Titanium-Cerium Electrode-Decoupled Redox Flow Batteries Integrated With Fossil Fuel Assets…

- **Award Number: FE0032011**

Prime Recipient: Washington University

PI: Vijay Ramani

Co-PIs: Ben Kumfer (presenting), Shrihari Sankarasubramanian

Sub-Recipient: Giner, Inc.

Utility Consultant: Ameren Missouri

Location: Saint Louis, MO

DOE: $500,000

Non-DOE: $125,615

Total: $625,615

Washington University in St. Louis

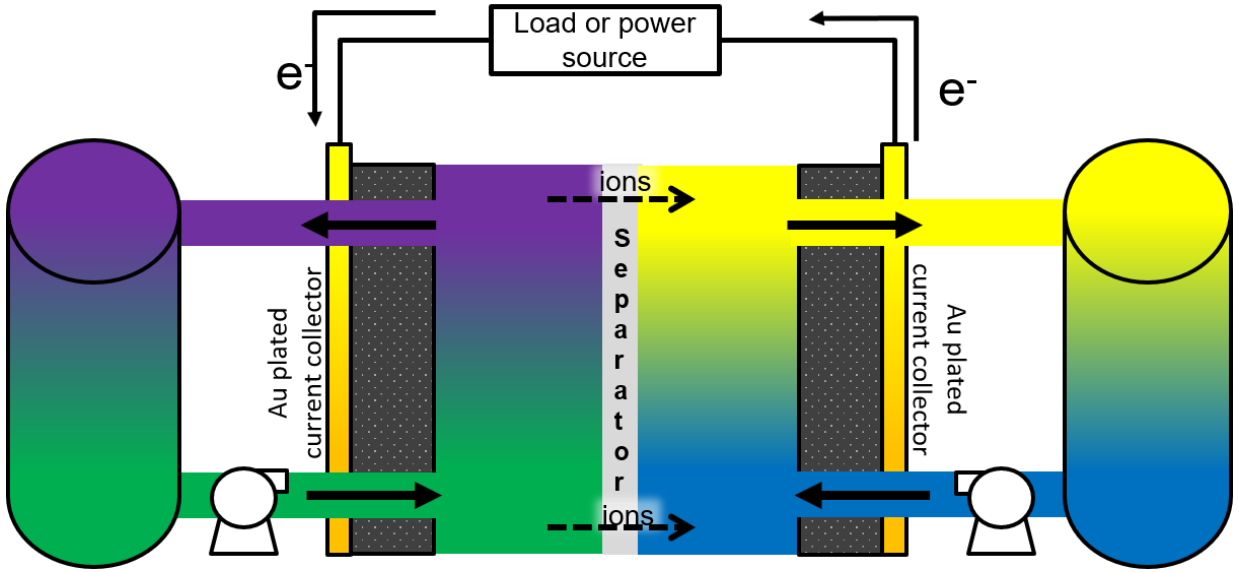
James McKelvey School of Engineering

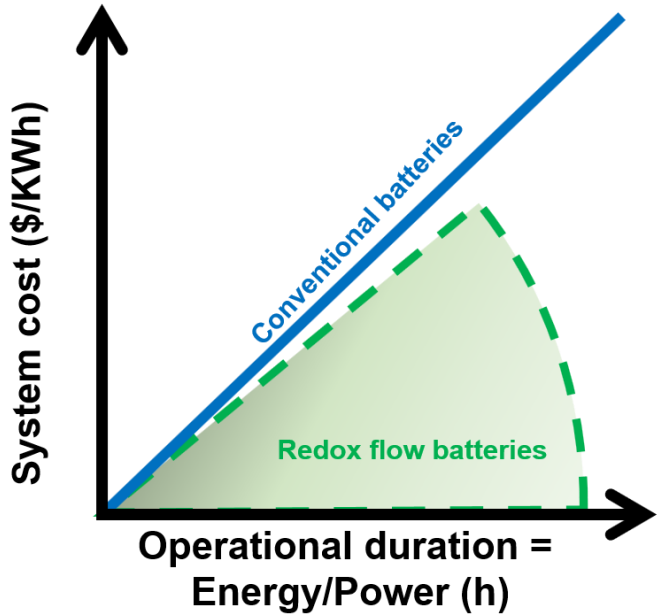
Objectives

- Increase TRL from 4 to 5, by building and demonstrating a ED-RFB cell stack with following performance characteristics:
  - 0.5 A/cm^2 current density
  - 400 cm^2 cell size
  - Capable of 48-hr cycle duration
  - <5% capacity loss in 1- week standby
