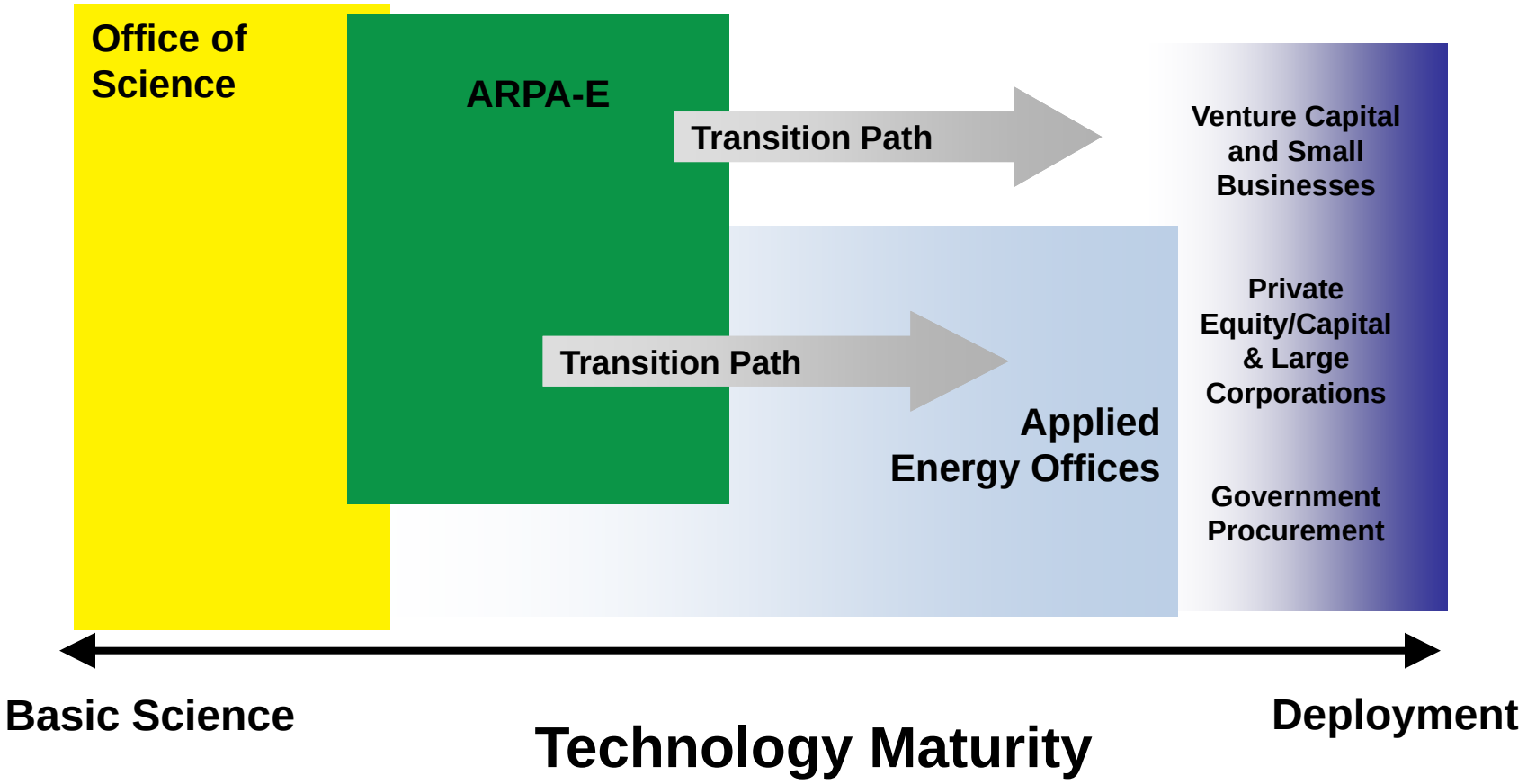
Overview of Gridscale Rampable Intermittent Dispatchable Storage (GRIDS) Program

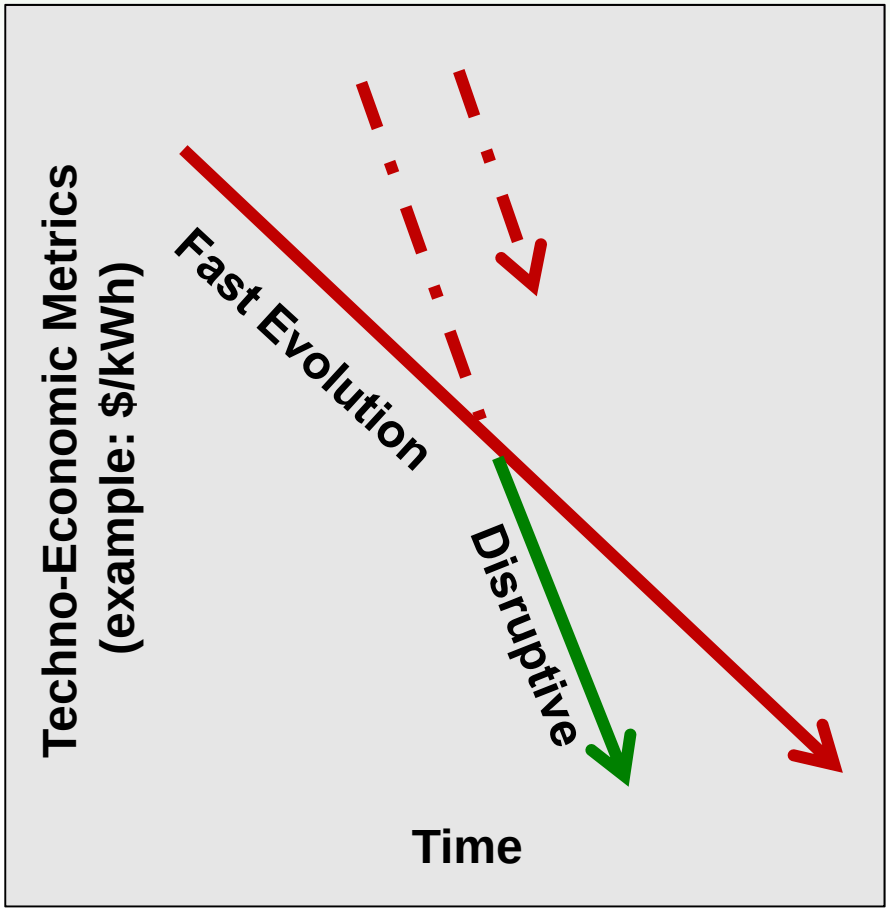
Mark Johnson, Program Director
Advanced Research Projects Agency – Energy

