ZINCNYX
ENERGY SOLUTIONS INC.

The ZincNyx Flow Battery

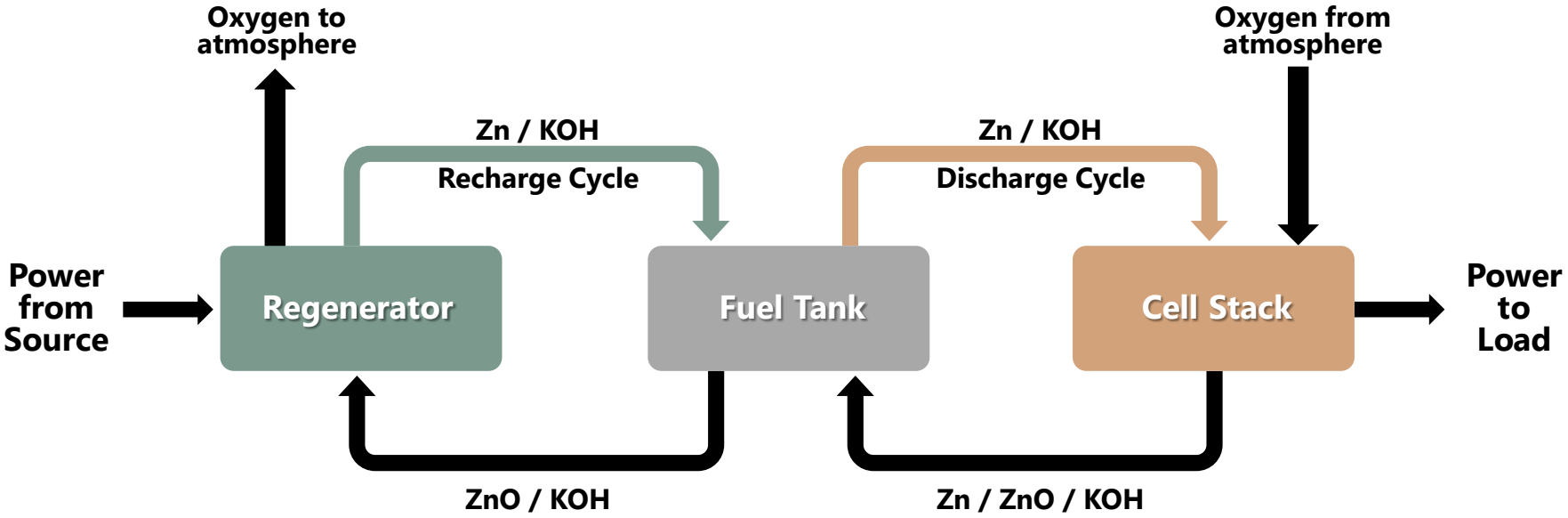
ZincNyx Energy Solutions

- The Mission
  - Provide the lowest cost energy storage system for long duration applications including renewables firming, diesel generator replacement and telecom facility backup
- The Company
  - Backed by Teck Resources, Canada's largest diversified resource company
  - Unique zinc-air flow-battery technology
  - Team comprises mechanical, electrical, software, electrochemistry and materials science skills

Agenda

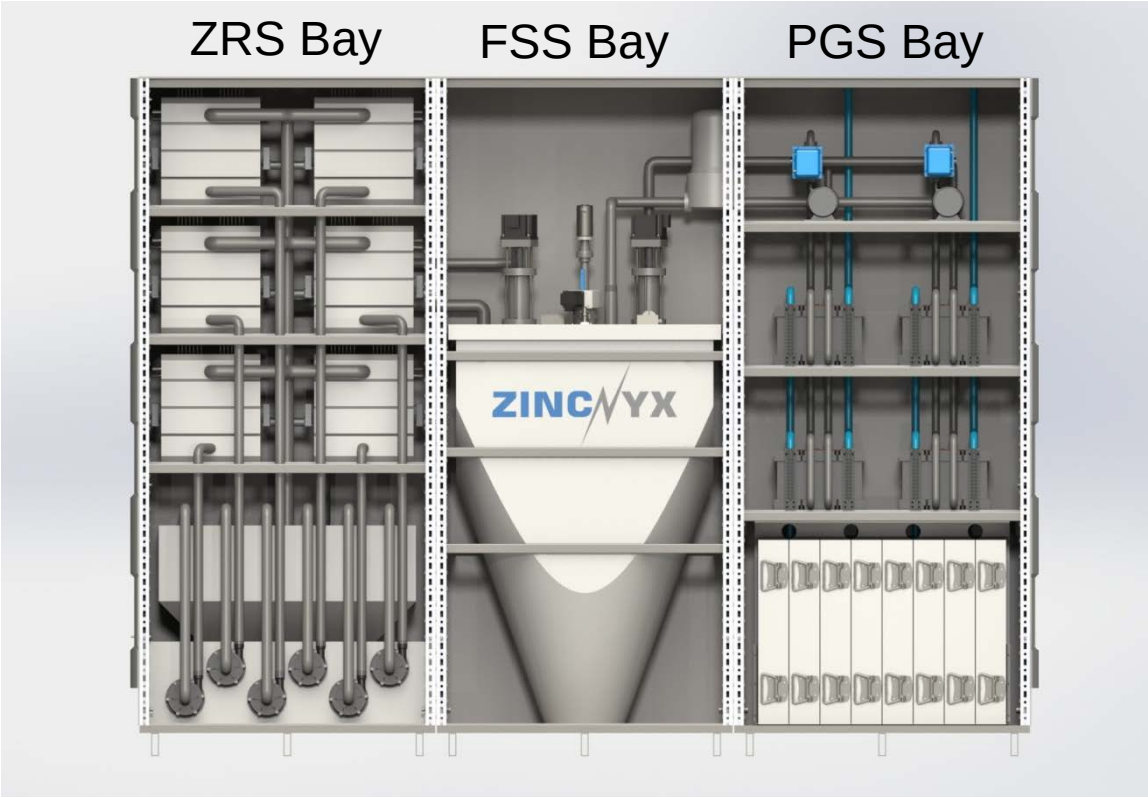
- Overview of zinc-air flow battery
- Flow battery distinctions
- The ZincNyx implementation
- System configurations
- Market for long duration energy storage

