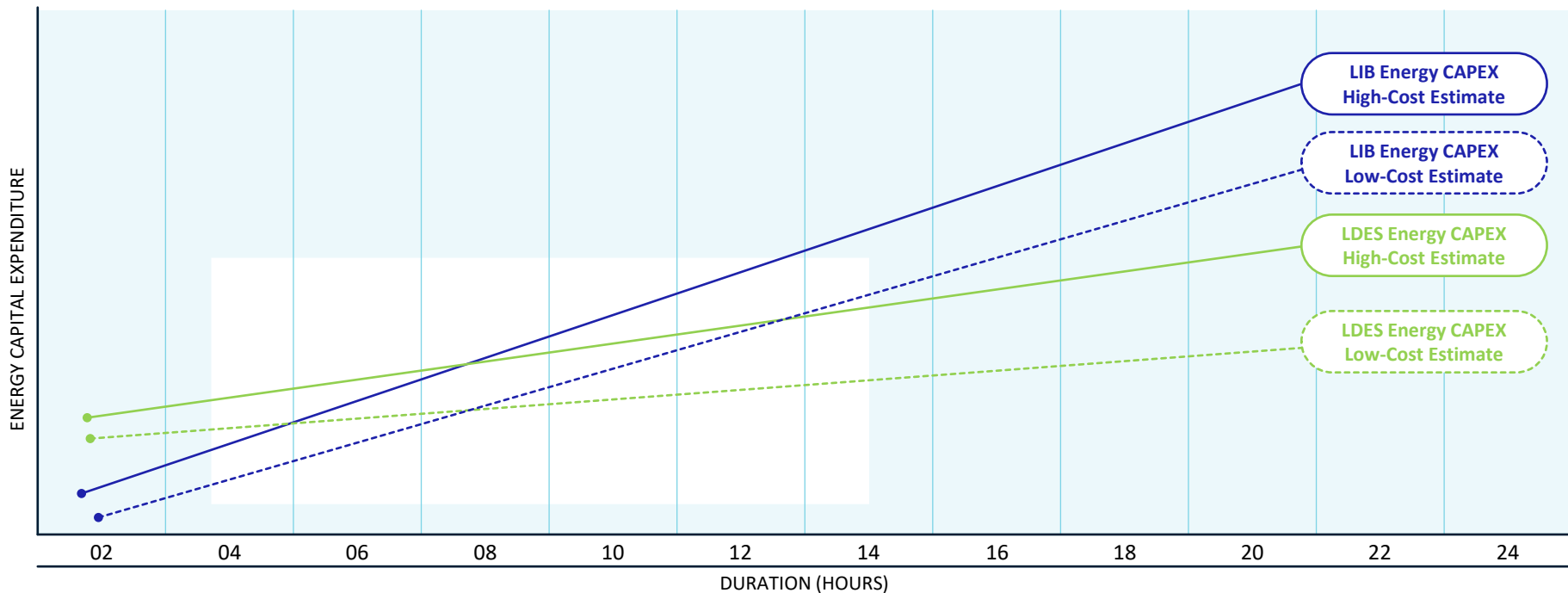


Molten Salts  
Steam  
Miscibility Gap Alloy

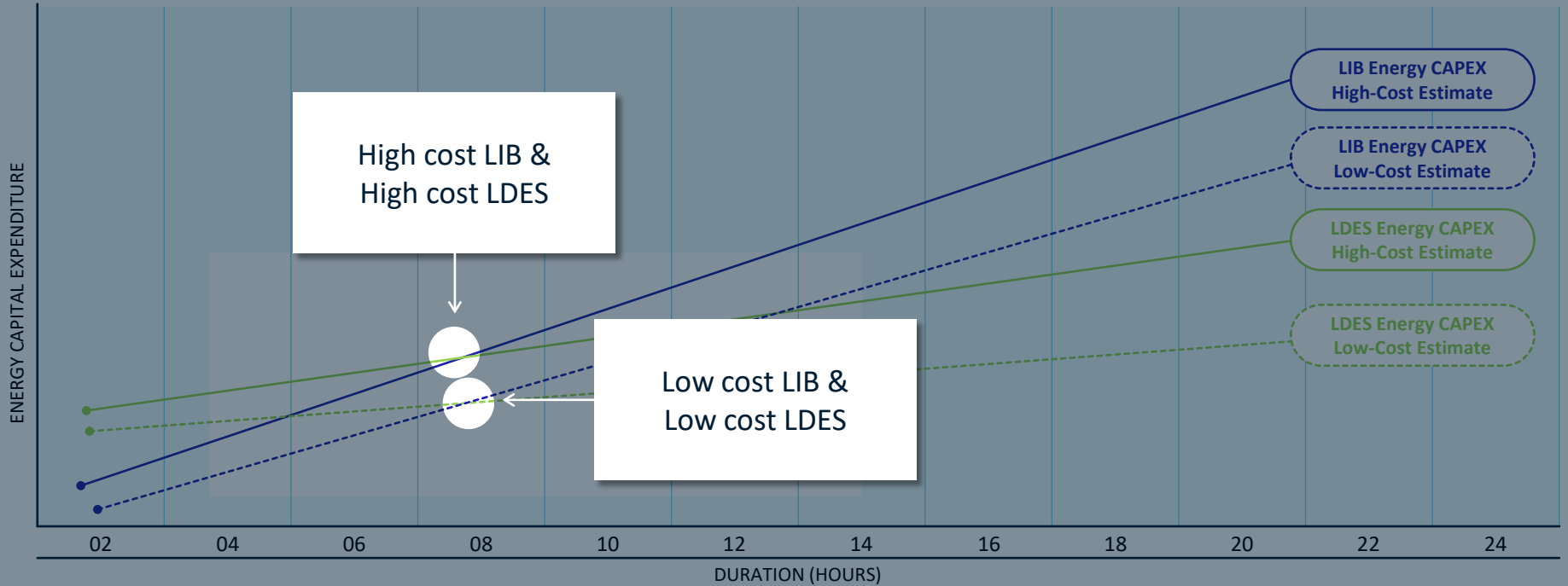