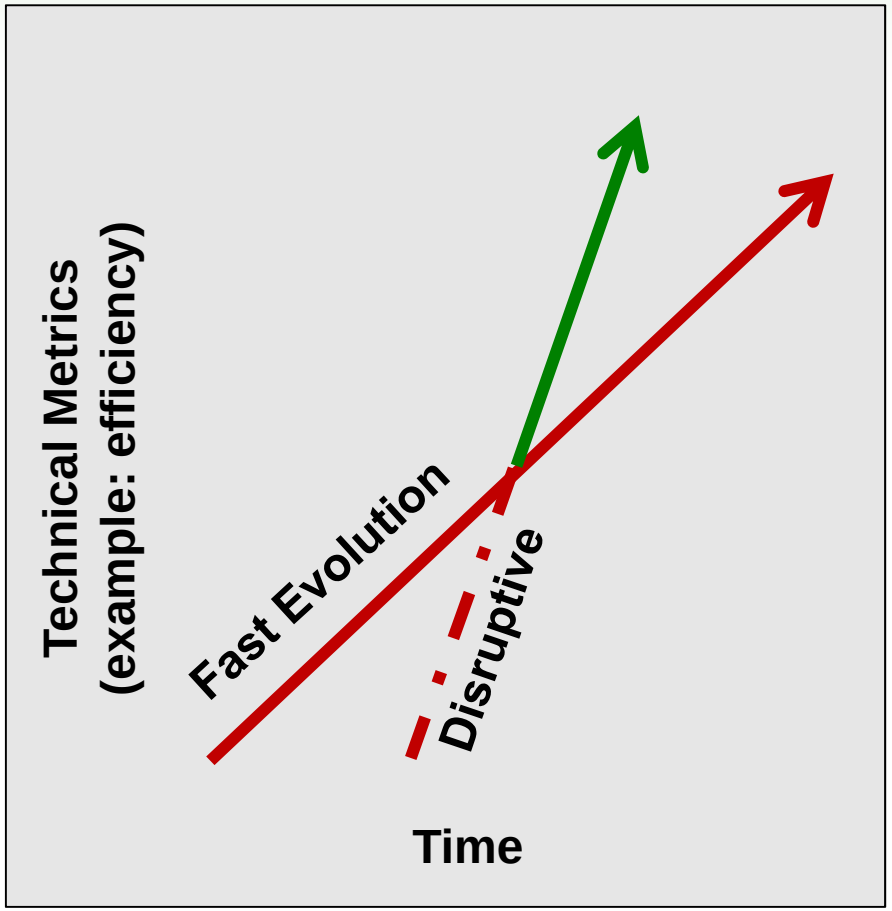
March 7, 2012

Energy Innovation Pipeline



Evolutionary and Transformational Technologies for Use Inspired, Application Driven Research





Disruptive Technologies Not Only Result in Quantitative Advances – They are Fundamentally New Technology Learning Curves

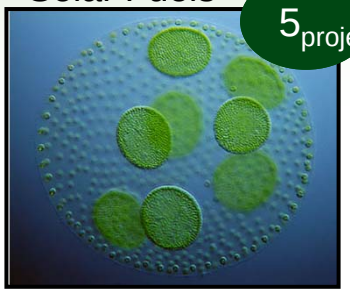
FOA-1 Projects Span 10 Areas

Energy Storage — 6 projects

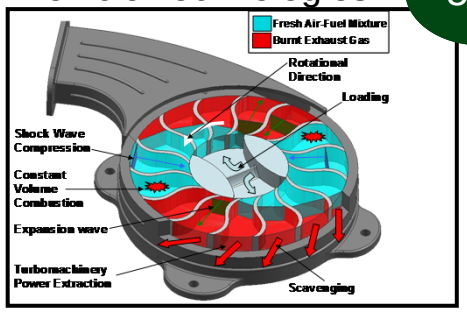
Biomass Energy — 5 projects

Carbon Capture — 5 projects

Solar Fuels — 5 projects



Vehicle Technologies — 5 projects



Renewable Power — 4 projects

Building Efficiency — 3 projects

Waste Heat Capture — 2 projects

Conventional Energy — 1 project

Water — 1 project

What makes an ARPA-E project?

1. Impact

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

2. Transform

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

3. Bridge

- Between basic science and applied technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

4. Team

- Best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

What is the Problem to be Solved?