Principle Of Operation



Zinc is conserved within the system

Typical System Structure

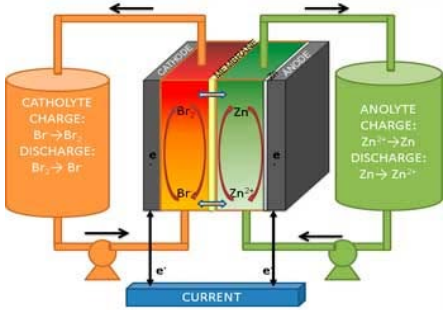


Battery Classification

Secondary Cell

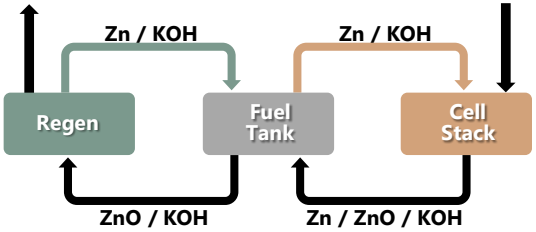
Solid reactant on two electrodes

Hybrid Flow Battery



Solid reactant on one electrode

True Flow Battery



Solid reactant on no electrodes

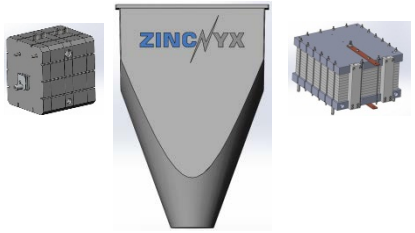
Only a True Flow Battery can fully decouple Energy and Power

