EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Renewable Energy Integration: Innovation, Commercialization and Transmission

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NASEO

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The Electric Power Research Institute

Objective and Independent Research on

- Renewable, Nuclear and Fossil Generation
- Energy Efficiency and Utilization
- Transmission and Distribution
- Environmental Studies

Over 500 Engineers and Scientists

360 Research Participants from over 40 Countries

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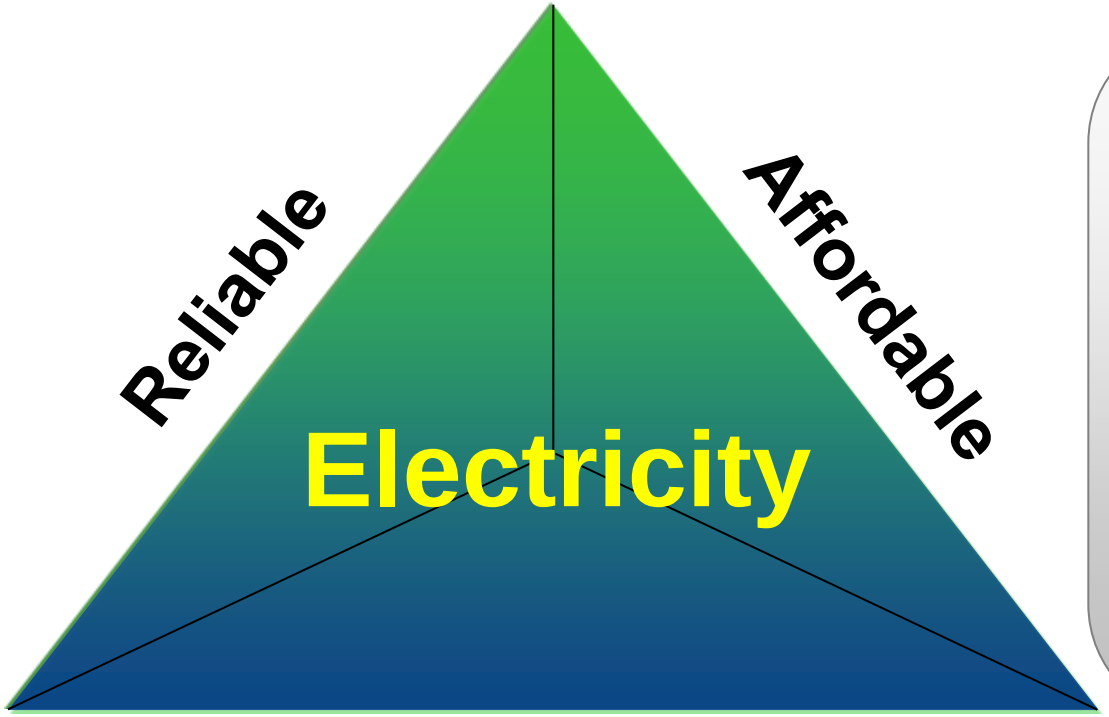
The Challenge