# HIGHLIGHTS

## Alternative LDES are needed to fill the gap



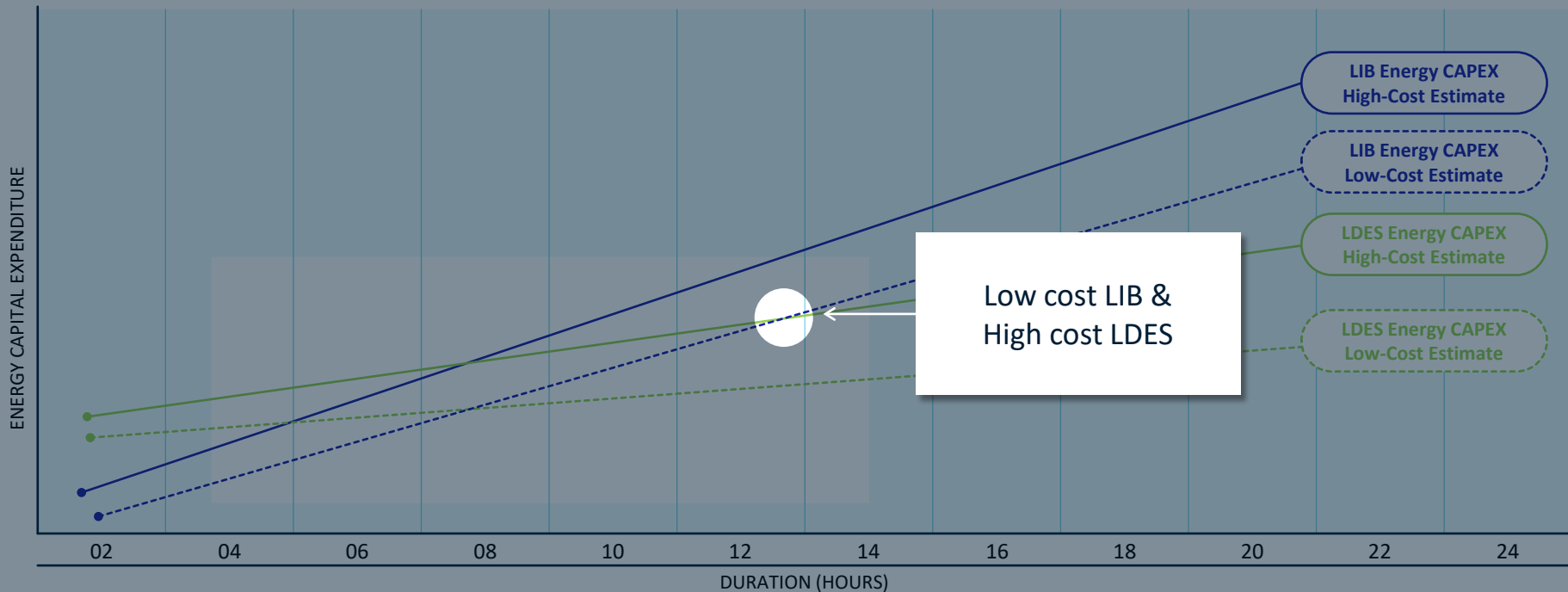
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# HIGHLIGHTS