Lowest Cost Energy Storage

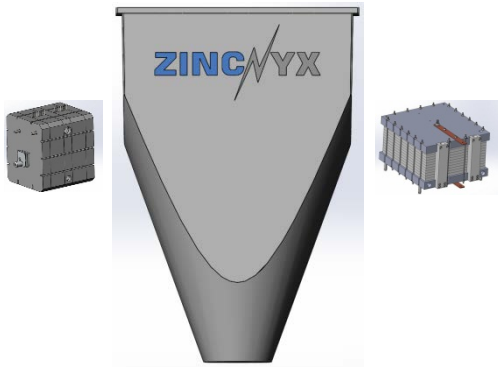
Lithium-ion

> $250 / kWh

Zinc-Air



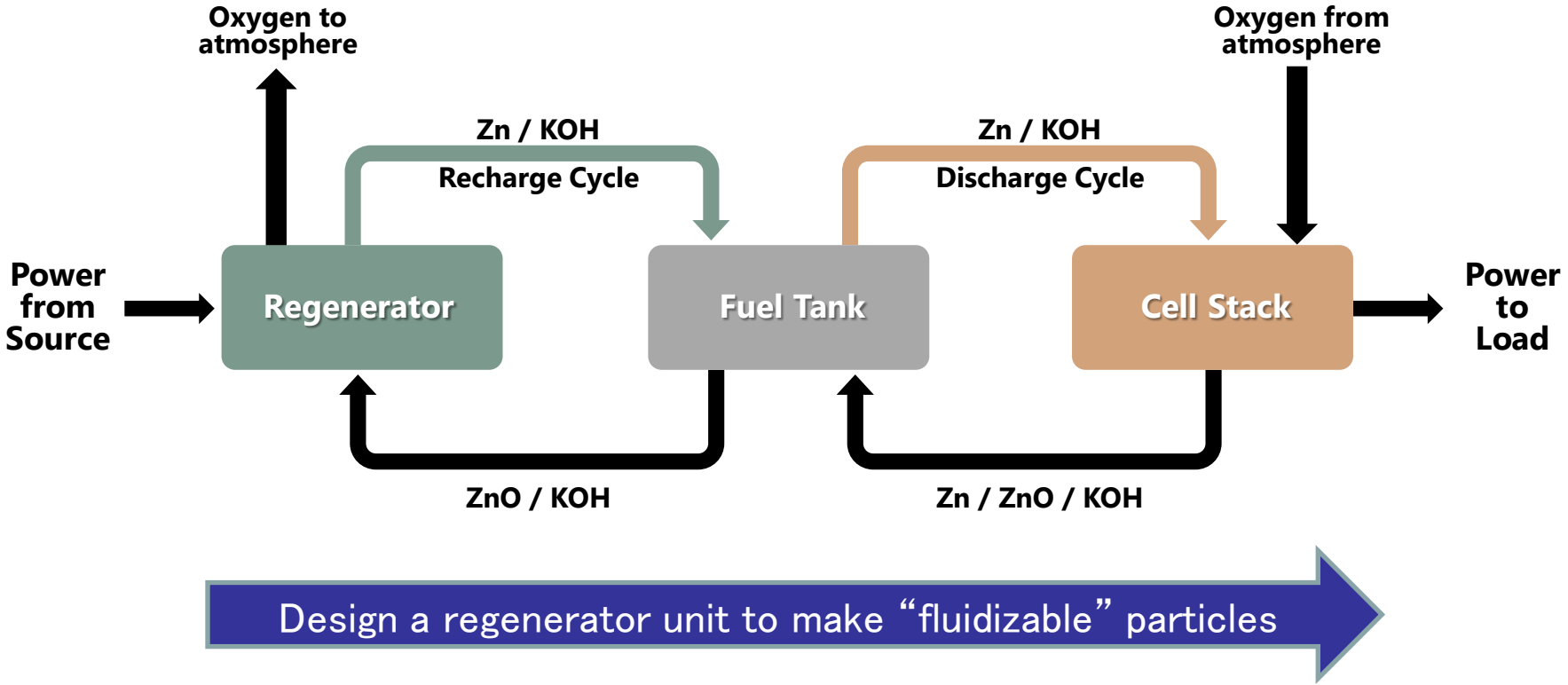
< $25 / kWh



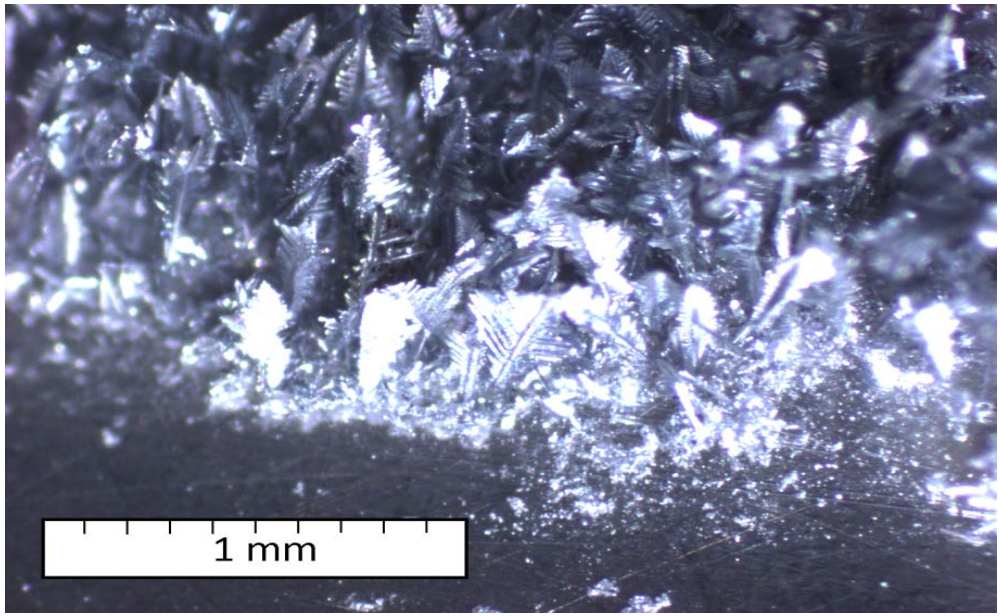
Zinc-air Value Proposition

- Lowest cost energy storage for durations of 4 hours and greater
- Scalable, robust, reliable
- Insensitive to environmental and operational conditions
- Safe: No toxic, explosive or combustible materials or poisonous gasses