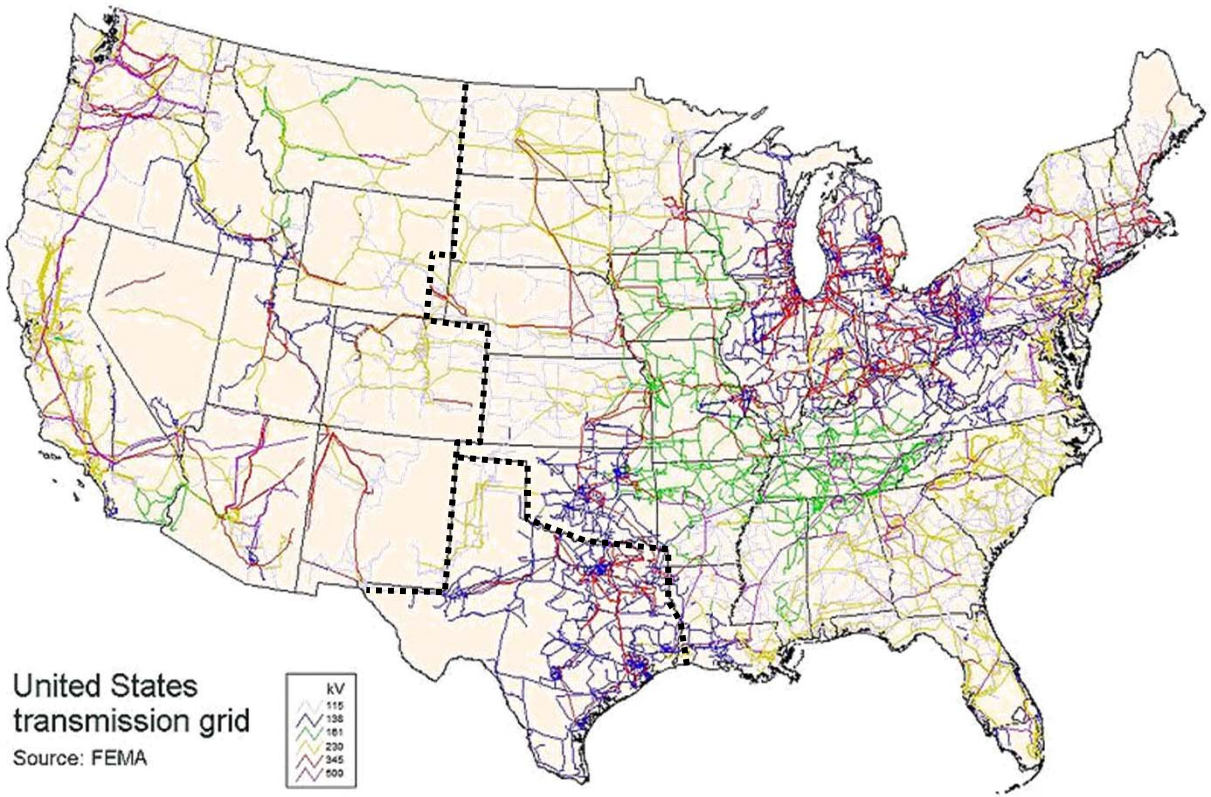
Flow Technologies

US Power Grid: World Largest Supply Chain With No Warehouse

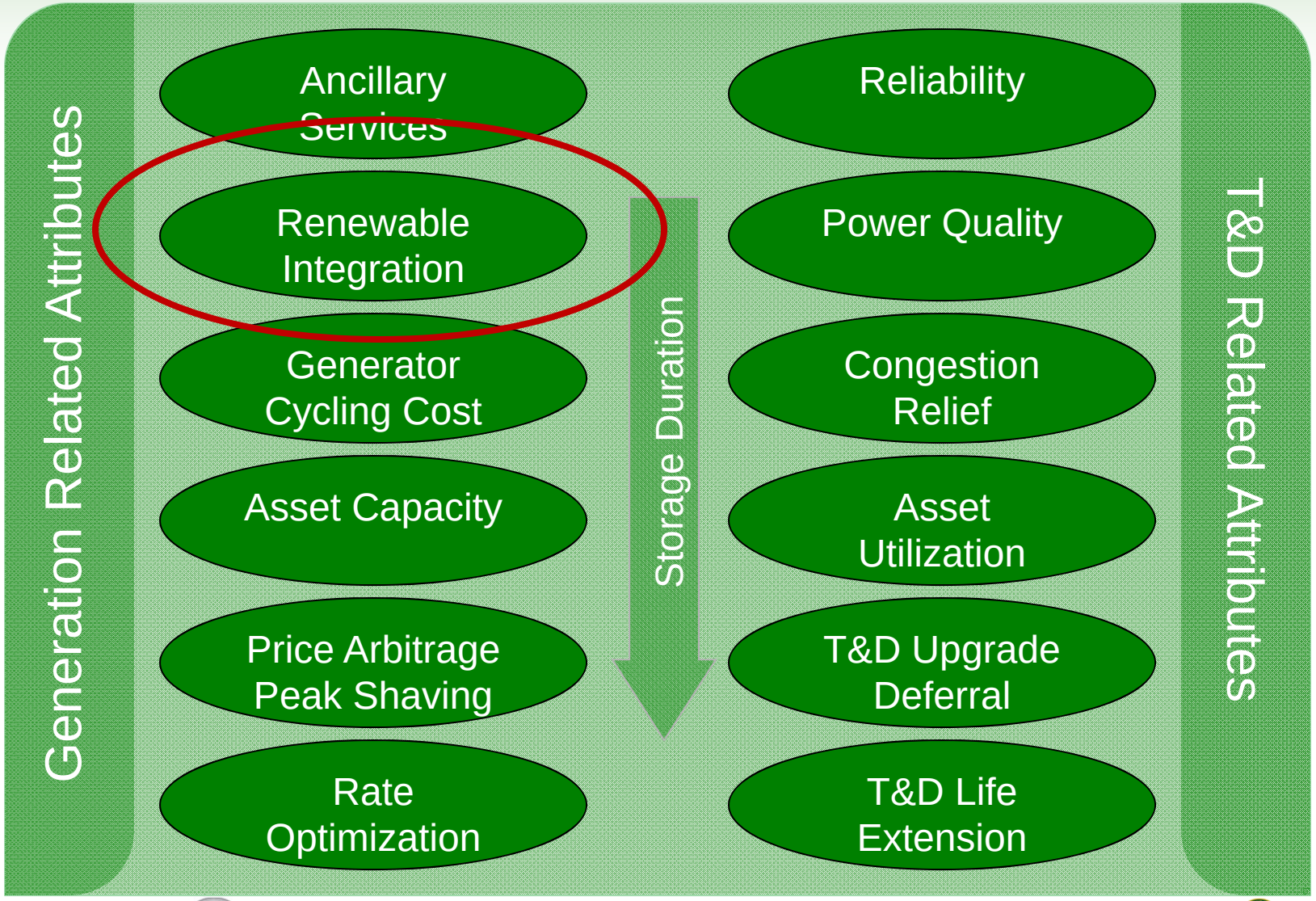
Electric Grid: Premier Achievement of 20th Century [NAE]