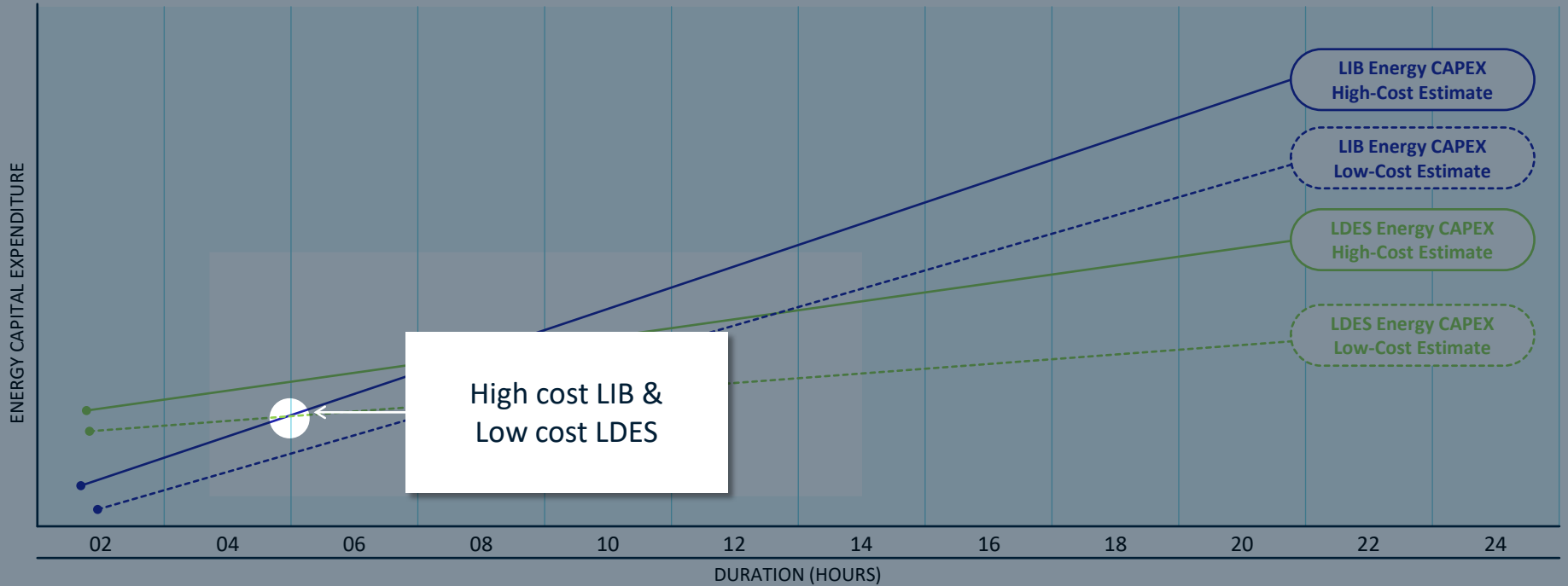
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# HIGHLIGHTS

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## HIGHLIGHTS

### Alternative LDES are needed to fill the gap

	A-CES	VRB	Zr-Br RB	CST TES	MGA
Rated power output (MW)	200 - 500	10 - 100	10	300	100
Energy Duration (h)	8 - 12	8 - 12	8 - 12	12 - 24	12 - 24
Round trip efficiency (%)	40 - 80	60 - 85	60 - 70	60 - 80	20 - 50
Cycling capability (Cycle)	NA	15,000 – 20,000	11,000	NA	10,000
Lifespan (year)	up to 60	25 +	10 - 20	40+	20+
Locational dependency	Moderate	Low	NA	High	Low
Capital cost (US\$/kWh)	120 - 280	640 -1,100	370 - 1,470	47 - 84	30 - 60
Construction year	2 -3	1	1	1-2	1-2