- Flexibility to optimize for power & energy needs

Design Approach



Dendritic Zinc Fuel



Particles range from 10 microns to 250 microns.

Size distribution depends on regeneration current and time.

Zinc Air Recharging Process

Anode Reaction:

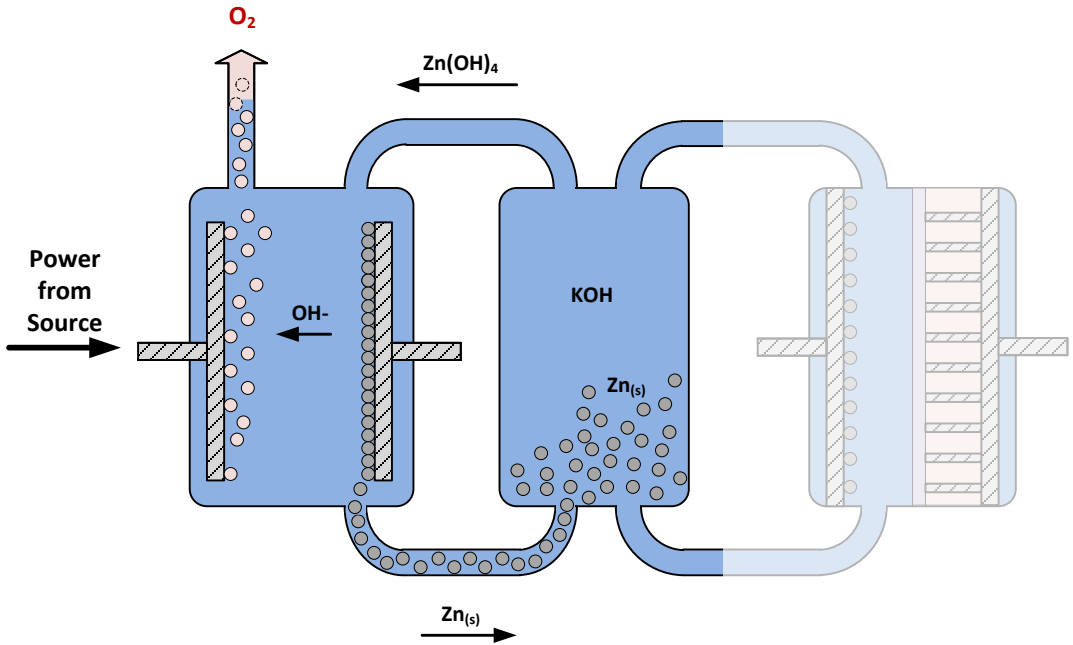
$4OH^- \rightarrow O_{2(g)} + 2H_2O + 4e^-$

Cathode Reaction:

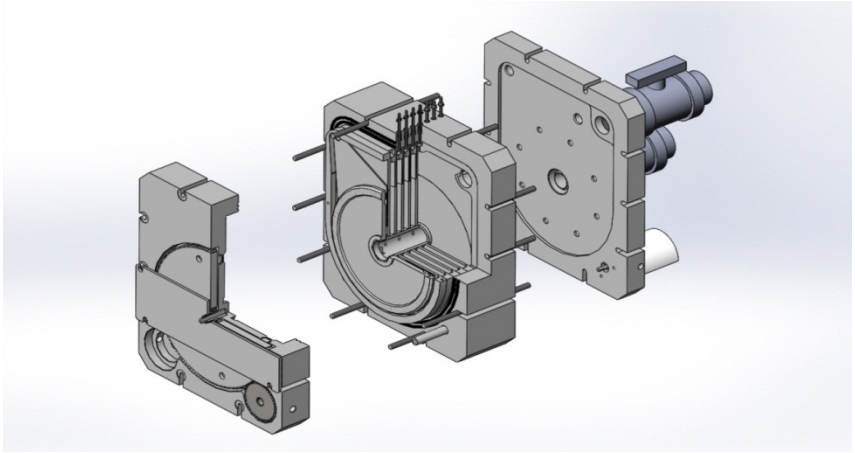
$Zn(OH)_4^{2-}{}_{(aq)} + 2e^- \rightarrow Zn(s) + 4OH^-$