Harness Renewable Power: #1 Grid Challenge for 21st Century

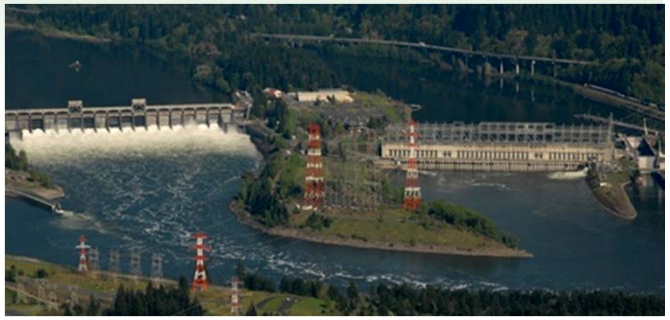
Storage Separates Electric Generation and Load in Space and Time

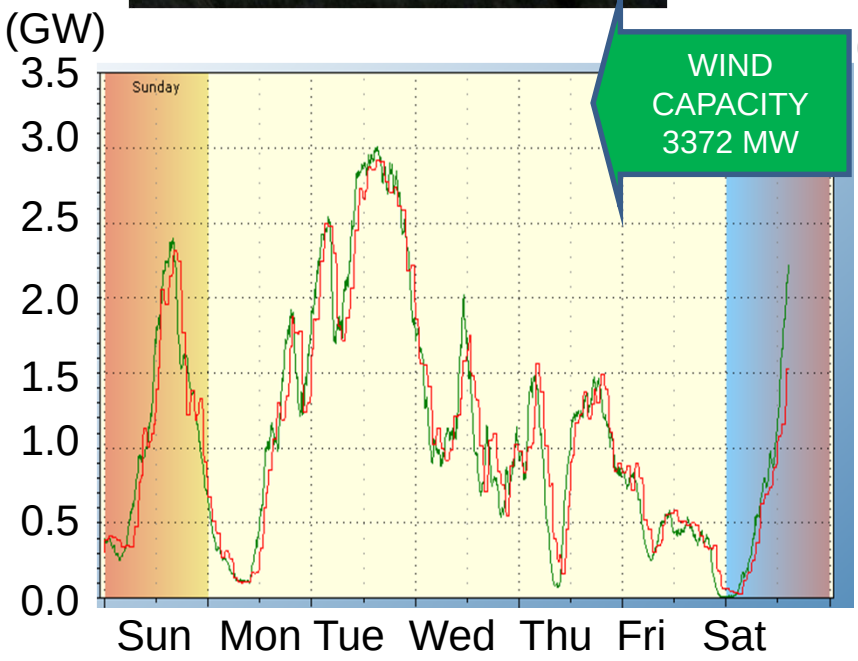


Electric Energy Storage Applications

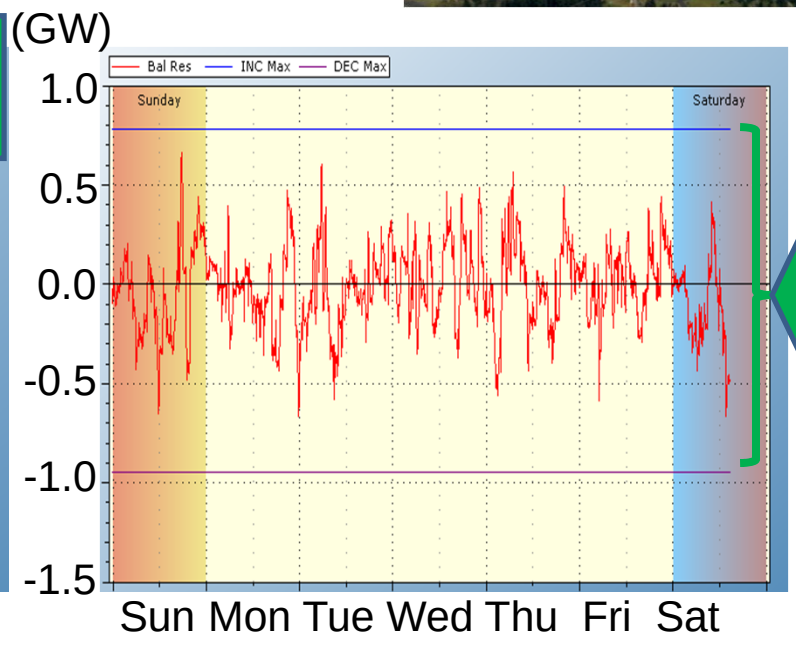


Balancing Reserves Firm Wind Generation for High Renewable Penetration on Power Grid