# ENERGY STORAGE R&D ACROSS CSIRO



# ENERGY STORAGE R&D ACROSS CSIRO

## Compressed Air storage

- A-CAES is demonstrated, cost-effective technology suitable in areas of hard rocks (caverns-demonstrated), or sedimentary rocks that are sufficiently permeable (not demonstrated)
- Further development to enhance efficiency through better waste heat harvesting, storage and recovery

Xin Yang, Ben Clennell, Jason Czapla, Chunhui Lu

The image contains two main parts. The top part is a screenshot of a journal article page from the 'Journal of Energy Storage' (Volume 99, 2024, 112202). The article title is 'Understanding the influence of aquifer properties on the performance of compressed air energy storage in aquifers: A numerical simulation study' by Xin Yang, Jason P. Czapla, Michael B. Clennell, and Chunhui Lu. The bottom part is a schematic diagram of a CAES system. It shows wind turbines providing 'ELECTRICITY IN' to a 'COMPRESSOR'. The compressor takes 'AIR IN' and sends it to an underground 'AQUIFER' where it forms an 'AIR BUBBLE'. A 'CAPROCK' layer is above the aquifer. The system also includes a 'HEAT STORAGE' unit and a 'TURBINE'. The turbine takes 'AIR OUT' from the aquifer and produces 'ELECTRICITY OUT'.





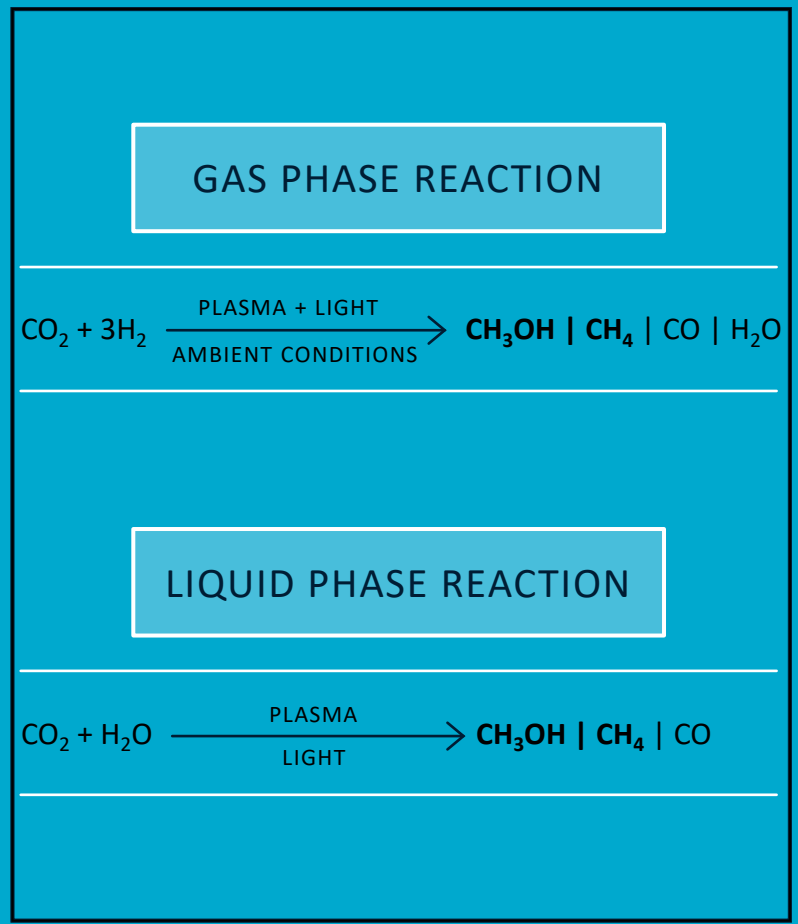
## ENERGY STORAGE R&D ACROSS CSIRO

### Plasma enhanced CO<sub>2</sub> hydrogenation

- Ambient conditions
- ~150°C
- ~80% conversion
- 99% CH<sub>4</sub> selectivity
- Well suited for RE
- Reactor design

**Yunxia Yang**

A/Prof Jason Scott (UNSW), Dr Emma Lovell (UNSW)  
Karen Wilson (Griffith University), Adam Lee (Griffith University)