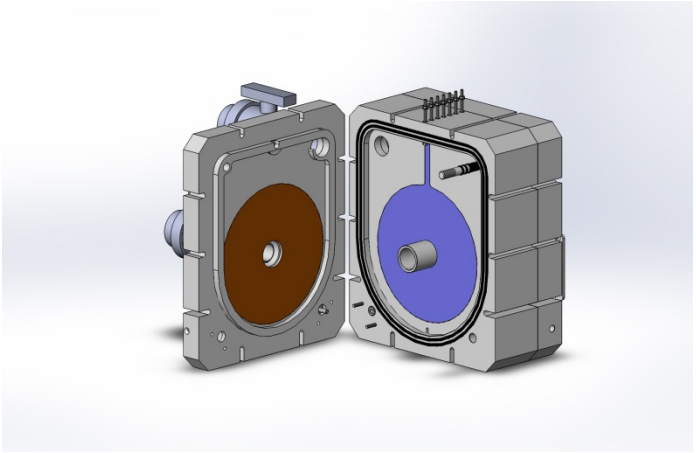
Overall Reaction:

$2\ ZnO \rightarrow 2\ Zn + O_2$



Zinc Regenerator





- Zinc dendrites are grown on magnesium plates
- Washing cycle returns zinc particles to the fuel tank
- Individual cells are connected in series electrically

Zinc Regeneration Subsystem

- Up to 6 Zinc Regeneration Stacks
  - Each “double” stack is composed of two 7-cell units
  - Reverse current rods for individual cell cleaning
- Sump tank
  - Decouples regen stack height from main tank height
  - Enables the “wash cycle” to be decoupled from the “fuel storage” cycle
- Electronic control system
  - Stack and Bay level

Zinc Air Discharging Process

Anode Reaction:

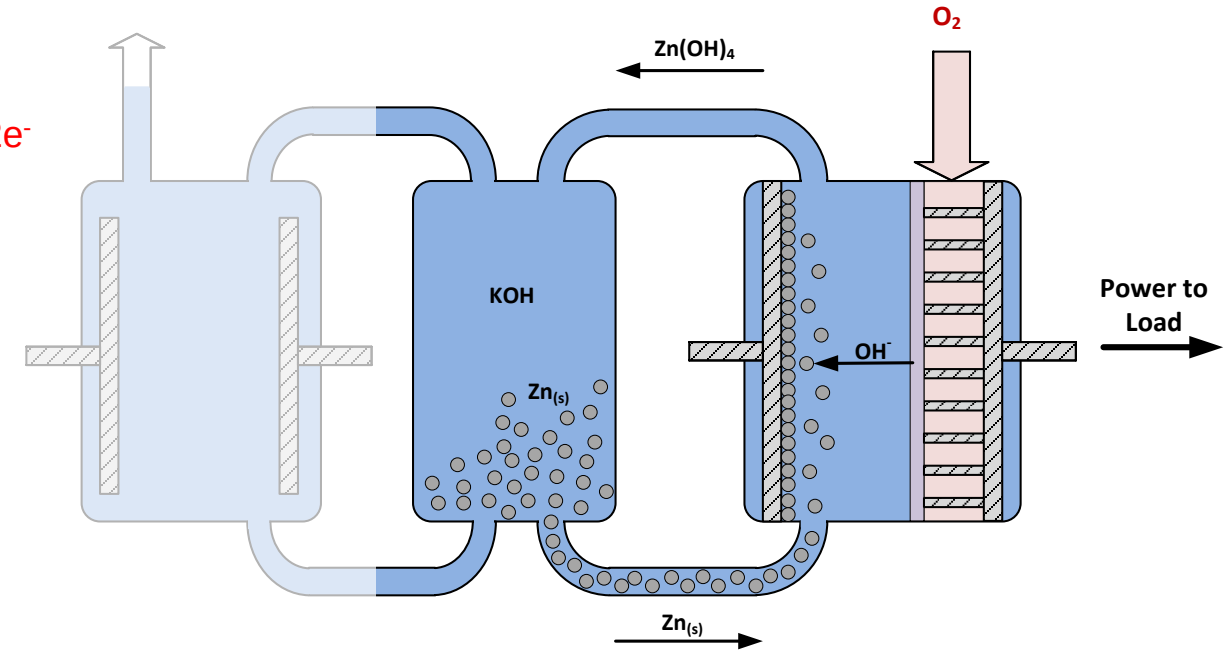
$Zn_{(s)} + 4OH^- \rightarrow Zn(OH)_4^{2-}{}_{(aq)} + 2e^-$

Cathode Reaction:

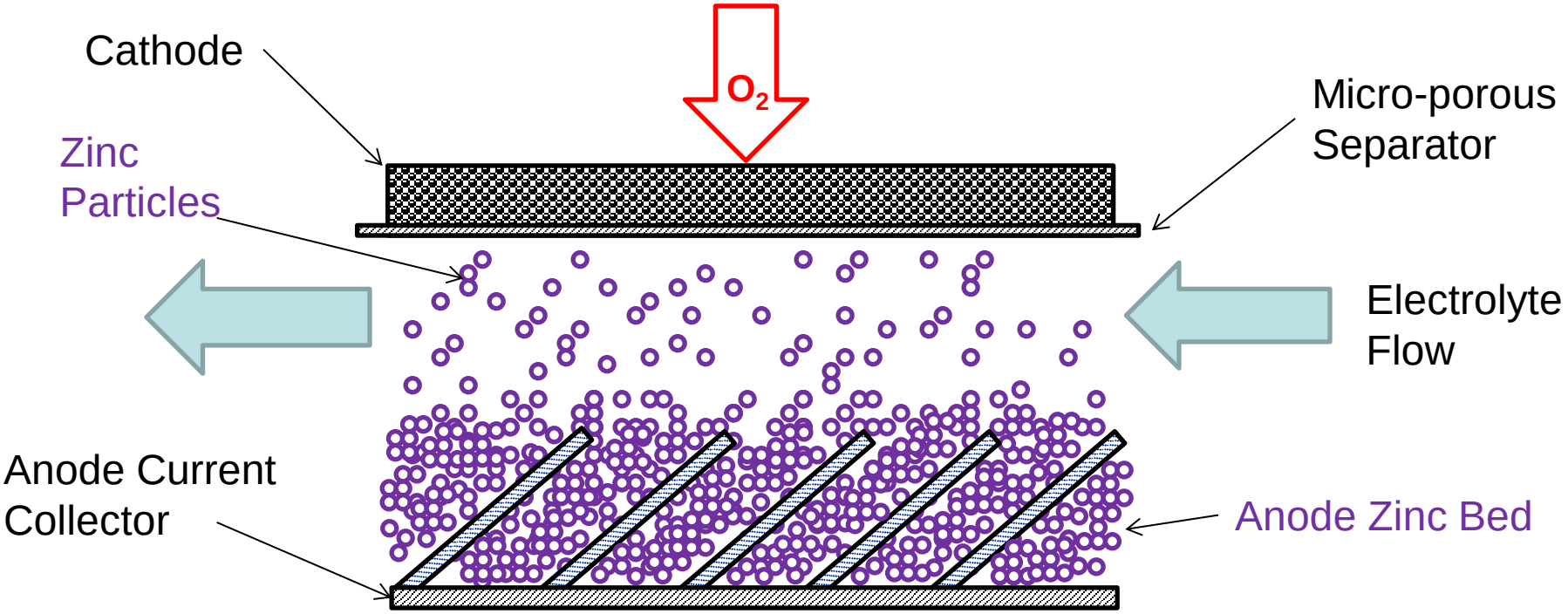
$O_{2(g)} + 2H_2O + 4e^- \rightarrow 4OH^-$