- Demonstrate a pathway to achieve following cost targets for a large-scale system:
  - Capex values of < $500/kW (power) and < $ 50/kWh (energy)
  - Levelized cost of storage (LCOS) of < $0.05/kWh-cycle
- Reveal and quantify the benefits of co-locating the storage system within the fence-line of a fossil plant.
- Develop path to commercialization through market research, gap assessment, and technology maturation and commercialization planning

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**





- Energy and power are decoupled

  => greater design flexibility

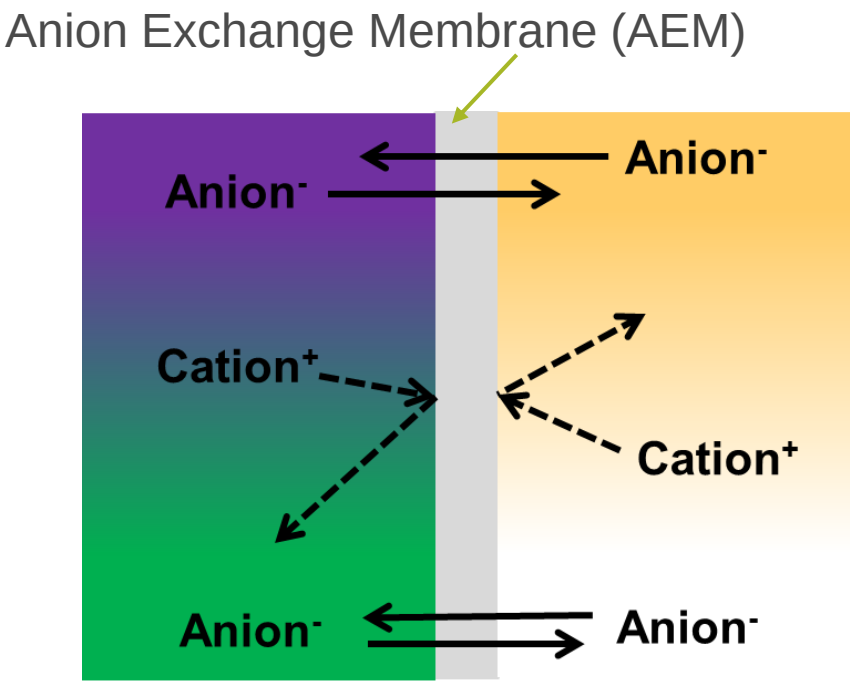
  => lower scale-up costs

- Rapid response
- Suitable for multiple time scales (minutes – weeks)
- Grid-scale demonstration projects underway (Vanadium type)