## ENERGY STORAGE R&D ACROSS CSIRO

### New Electrolyte Strategy

- Cheap
- Environmentally friendly
- Stable
- High voltage
- Fast kinetics and transport
- High solubility (capacity)

Tim Jones, Gavin Collis

Tim Jones, Gavin Collis



High theoretical capacity over  $50 \text{ Ah L}^{-1}$



Precursors scaled to 50 g scale



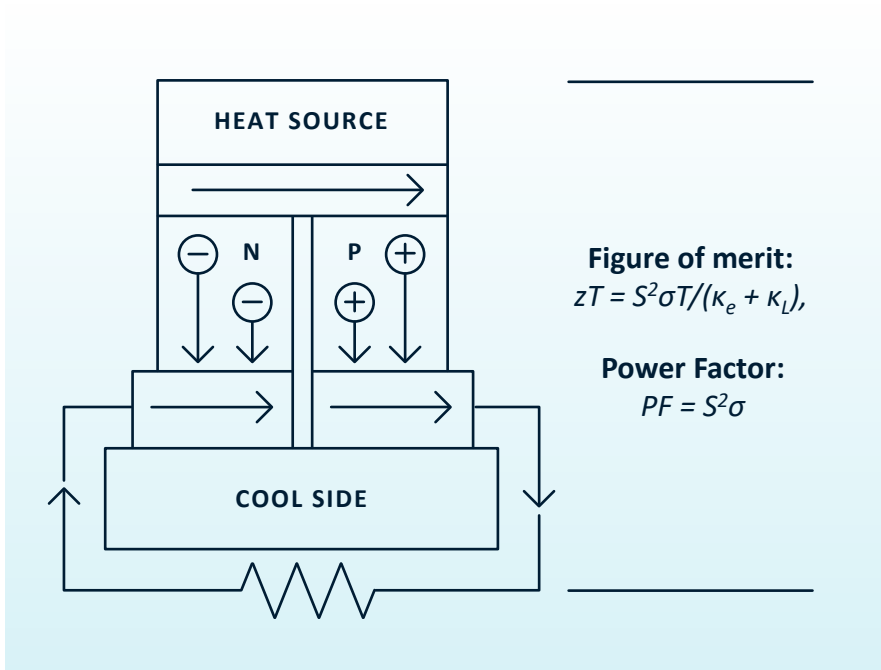
Stable to strong acid and base for over 100 days



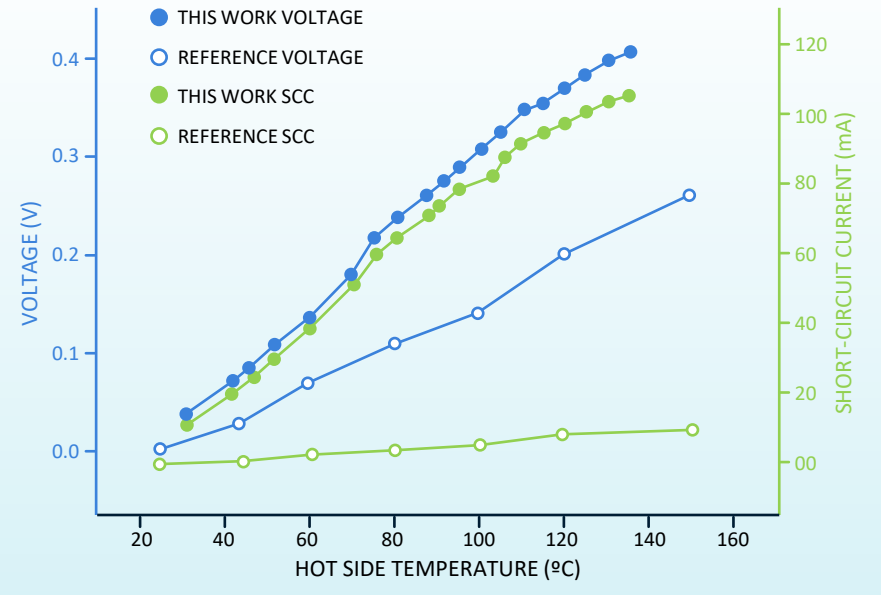
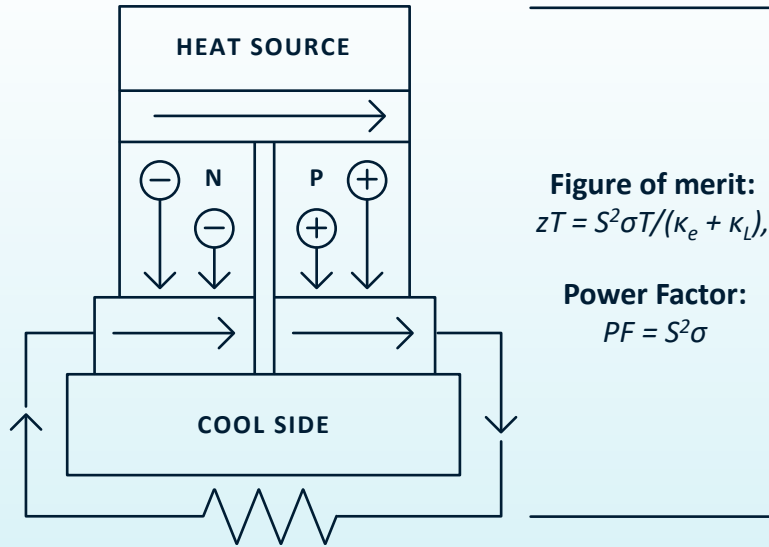