Provide society with

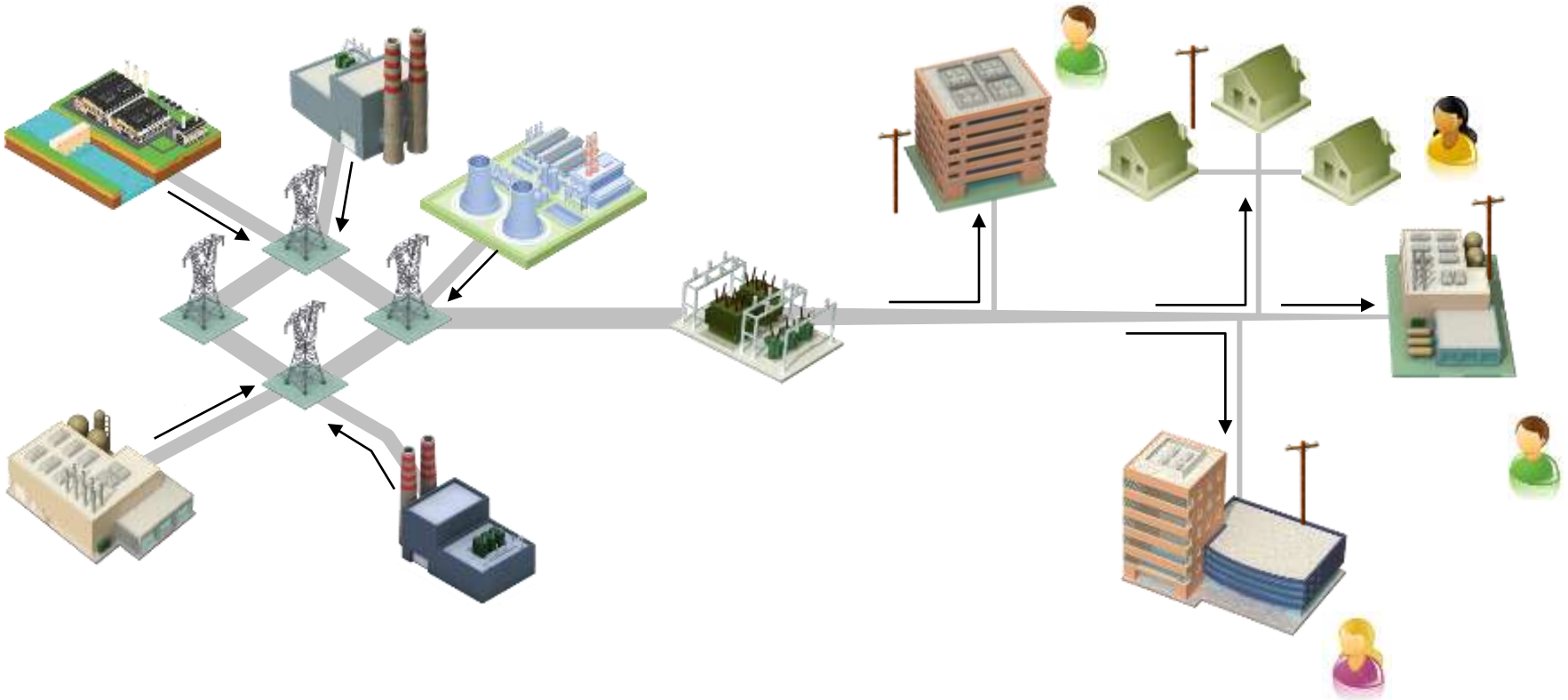


Sustainable

. . . while navigating competing constraints

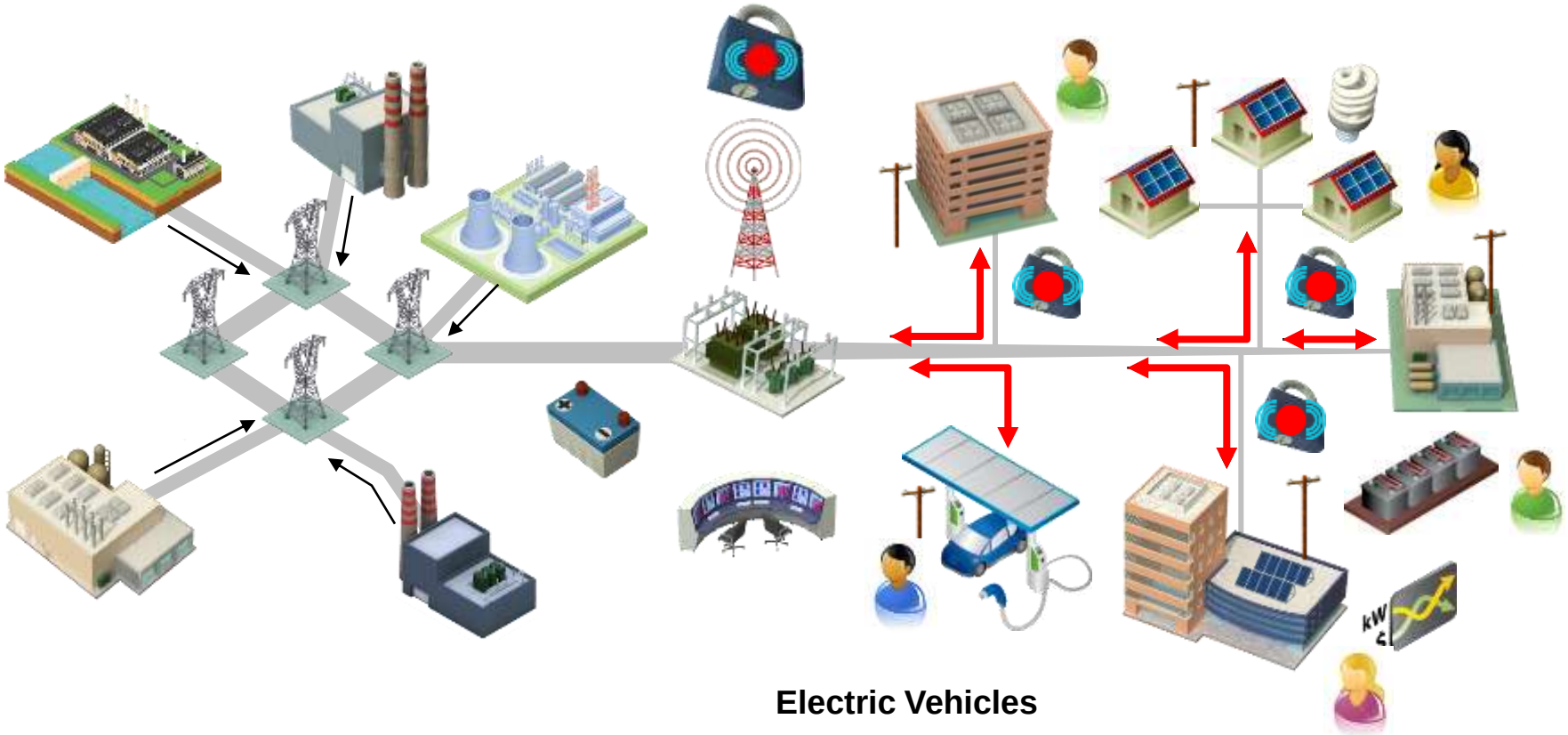
- Fuel Price and Availability
- Water Resources
- Energy and Climate Policy
- Environmental Performance
- Capital Availability
- Customer Expectations
- Demand Growth

The Power System Challenge



. . . while transforming to a cleaner, modernized generation fleet, and an interactive electrical grid.

The Power System Challenge



Electric Vehicles

Demand Response & Efficiency

Distributed Energy Resources

Energy Storage

Sensors, Controls & Cyber Security

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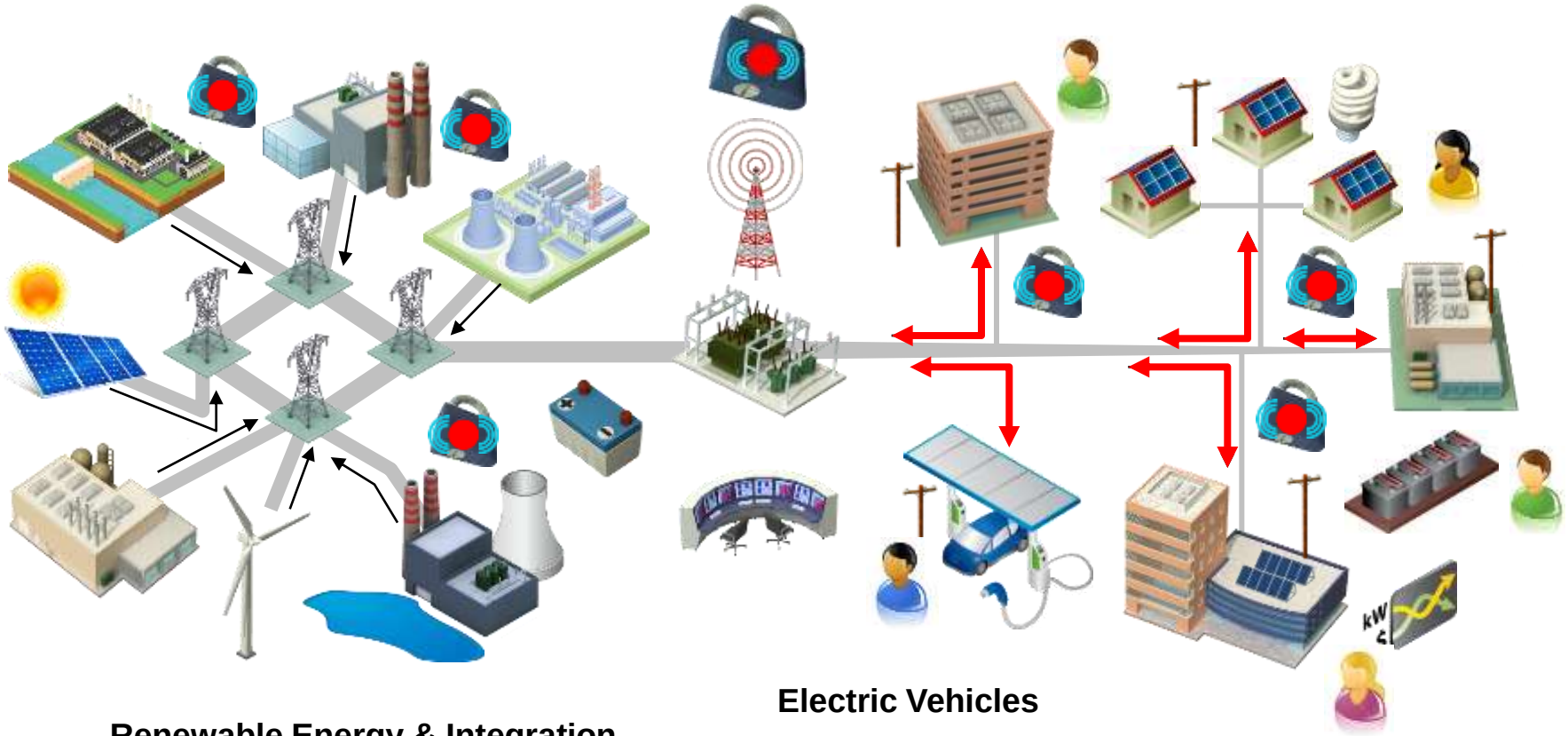
The Power System Challenge