Washington University in St. Louis
James McKelvey School of Engineering

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**

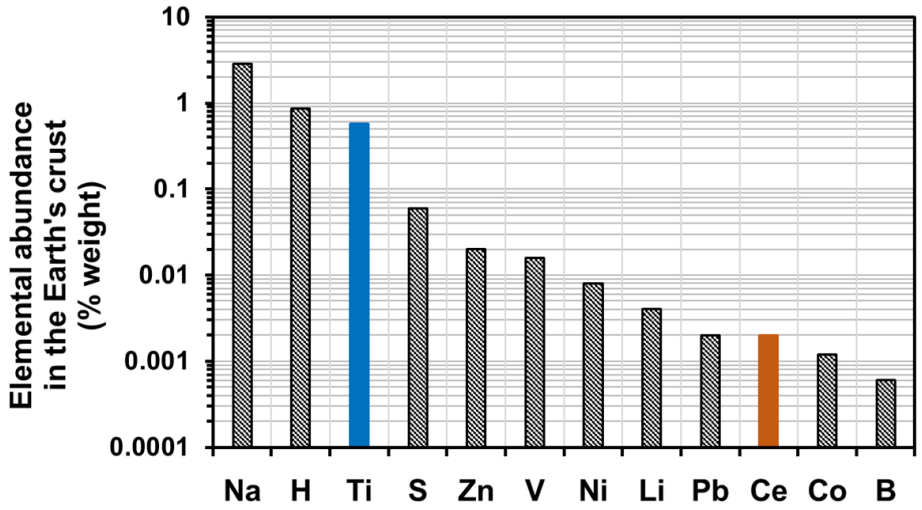


Ti^{4+} (as TiO^{2+}) + e– ↔ Ti^{3+}
(E^0 = 0.19V vs. SHE)

Ce^{4+} + e– ↔ Ce^{3+}
(E^0 = 1.61V vs. SHE)

- Produced with H_2SO_4- or CH_3SO_3H-supported electrolyte
- Anion: SO_4^{-2} or $CH_3SO_3^-$

SHE: Standared Hydrogen Electrode



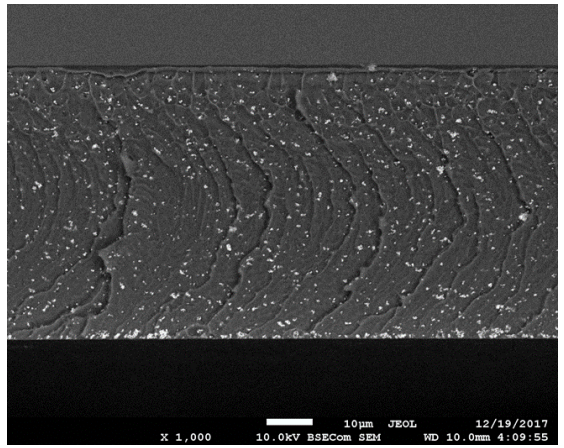
- Abundant active elements
- Lower material costs vs. All-V and V-Ce
- Proven reserves for >300x the total world electricity production (25,000 TWh/year)

Washington University in St. Louis
James McKelvey School of Engineering

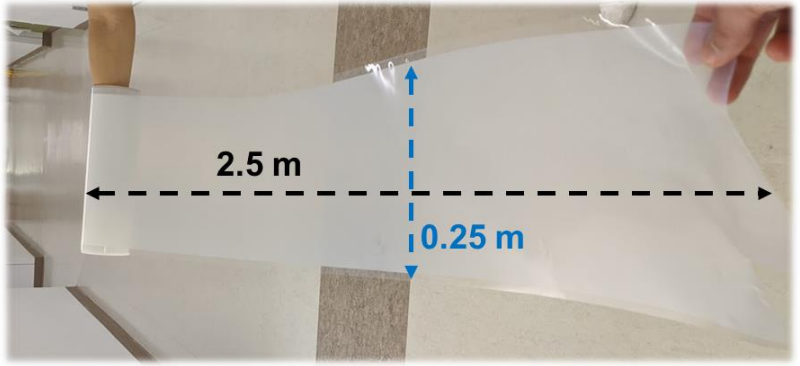
Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**