# RESS FSP PORTFOLIO

## High power thermoelectric devices



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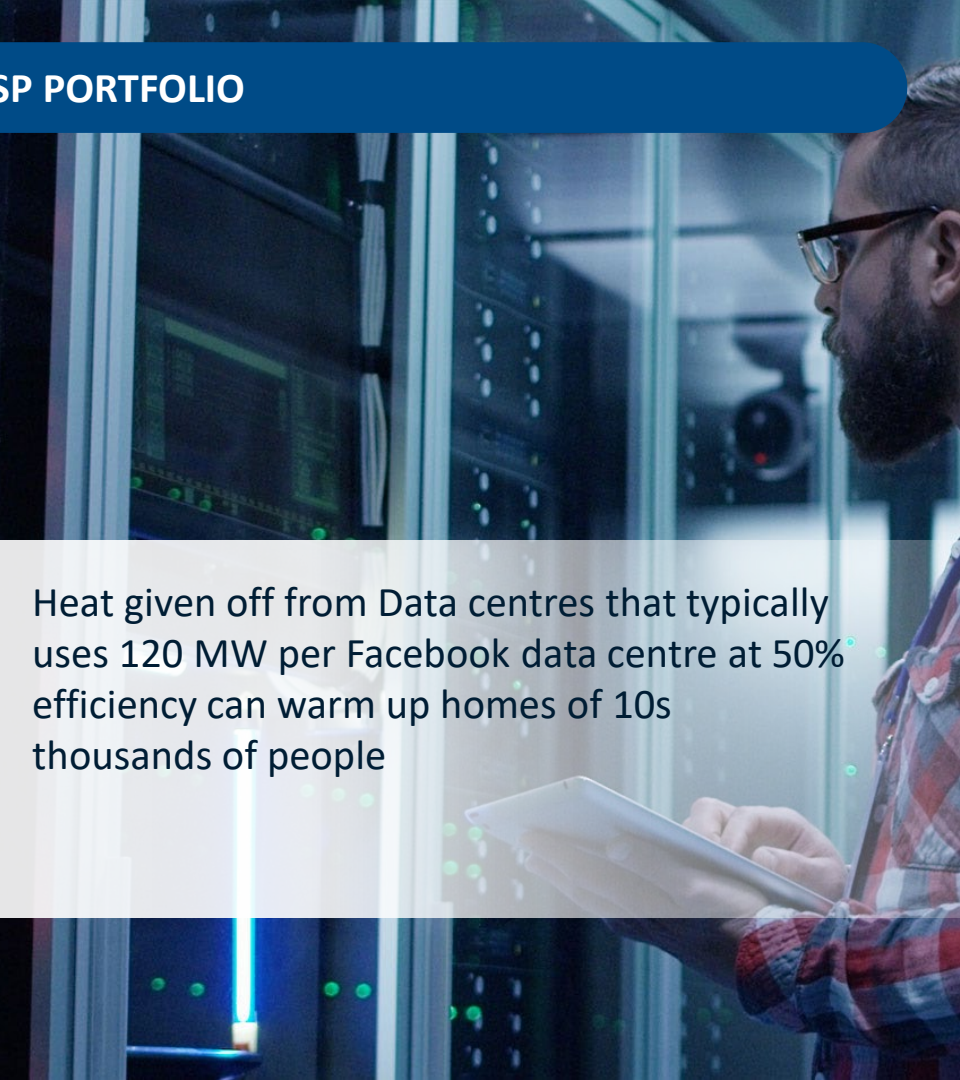