Renewable Energy & Integration

Near-Zero Emissions

Long-Term Operations

Water Management

Electric Vehicles

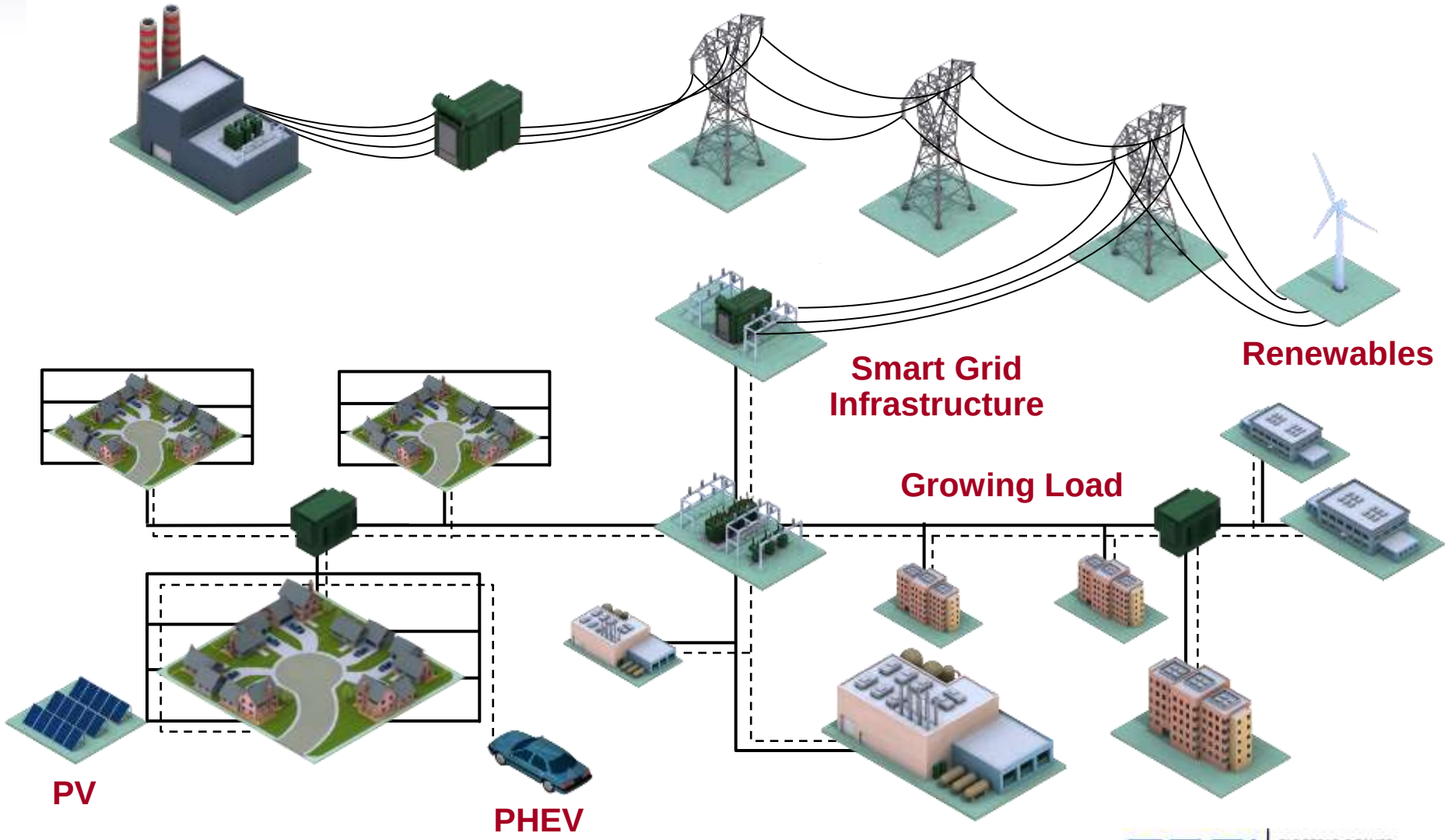
Demand Response & Efficiency

Distributed Energy Resources

Energy Storage

Sensors, Controls & Cyber Security

How the Grid is Changing



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EPRI's Innovation Focus

Smart Grid

Energy Efficiency

Long-Term Operations

Renewable Resources and Integration

Near Zero Emissions

Water Resource Management

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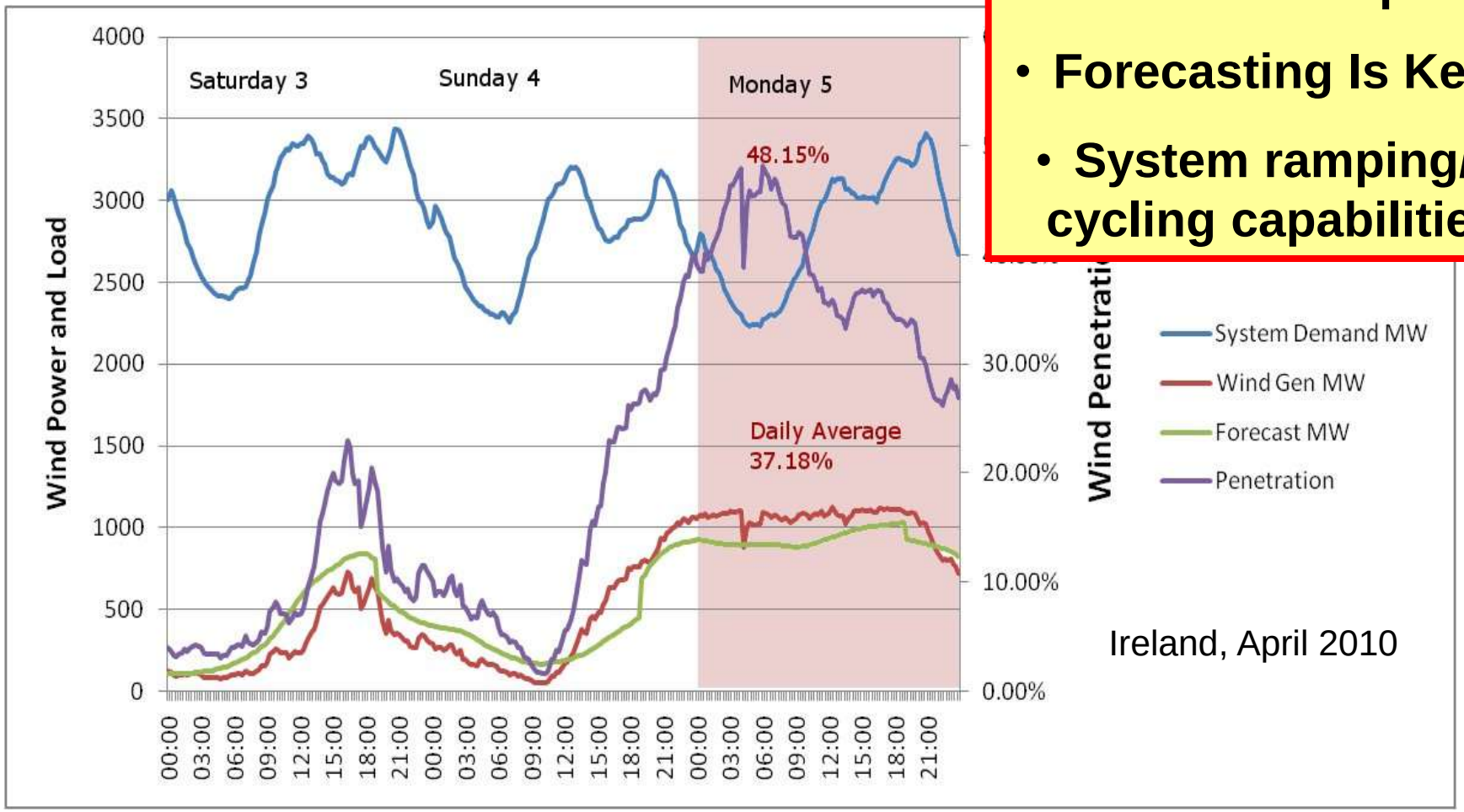
Renewable Energy Overview

- Challenges for integrating wind
  - Variability