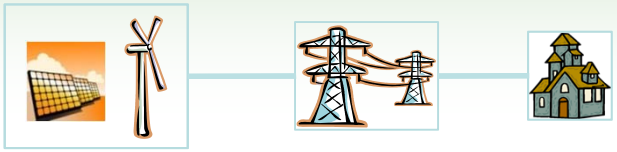
WIND CAPACITY 3372 MW



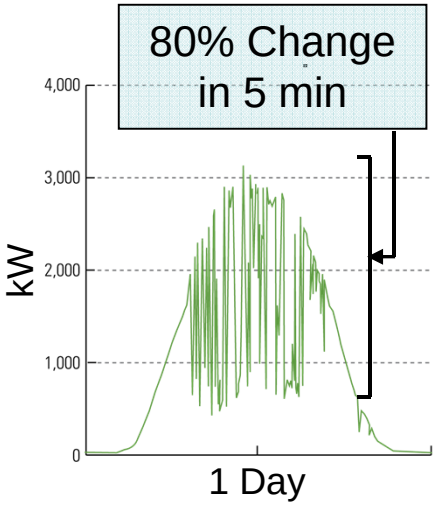
HYDROPOWER RANGE 1600-2000MW

System Challenge: Efficient Energy Storage at Minutes to Hours Duration to Firm Ramping Balance

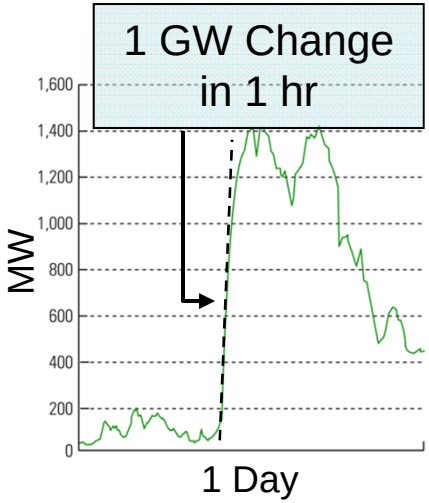
Storage For Firming Renewables



Solar PV in AZ (TEP)



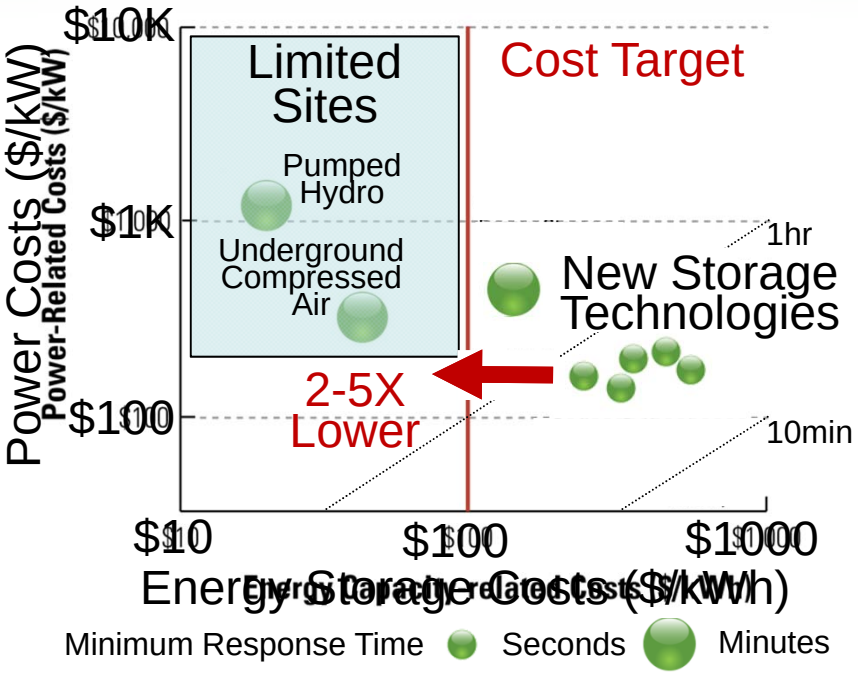
Wind in OR (BPA)



Problem:
Minutes-to-Hours Changes in Power

Need: Grid Storage that is Dispatchable and Rampable
ARPA-E: Energy Storage to Enable High Penetration of Renewables