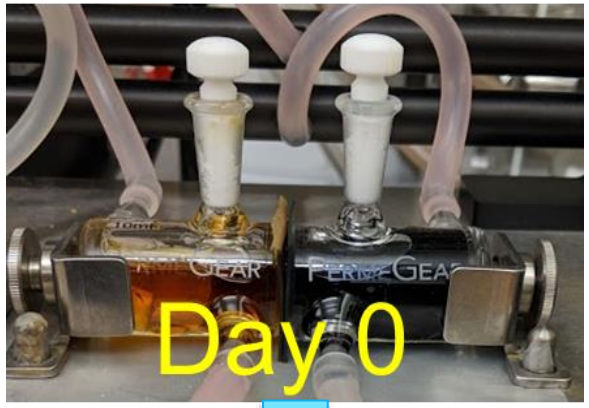
- ❑ Anion Exchange Membrane - <u>Key enabling technology</u>
- ❑ Highly permselective to maintain separation of Ti and Ce species and prevent capacity fade



Made from 100cm² to roll-to-roll



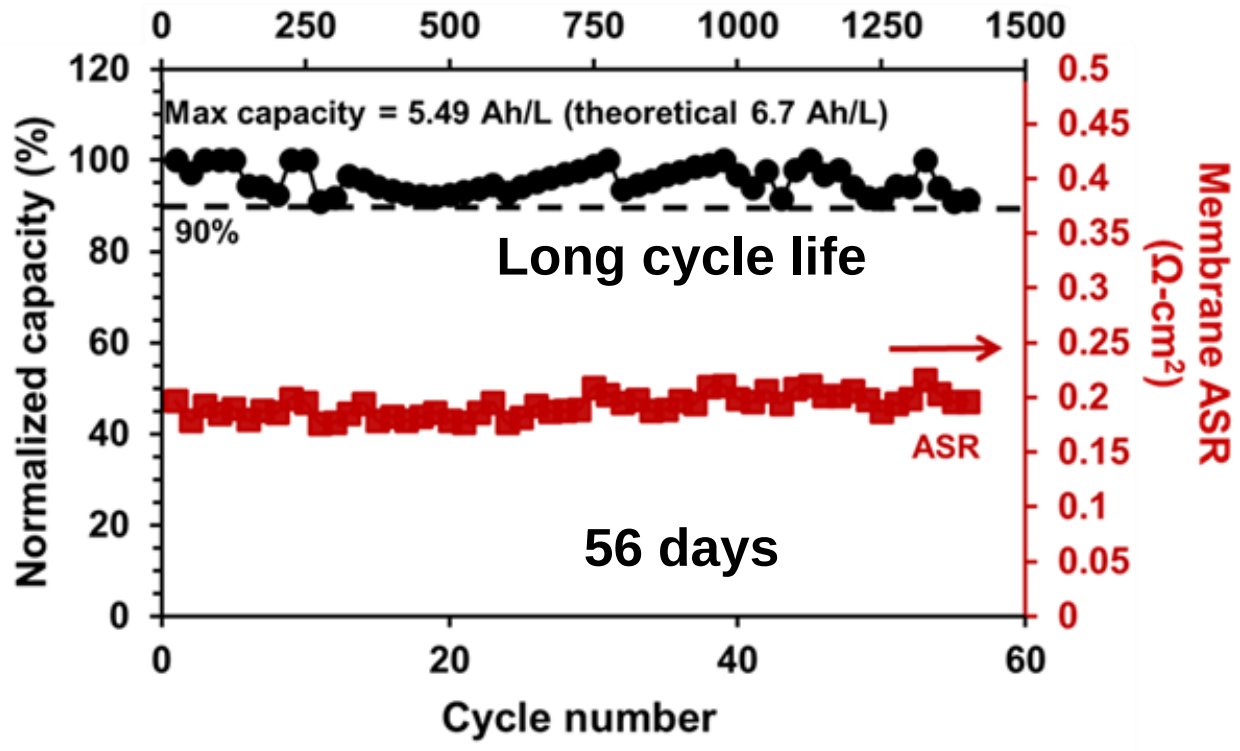
Highly selective



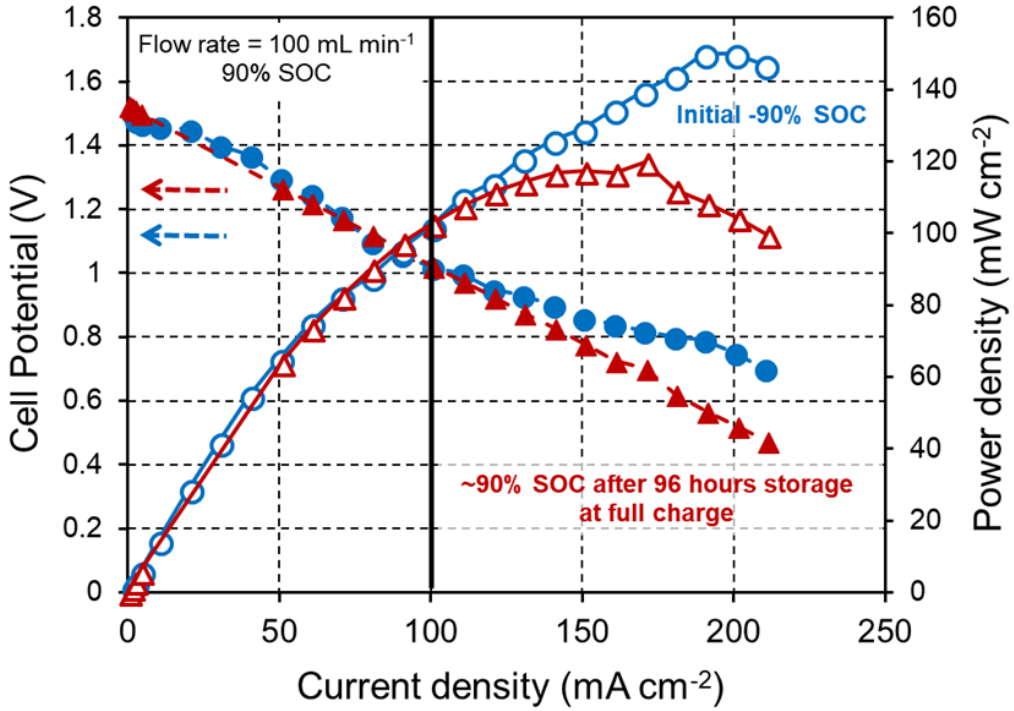
Washington University in St. Louis
JAMES MCKELVEY SCHOOL OF ENGINEERING

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**



>3 day charge retention



Clear pathway to <$90/KWh installed cost and <$0.05/KWh-cycle LCOS

Washington University in St. Louis
James McKelvey School of Engineering

New electrolyte formulations double energy density

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**

Relevance and Outcomes/Impact

- Increased value of existing fossil plants
- Greater flexibility in operation
- Achieve storage/discharge capacity across multiple time scales
- Reduce wear due to cycling, extend life
- Increased efficiency, reduced emissions
- Take advantage of grid market opportunities to increase revenue
- Eliminate stranded renewable electricity
- A stable, reliable, resilient electricity grid

Questions for Discussion

1) What is needed to be able to pilot **a demo plant by 2025?**

2) What does NETL need to consider in regard to a **low-carbon future**?

3) How can NETL help **transition coal assets** as they retire over the next 10-15 years?

Washington University in St. Louis
James McKelvey School of Engineering

Titanium-Cerium Electrode-Decoupled Redox Flow Batteries

- **Award FE0032011**

Thank You!

Ben Kumfer

Research Assistant Professor
Dept. Energy, Environmental and Chemical Engineering
Washington University in St. Louis

kumferb@wustl.edu

Shrihari Sankarasubramanian, Yunzhu Zhang, Cheng He et al.
An Aqueous, Electrode-Decoupled Redox-Flow Battery for Long Duration Energy Storage,
27 January 2021, PREPRINT (Version 1) available at Research Square
[https://doi.org/10.21203/rs.3.rs-150474/v1]