  - Stability and Reliability

- How do these impact system?
- What can we do to reduce the impacts?

Wind & PV Variability/Uncertainty Increases the Need for System Flexibility

- **Wind Ramp**
- **Forecasting Is Key**
- **System ramping/ cycling capabilities**

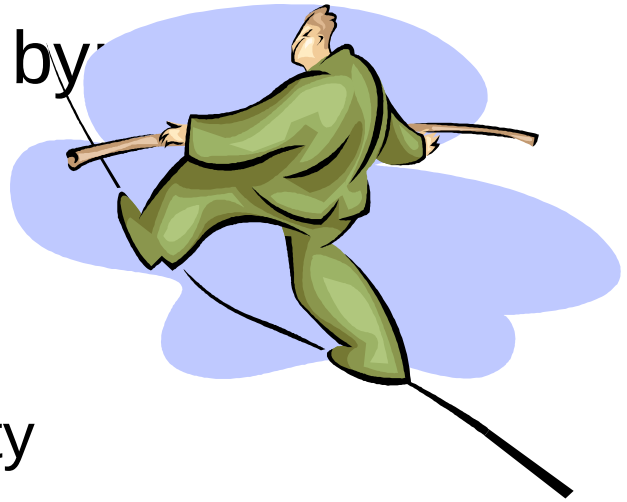


Ireland, April 2010

Source: Constructed from EIRGRID online data (www.eirgrid.com).

Balancing variability and uncertainty

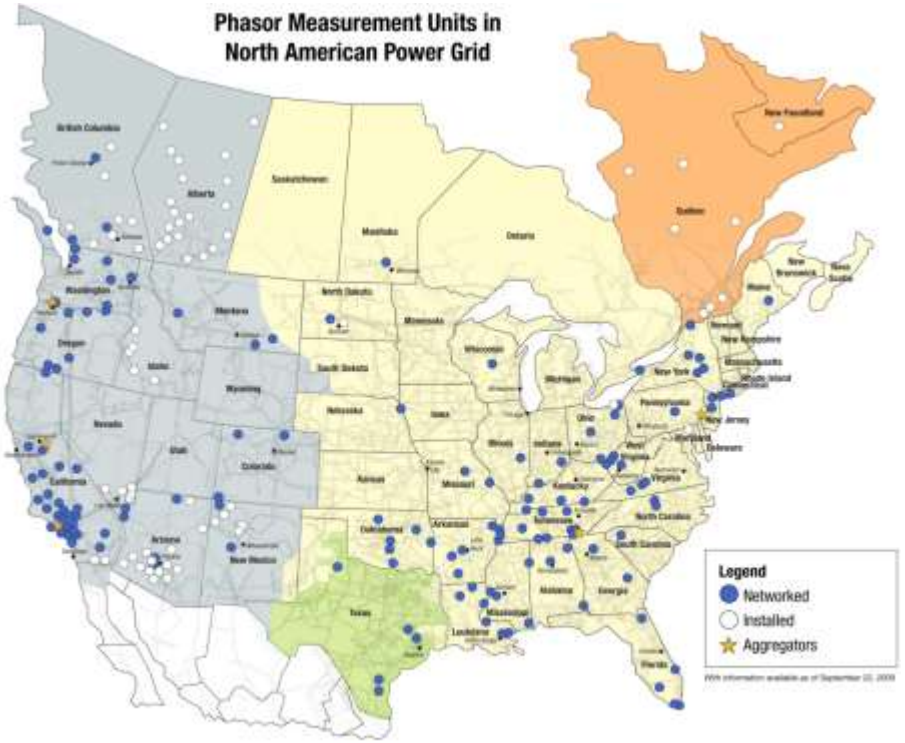
- Integration costs can be reduced by:
  - Better operational methods
  - Increased coordination
  - Standards for interconnection
  - Planning methods to ensure flexibility
  - Flexible resources