Overall Reaction:

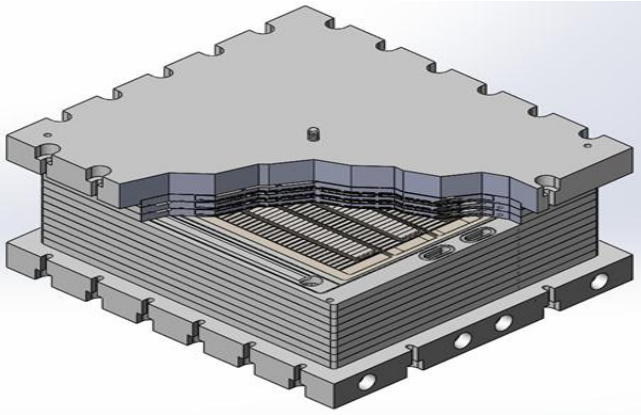
$2\,Zn + O_2 \rightarrow 2\,ZnO$



Fuel Cell Operation

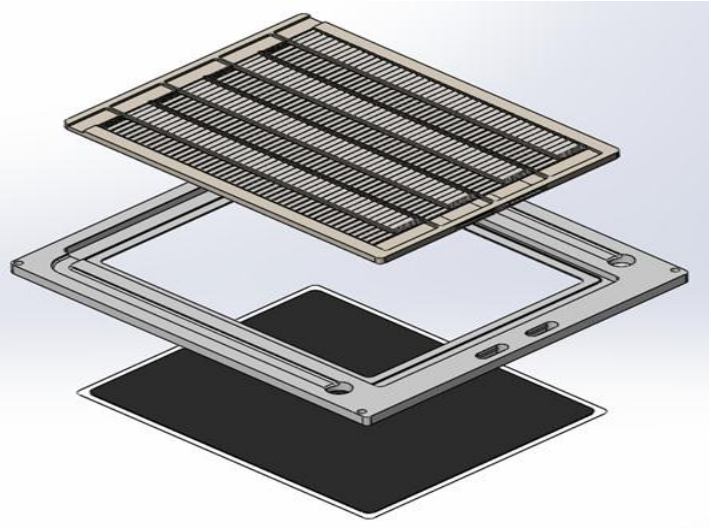


Fuel Cell Stack

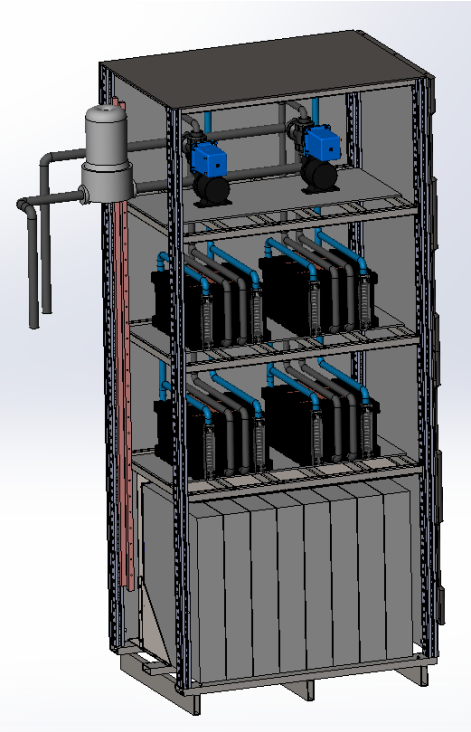


- Bipolar plates form adjacent cells

- Typical stack delivers 100 Amps at 12 Volts

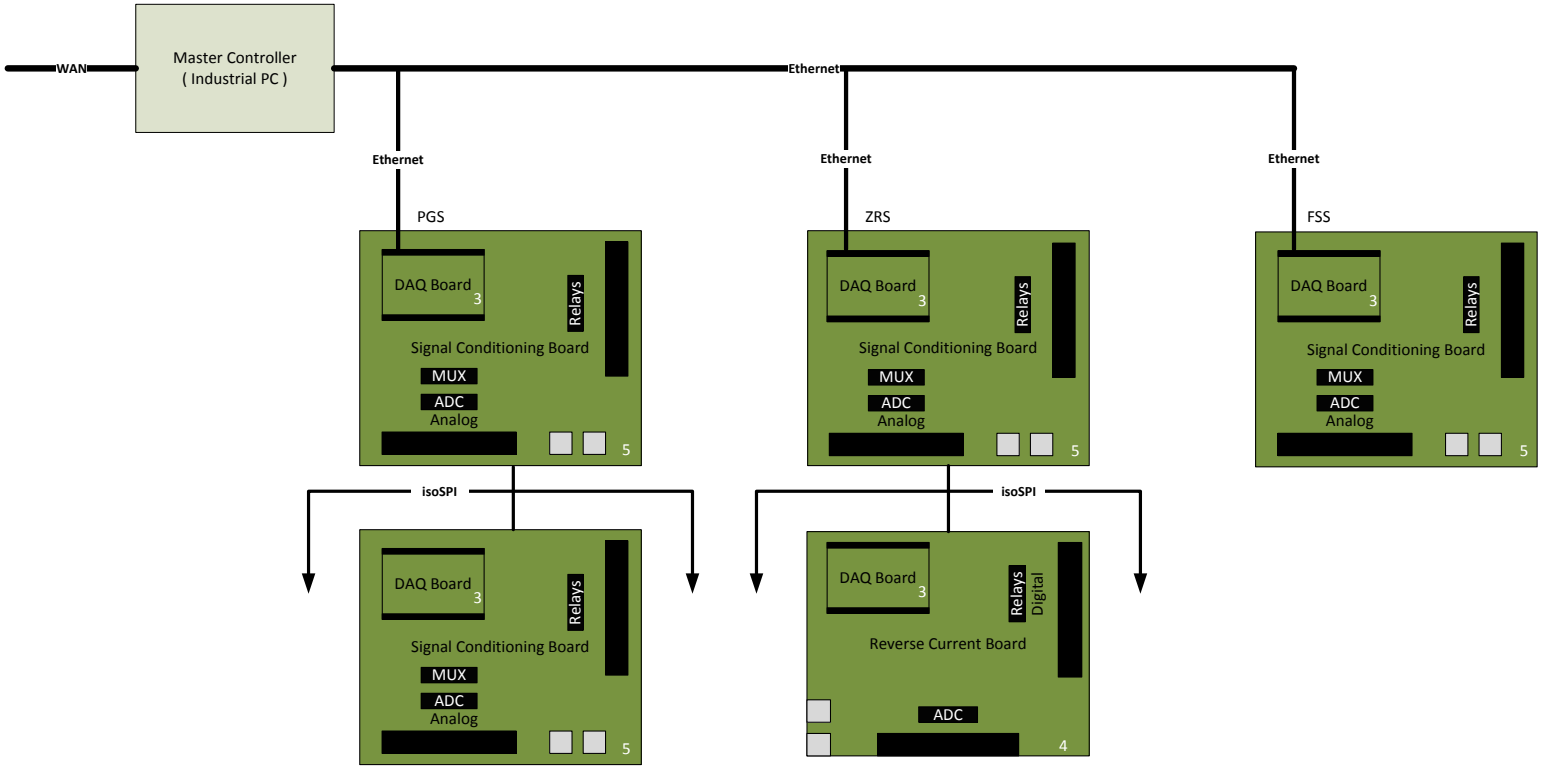


Power Generation Subsystem



- Up to 4 Power Generation Stacks
  - 12 cells per stack
  - Room for larger stacks
  - Stacks are paired for 24V output
  - Booster pumps decouple stacks from fluidizer
- CO_2 scrubber
  - Sorbent cartridge for easy maintenance
  - CO_2 sensors included in bay
- Electronic control system

Control and Monitoring (CMS)



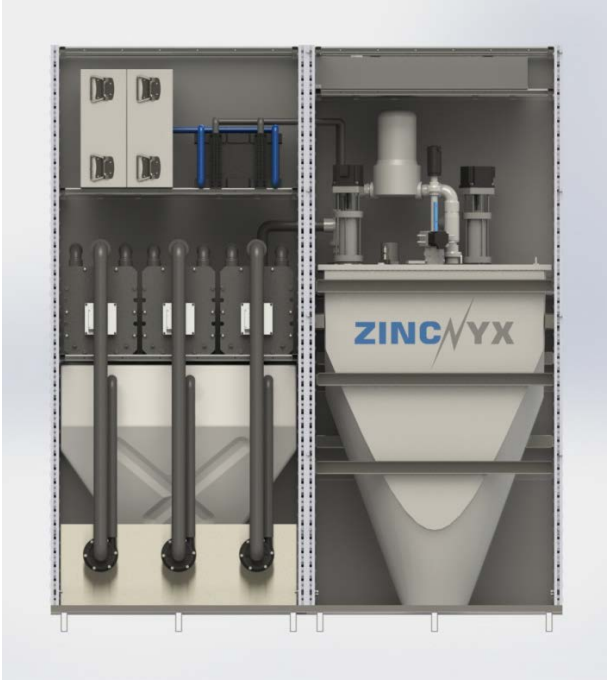
Standard 5 kW Module

Rated Power	5 kW
Maximum Power	7 kW
Energy	40 kWh
Discharge time	8 hours at rated power
Recharge time	16 hours at rated power
Operating life	20,000 hours
Cycles	Unlimited within lifetime
Efficiency	55 – 65% round trip
Electrical Interface Interface	48 V DC