Grid-scale Rampable Intermittent Dispatachable Storage (GRIDS) Metrics



Greater than 5000 cycles and 80% RTE

Economics of Hydro / Deploy Anywhere

Technology Agnostic:
Chemical, Mechanical, Electromagnetic

Connect Across Industry for Handoffs

Focus: Transformational approaches to energy storage to enable low cost

New Technology Need: Cost-Effective Energy Storage Solutions

Portfolio of Projects

UNIVERSITY/ LAB

USC University of Southern California

Rechargeable Fe-Air Battery

Berkeley Lab

Advanced Flow Battery

CUNY The City University of New York

Rechargable $Zn\text{-}MnO_2$ Battery

SMALL BUSINESS

PRIMUS POWER Smart Grid Storage

New Flow Battery Electrode

FLUIDIC ENERGY

High Power Metal-air Storage

Proton Energy Systems

Neutral Water Fuel Cell

Beacon POWER

Long Duration Flywheel

GENERAL COMPRESSION expanding clean power

Fuel-Free Isothermal Compression

CORPORATION

United Technologies Research Center

Advanced Flow Battery

General Atomics and Affiliated Companies

Soluble Lead Flow Battery

ABB

2G-HTS SMES

BOEING

High-Energy Flywheel

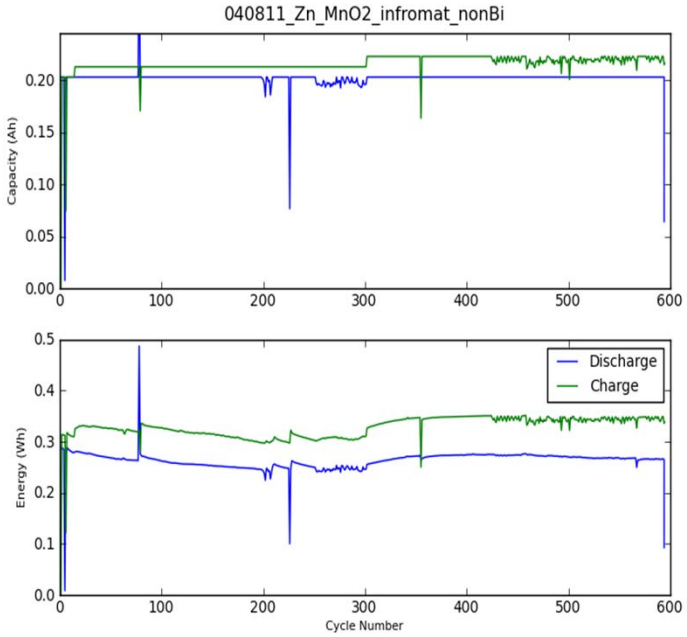
What is the Problem to be Solved?

Flow Technologies

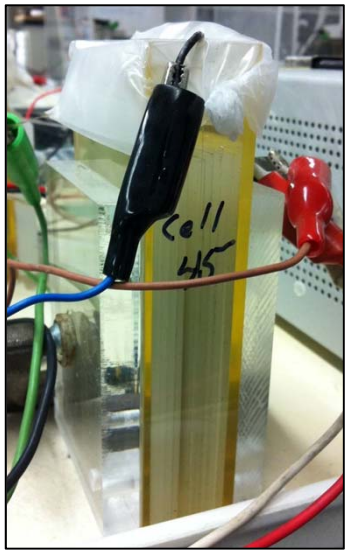
Flow Assisted Rechargeable Zn-MnO_2 Battery

CUNY ENERGY INSTITUTE

- non-toxic
- extremely inexpensive
- water compatible
- $1200/MT



Now



Several formulations of MnO_2 material cycled in 1.5 Ah **Zn-MnO_2** batteries have **reached >500 cycles** demonstrating the cycleability of MnO_2 under the correct conditions

Transformative Electrochemical Flow Storage System

United Technologies Research Center

Clipper

Pratt & Whitney
A United Technologies Company

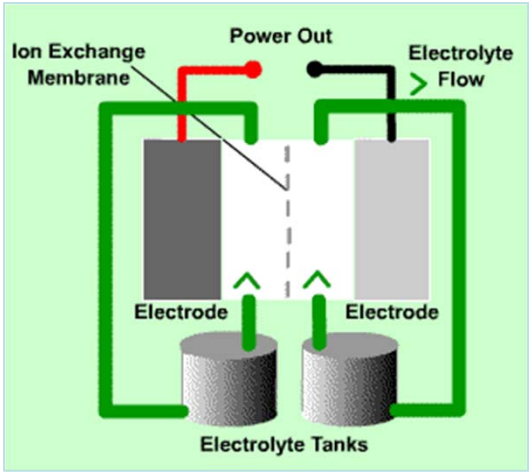
Pratt & Whitney Rocketdyne, Inc.

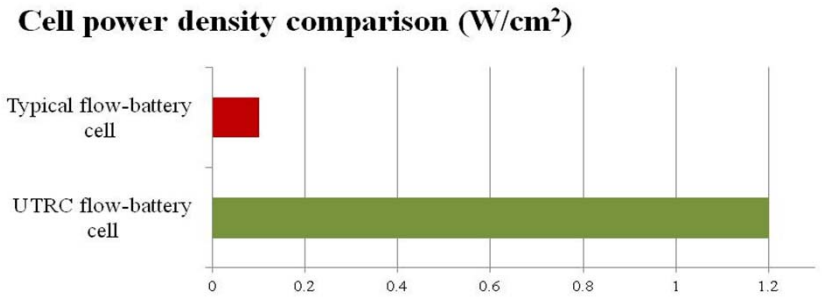
A unique flow battery cell that provides 10X increase in power density

Novel cell will reduce system cost by 2-4X

Initially Vanadium redox chemistry

Jump-starts domestic effort in redox flow batteries, which had migrated out of North America





Rechargeable Iron-Air Battery

Cell Reaction:

$Fe + H_2O + ½\ O_2 \Leftrightarrow Fe(OH)_2$

Anode: (discharge)