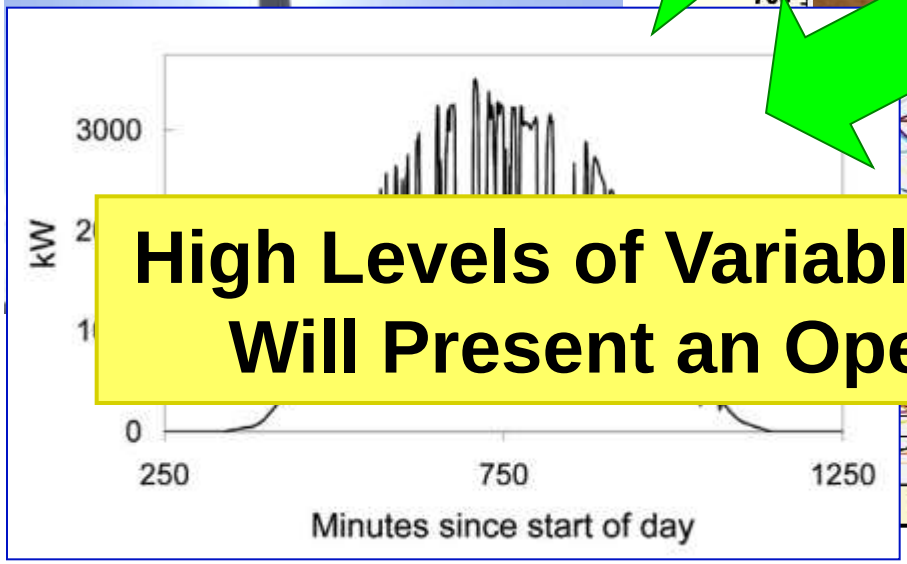
- Flexibility is key to balancing variability
  - Every system starts from a different place
  - No one answer for integration costs / needs

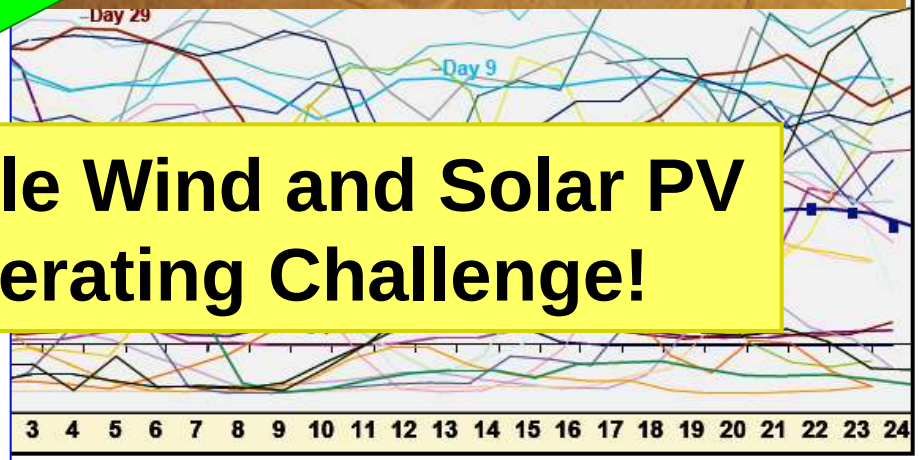
Integration issues

- Other areas relating to stability will also be impacted:
  - Voltage, Reactive power
  - Codes and Standards
- Grid modernization will aid integration
  - Sensors
  - Power Electronics
  - Communication
  - Situational Awareness



The Integration Challenge





High Levels of Variable Wind and Solar PV Will Present an Operating Challenge!

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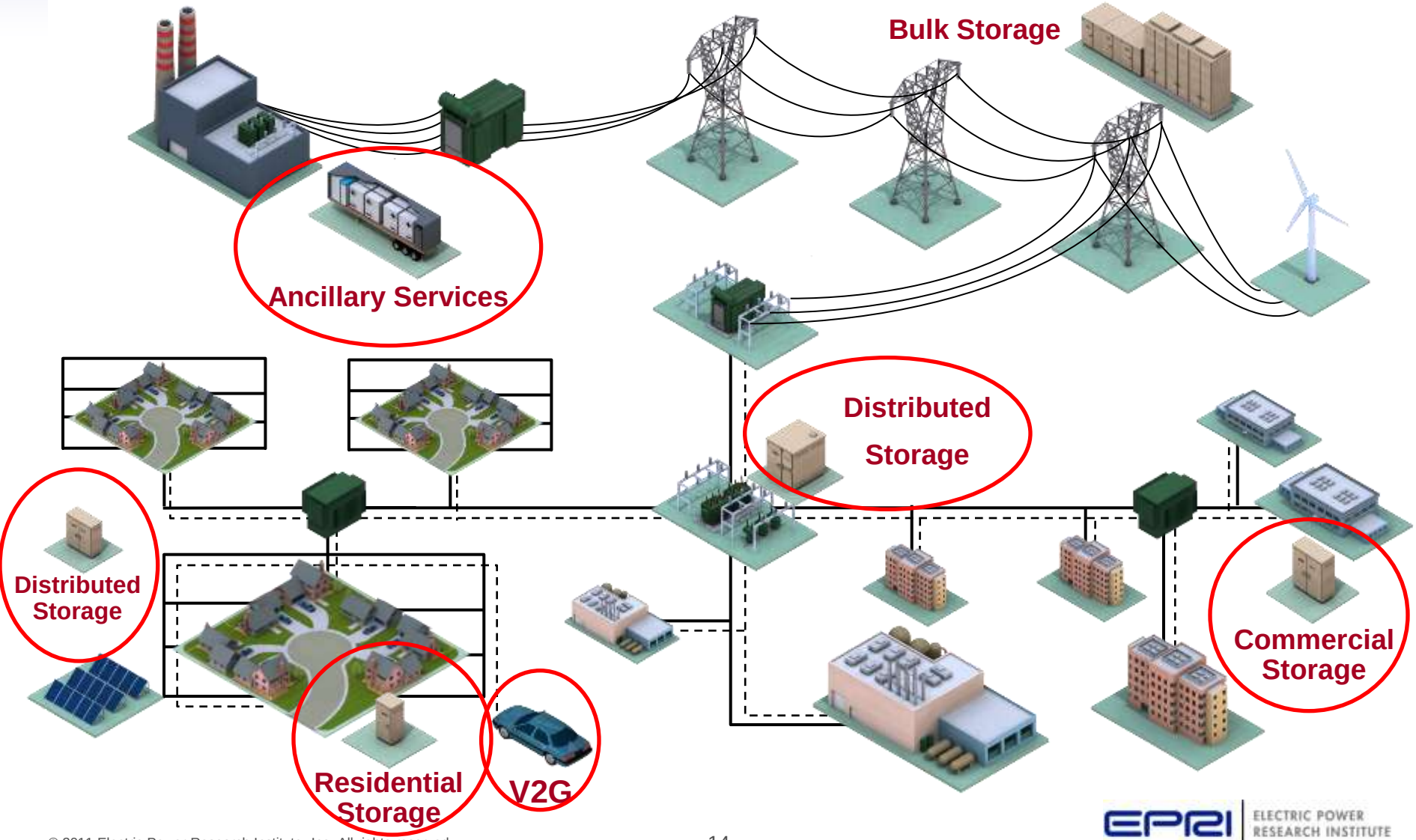
The Role of Batteries on the Grid