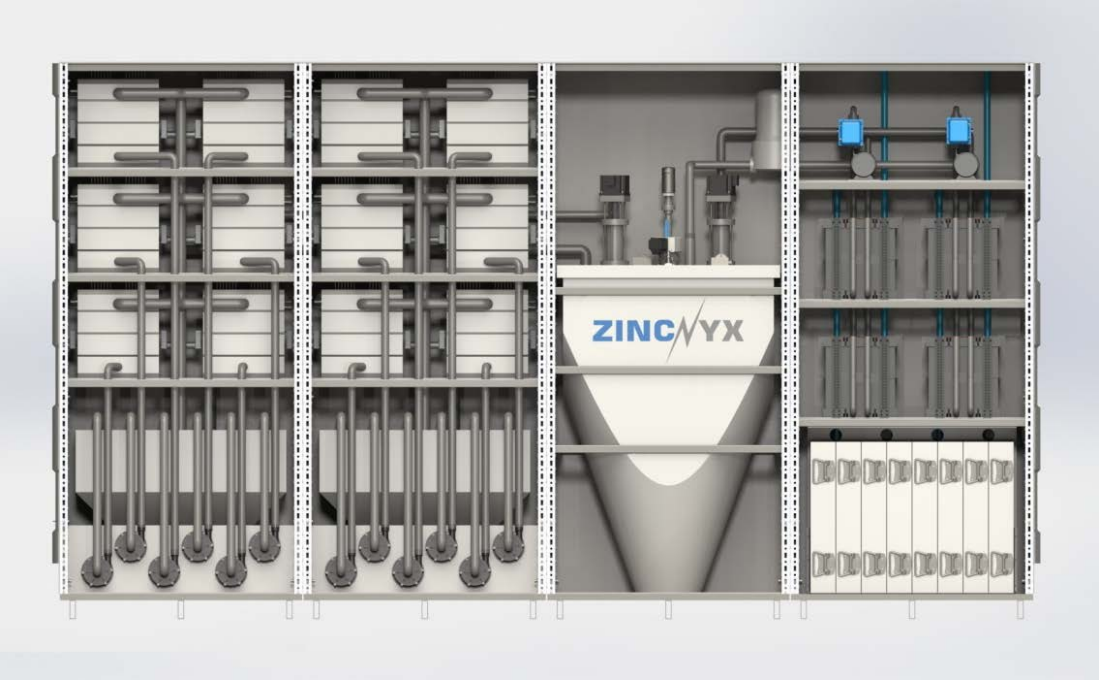
Safe Scalable Robust Flexible

Alternative Configurations

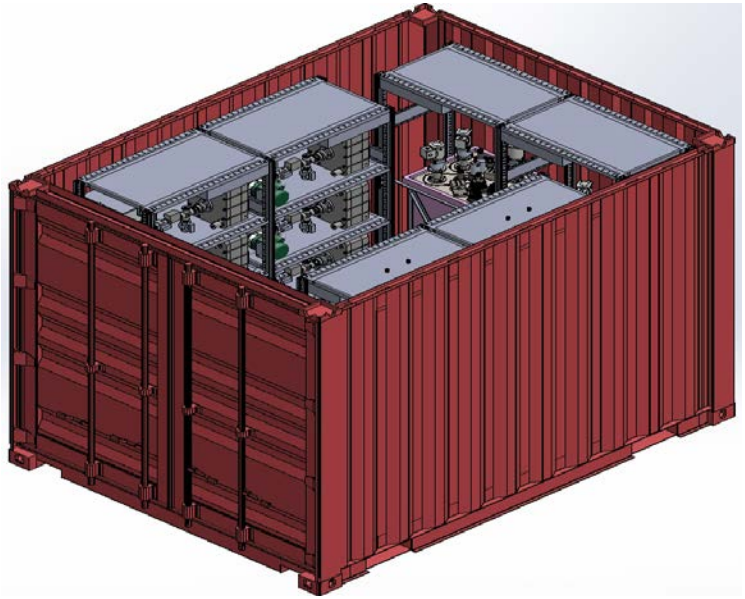
ZS-20

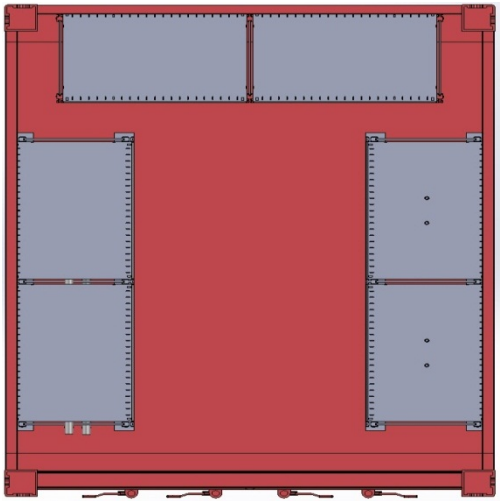


ZS-200

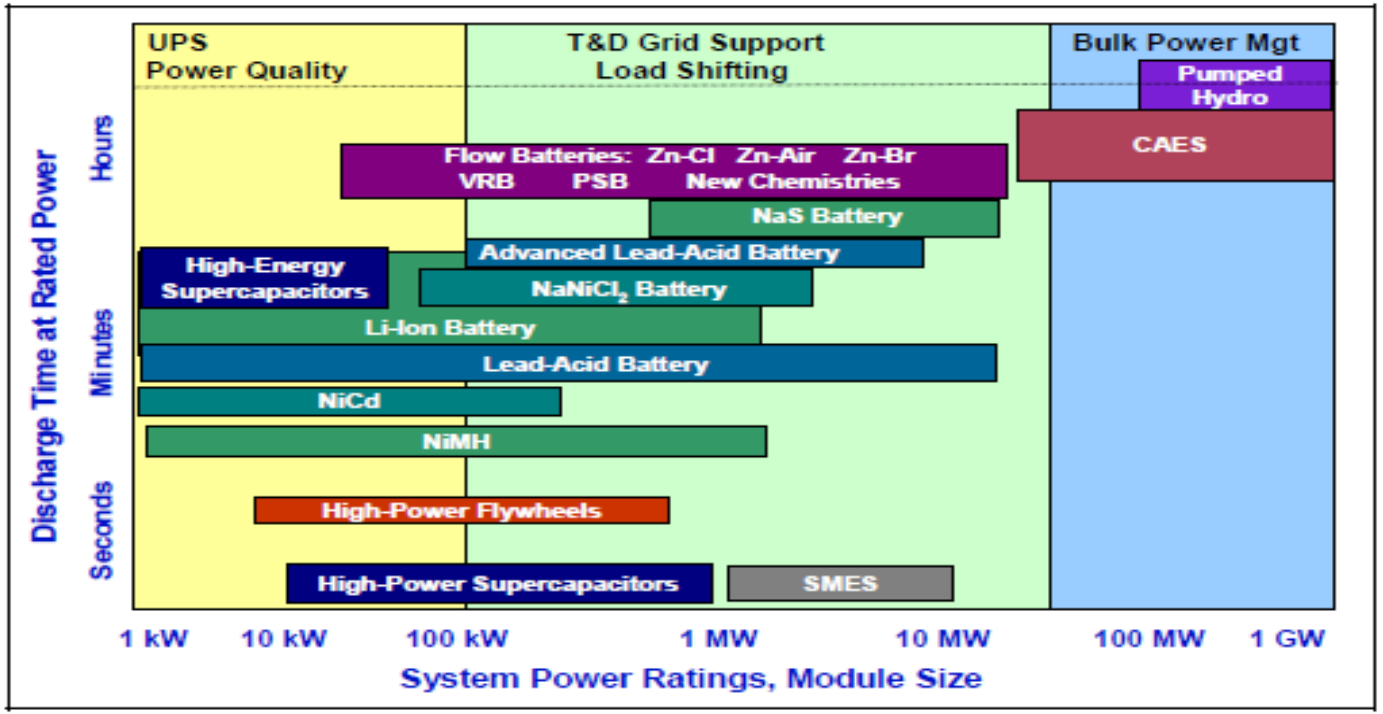


Container Installation





Market Position

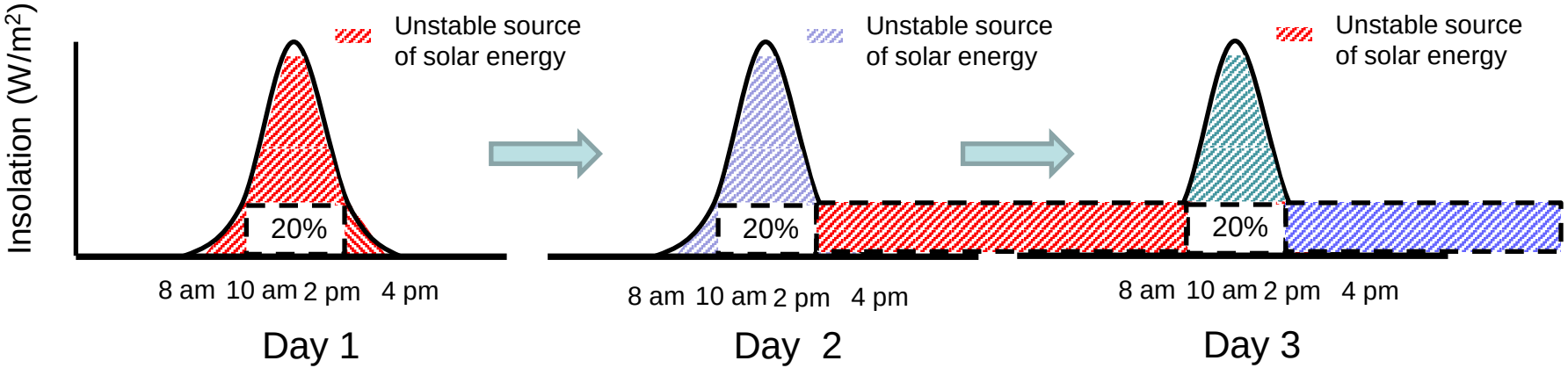


Source: EPRI

Synergistic Applications

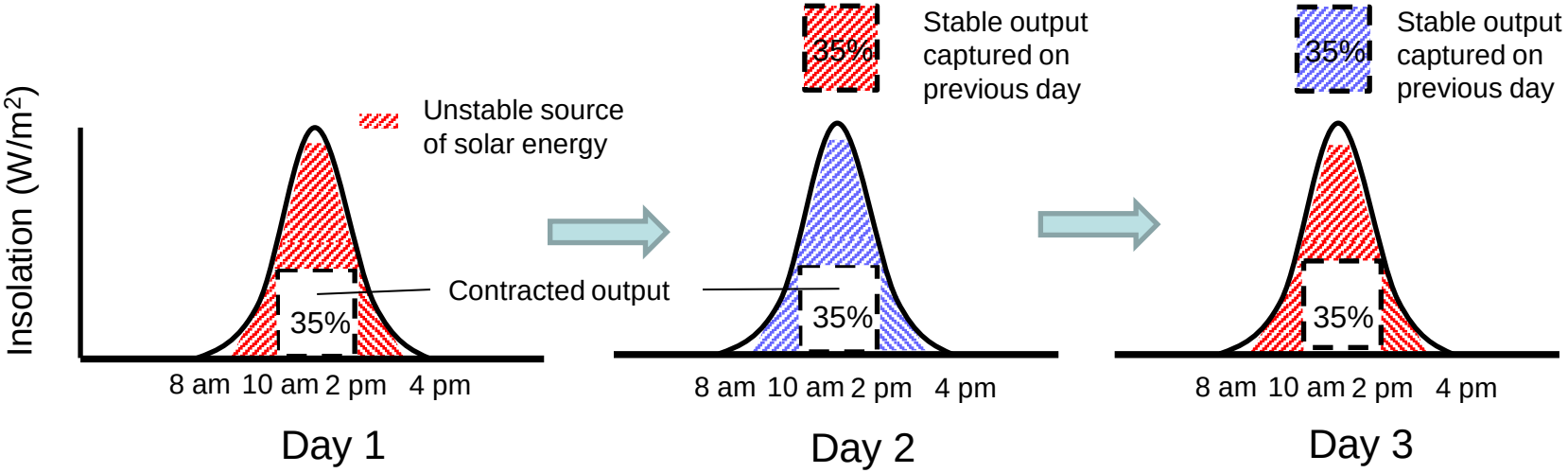
- Long duration backup (e.g. cellular backup)
- Renewables firming (wind, solar, tidal)
- Retail store overnight support (50 kW * 12 hours)
- Portable generation (containerized storage and PV)
- Motive power (rail or marine)

Flow Battery Applications



- **Supporting a constant load from an intermittent source**

Flow Battery Applications



- **Firming solar energy to double contractual output**

Market Entry Partners

Market	Demonstration & Marketing Partners
Telecom	Teck Resources Limited GenSys GmbH MSF Data Services
Commercial & Industrial	Teck Resources Limited Tri-State Generation & Transmission Association Aztera LLC
Regulatory / Approvals	Powertech Labs Sandia National Labs CSA, UL
Academia	AzRISE UBC

ZincNyx Research Partners

Institution	Collaborators	Projects	Funding Sources
UBC	Dr. Elöd Gyenge Department of Chemical & Biological Engineering - Professor Dr. Curtis Berlinguette Department of Chemical & Biological Engineering – Associate Professor, Canada Research Chair	• Non-noble Catalyst Development • Advanced Composite Gas Diffusion Electrode Development	- NSERC Engage, Engage+ - Mitacs Accelerate Cluster
Simon Fraser University	Dr. Byron Gates Department of Chemistry - Associate Professor, Canada Research Chair Dr. Michael Eikerling Department of Chemistry – Professor Dr. Majid Bahrami Department of Mechatronic Systems Engineering - Associate Professor, Canada Research Chair	• Catalytic Surface Development • Electrochemical Systems Modeling • System Component Failure Mode Analysis	- NSERC Engage, Engage+ - Mitacs Accelerate Cluster
UBC Okanagan	Dr. Lukas Bichler Department of Applied Science - Associate Professor	• Electrode Alloy Development	- NSERC Engage
Queen's University	Dr. Diane Beauchemin Department of Chemistry – Professor	• Integrated ICP-OES Particle Analysis	- NSERC Engage
Arizona	Prof. Barrett G. Potter Jr. Department of Materials Science & Engineering	• Material surface structure analysis	

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Thank You for Attending