## RESS FSP PORTFOLIO

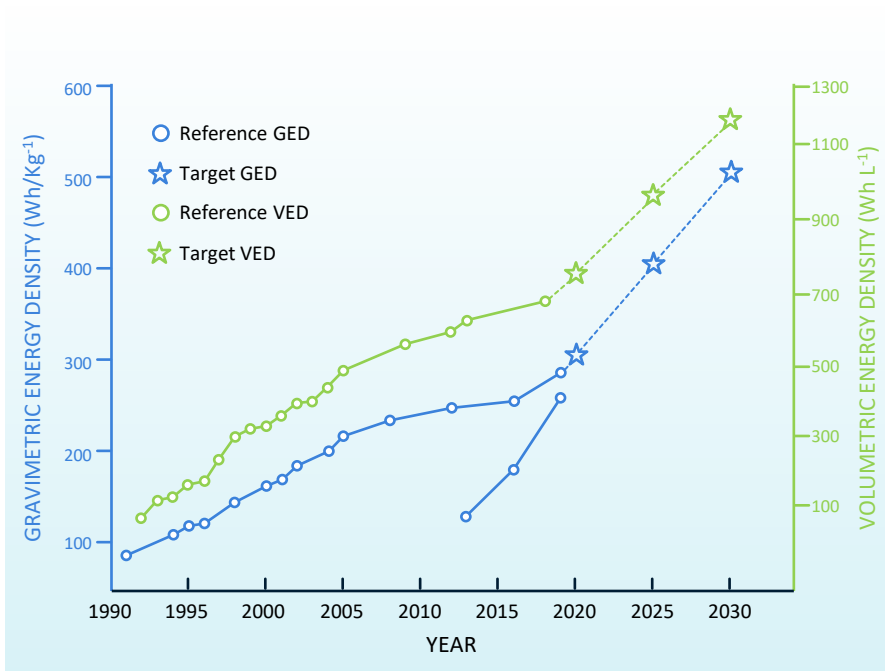
### High power thermoelectric devices

CSIRO CST-Steam power plant.  
Heat loss: 52-67%.

A photograph of a data center server room. The image shows rows of server racks with various components and cables. A person with a beard and glasses is visible on the right side, looking at a tablet device. The room is dimly lit, with blue and green lights from the server racks providing the primary illumination.