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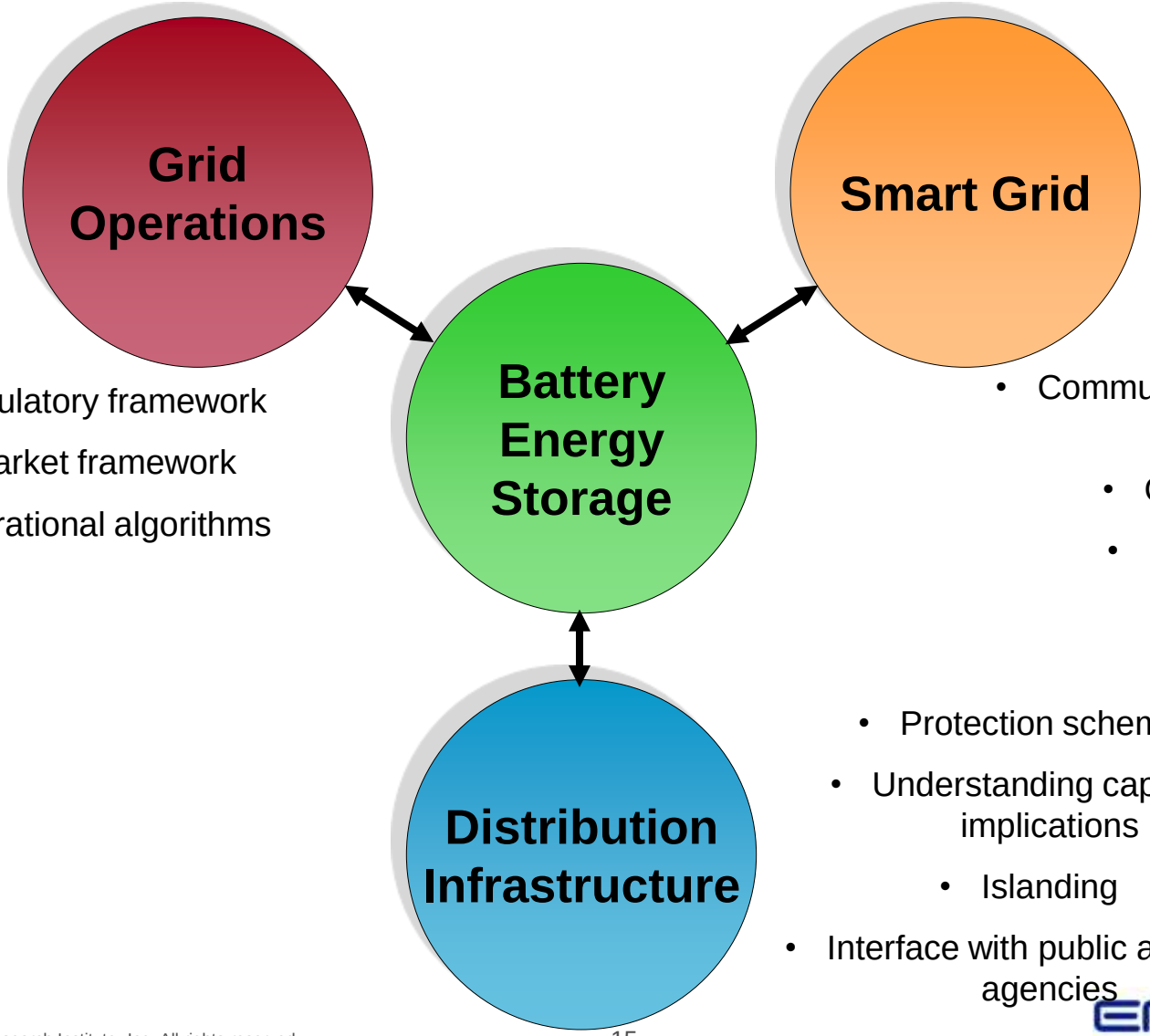
Storage must interface with all aspects of grid



- Regulatory framework
- Market framework
- Operational algorithms

- Communications and control protocols
- Object models
- Cybersecurity

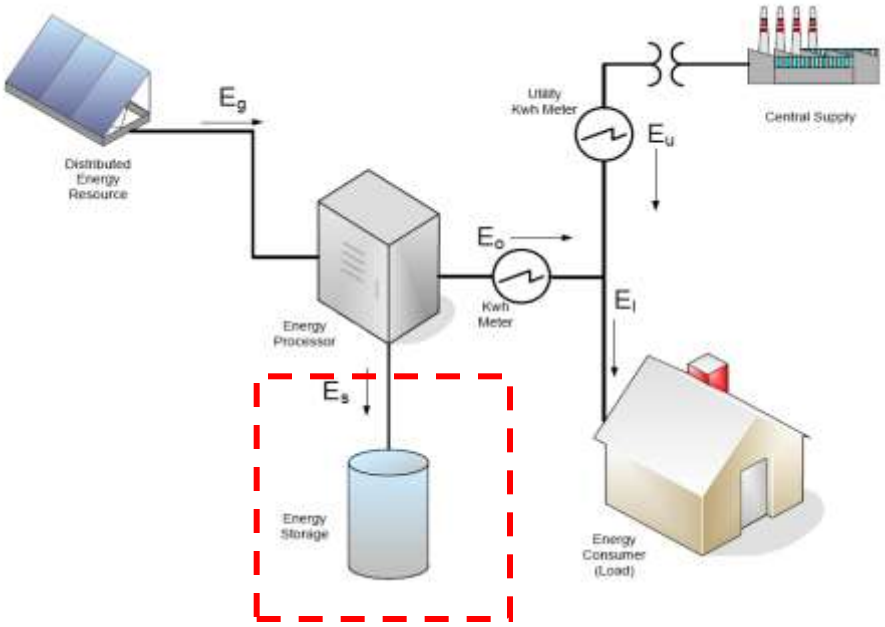
- Protection schemes
- Understanding capacity implications
- Islanding
- Interface with public and local agencies