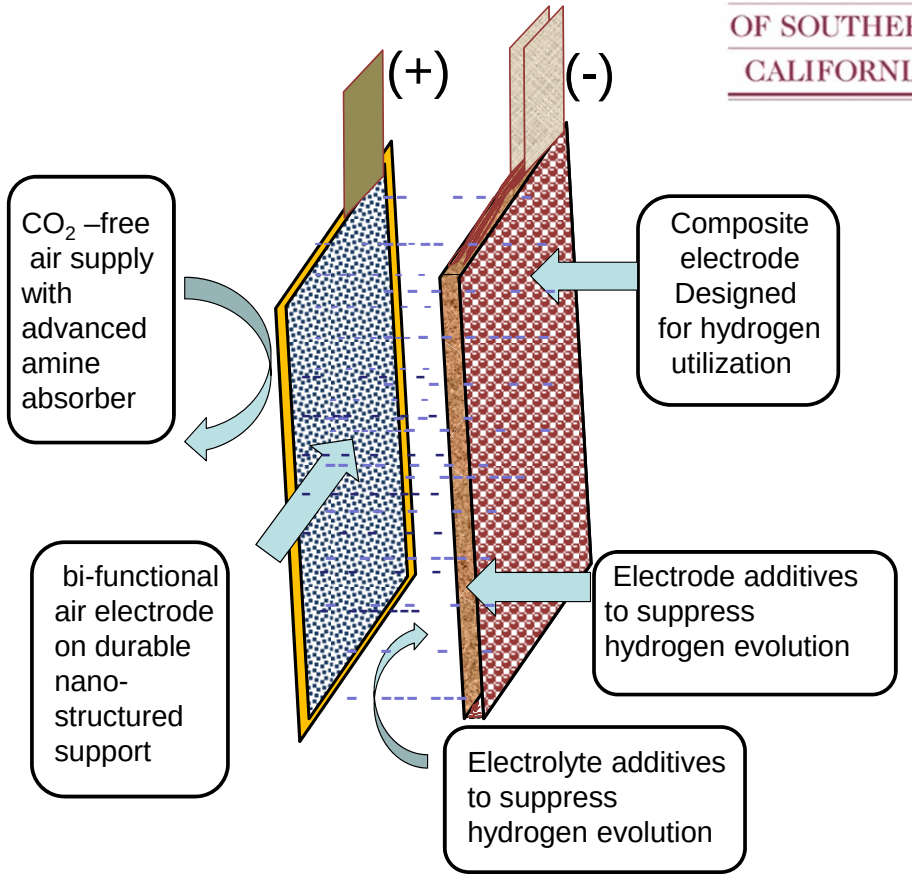
$Fe + 2OH^- \Rightarrow Fe(OH)_2 + 2e^-$

Cathode: (discharge)

$½\ O_2 + H_2O + 2e^- \Rightarrow 2OH^-$

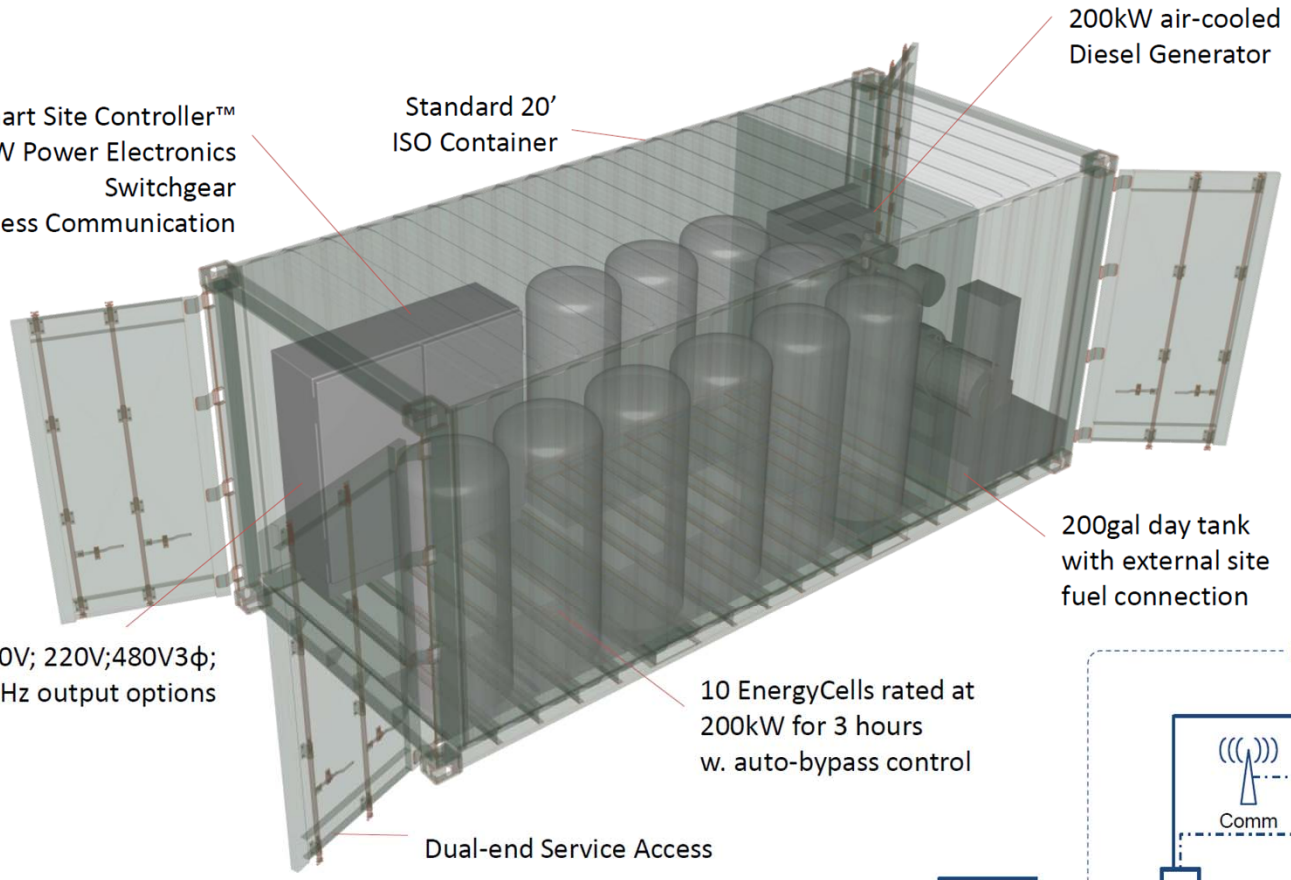
< $100/kWh & >5000 cycles high power, low cost, electrochemical storage