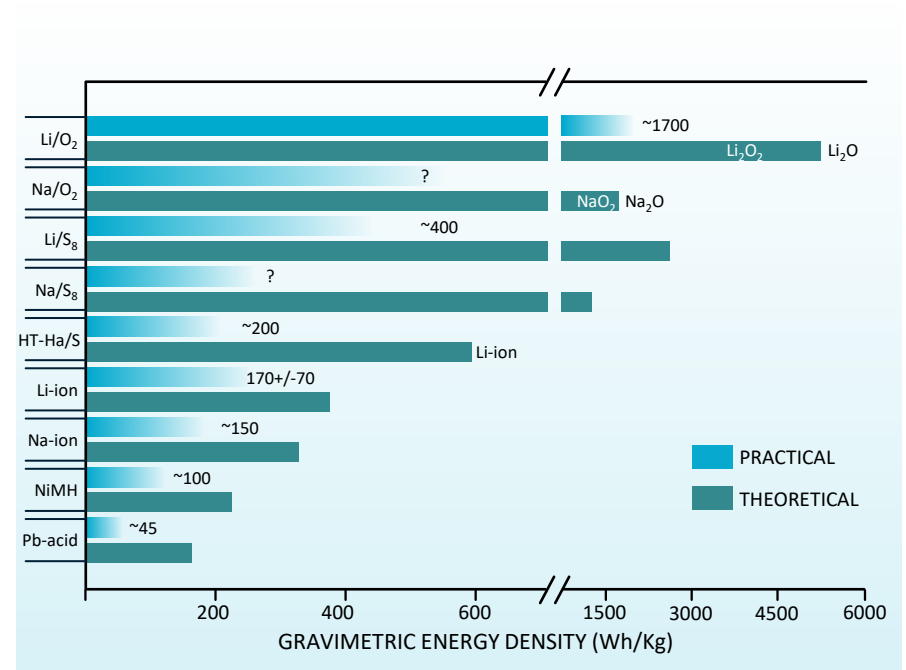
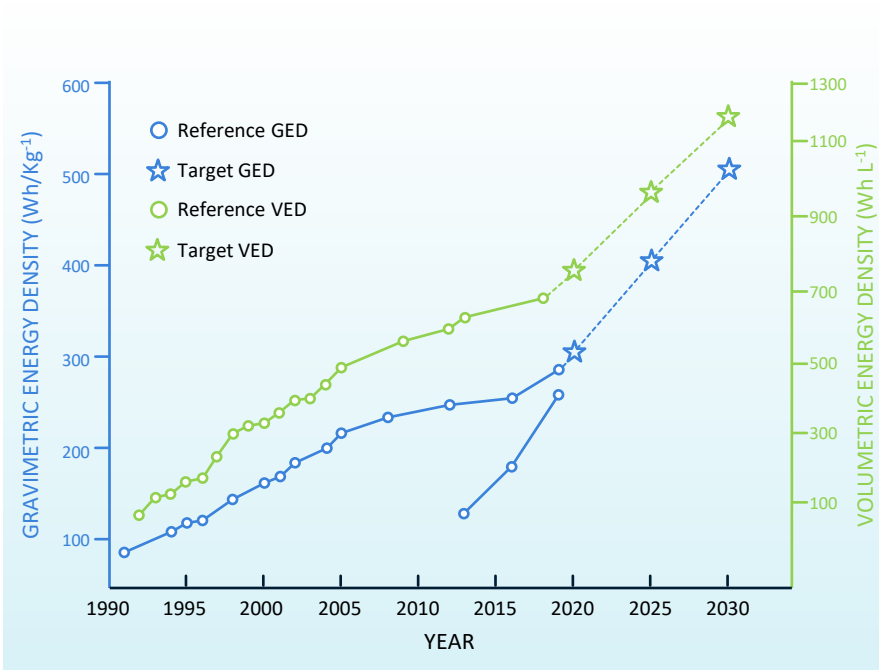
Heat given off from Data centres that typically uses 120 MW per Facebook data centre at 50% efficiency can warm up homes of 10s thousands of people

## Metal Air Systems





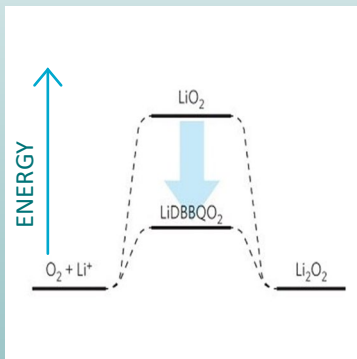
## Metal Air Systems



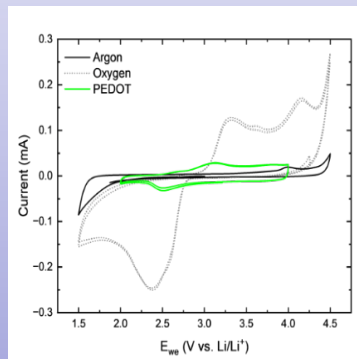


## Metal Air Systems

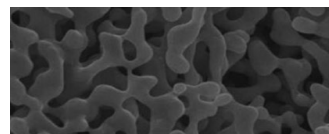
New electrolyte systems to reduce the charging over-potential



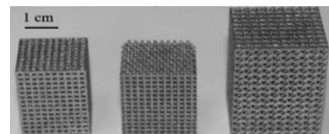
Nanomaterial catalysts to enhance kinetics of redox reactions



Stochastic (foam/mesh) and architected (micro-lattices/truss) metal and metal alloy cathodes to enhance oxygen permeability

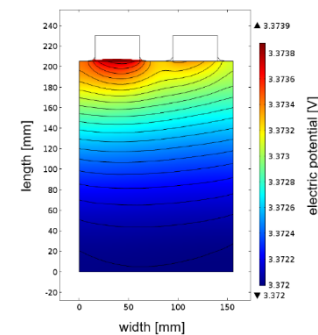


RANDOM POROUS STRUCTURE



LATTICE STRUCTURE

Modelling and simulation of electrochemical processes





Thank you  
Questions?