Transportation Batteries in Stationary Applications

1 Chevy Volt Pack

=

Residential Peak Shaver



Transportation Batteries in Stationary Applications

3 Chevy Volt Packs

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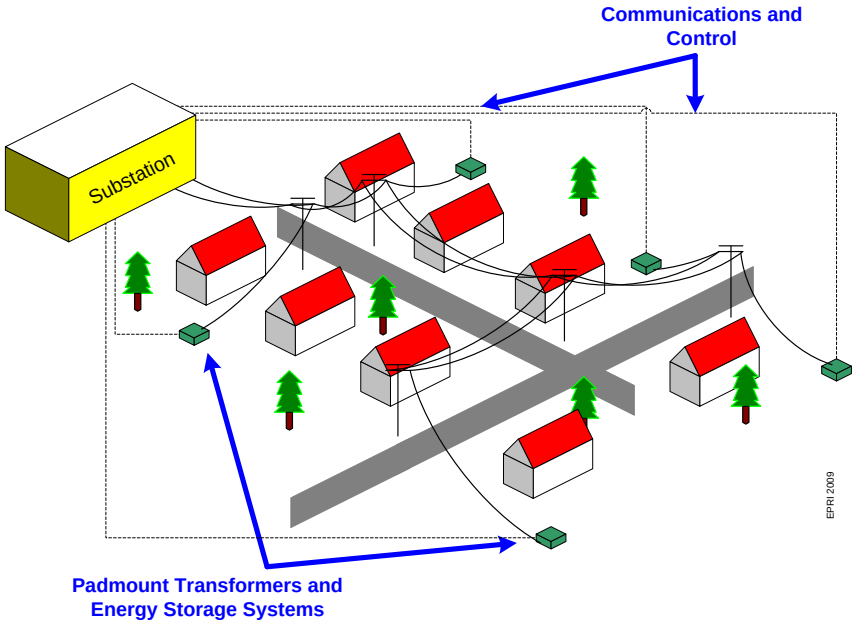
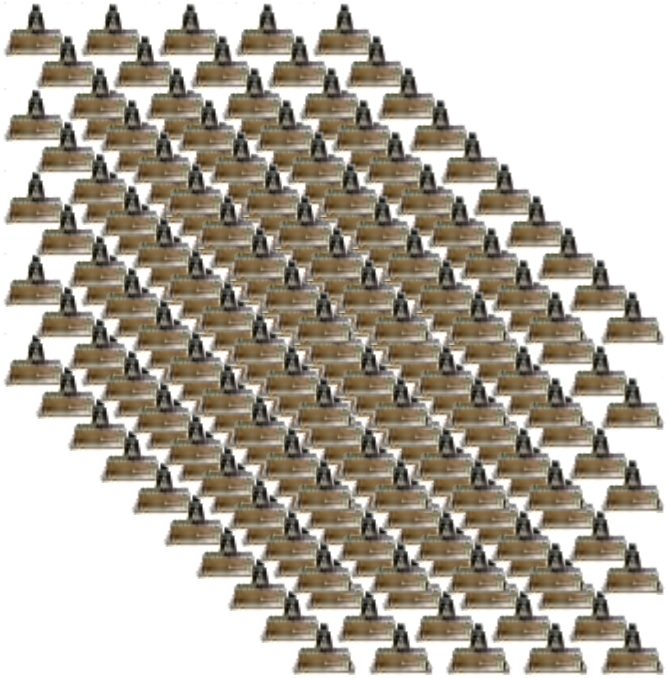
Distributed Energy Storage System



Transportation Batteries in Stationary Applications



250 Chevy Volt Packs

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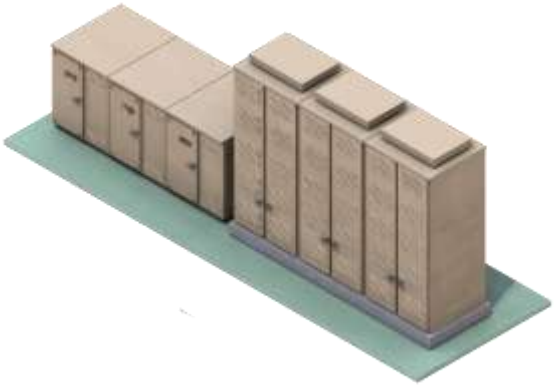

Substation Battery
(1 MW, 4 hours)

Battery Configurations

- Chevrolet Volt battery
  - 288 lithium ion cells
  - Cells made by LG Chem in Korea, packaged by LG Chem power in Michigan
  - 8 year warranty

- Nissan Leaf battery
  - 192 lithium ion cells
  - Cells and battery made by AESC (a joint venture of Nissan and NEC)
  - 8 year warranty

Mainstream EV Commercialization

Chevrolet Volt

- Extended Range Electric Vehicle
  - (EREV - A plug-in hybrid with a guaranteed electric range).
- EV Range of 25 – 50 miles

Nissan Leaf

- Battery Electric Vehicle
- EV range of 80 – 100-miles

Three Ways to Charge a PEV

120V – Level 1

Portable cordset
Use any 120V outlet

DC Fast Charging

Fast, expensive

Standard not yet in place

240V – Level 2

Permanent charge station

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Preliminary Charging Findings

- **Initial findings:**
- High proportion of Level 2 requests
- Significant issues with multi-unit dwellings
- Public infrastructure beginning
- Anticipate increased emphasis on workplace charging