"Iron is Cheap, Air is Free"



400kW PowerPod™ System Concept

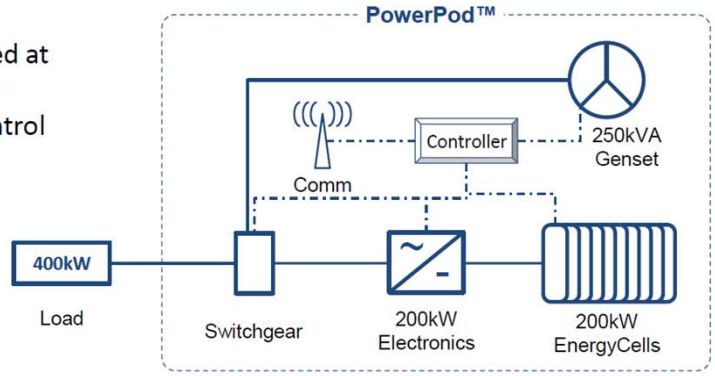
PRIMUS POWER
Smart Grid Storage



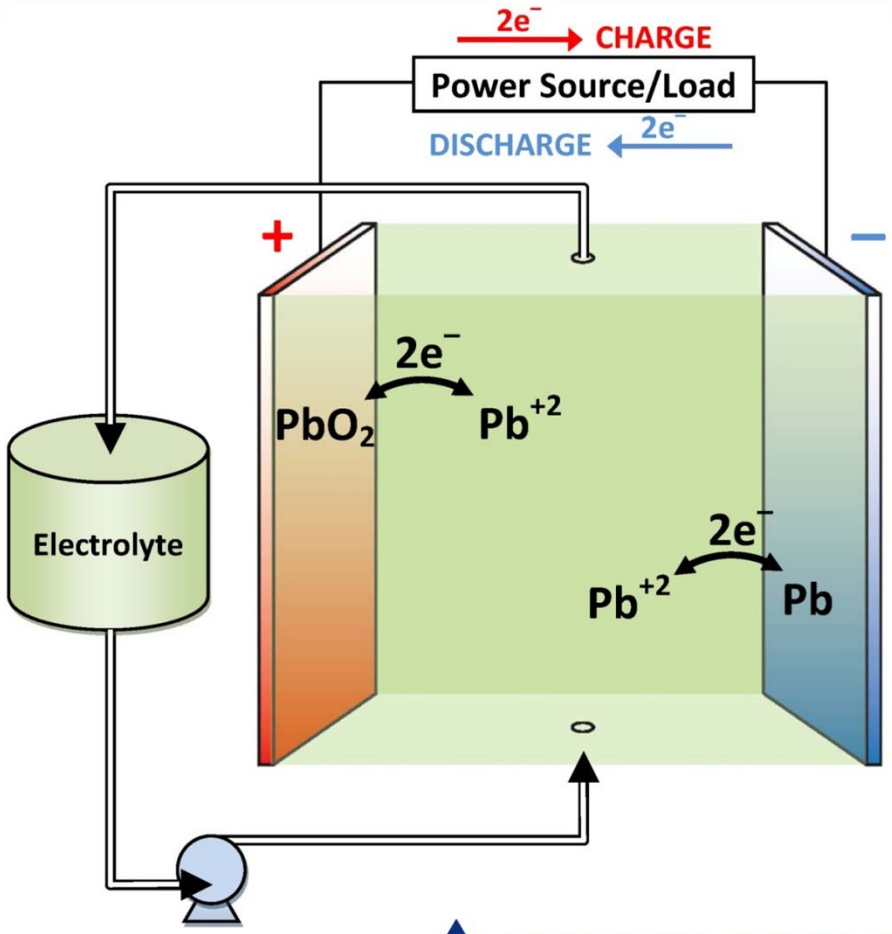
Standard 28"ϕ steel ASME, NFPA58 conforming tank

ARPA-E Project
Electrode for
>20 Year Lifetime

Unlike Today's
Technology
~2 Years



Grid Scalable Lead Acid Battery



Innovations

- MSA-based electrolyte
- Carbon-based electrodes
- Flow-battery design

Impact

- Cost Reduction
- Grid Scalable
- Cycle-life Improvement

GENERAL ATOMICS

UCSD Jacobs | Department of NanoEngineering

Fuel Cells to Flow Systems

- Membrane Properties
- Catalysts
- Electrolyte Densities
- Electrode Materials

- By Another Name: Redox Flow Cell
  Metal-Air
  Alkaline Exchange
  Semi-Solid Flow

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Questions?