Chevrolet Volt
50-mile roundtrip commute

Level 1 – Home Charging
Level 2 – Workplace

~92% Electricity Utilization

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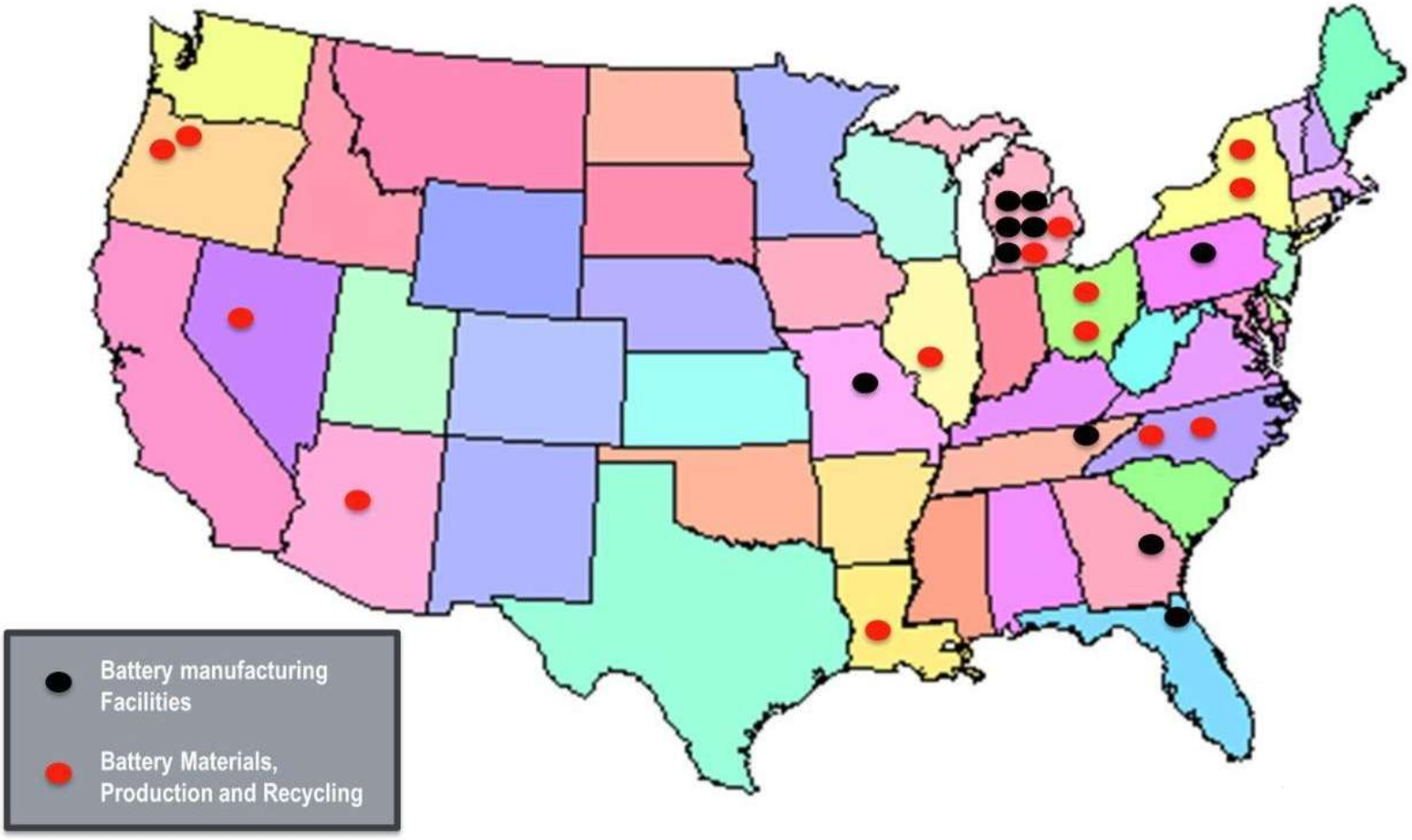
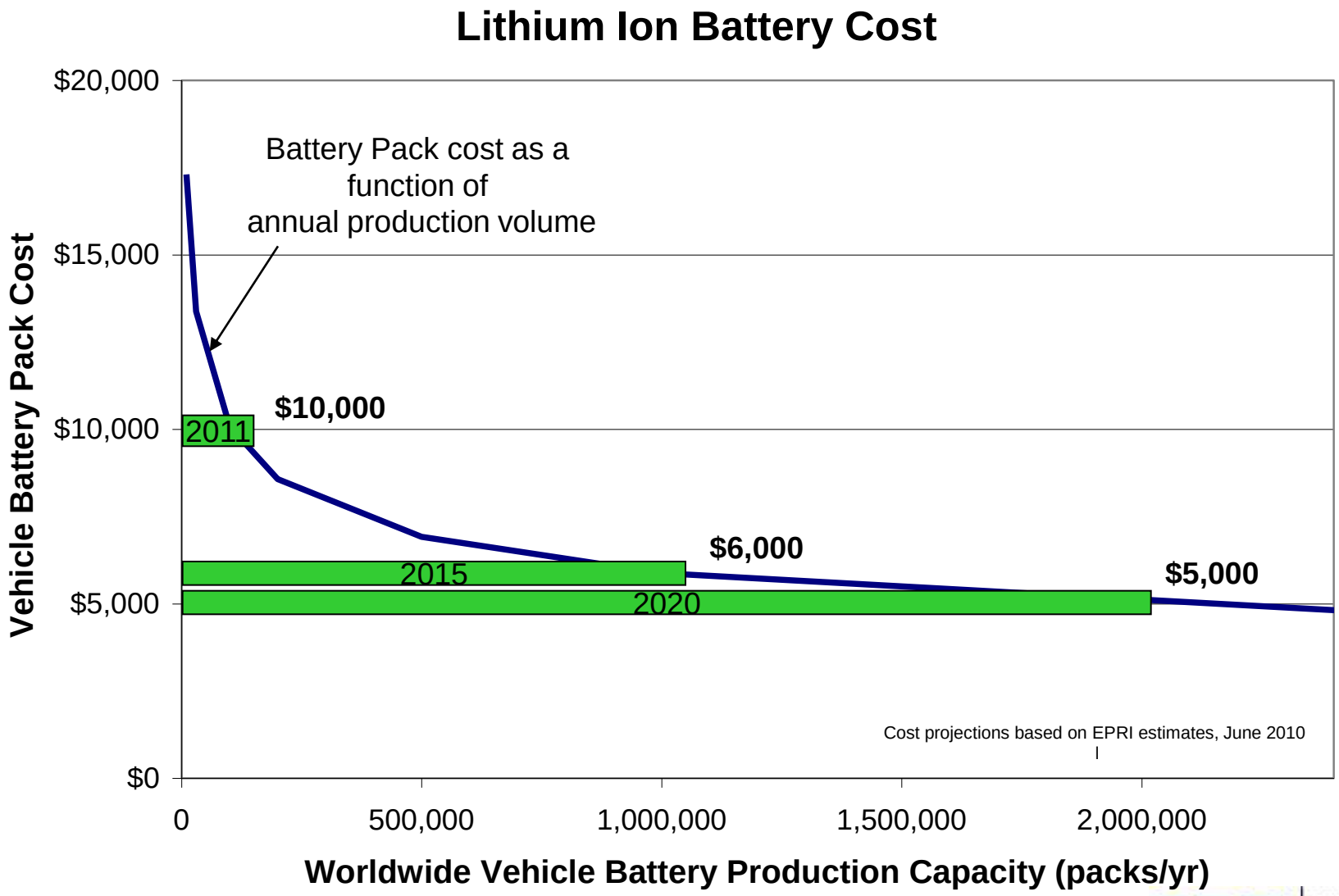
Lithium Battery Manufacturing in U.S.



Source: DOE

Lithium Ion Battery Costs



Technical Innovations – *Energy Storage*

Energy Density (Wh/kg)

2000
400
100
50
0

~2000 Li-Air

Lithium Ion w/ Si Nanowire 400

Lithium Ion 110 – 140

Nickel-Metal Hydride 50 – 75

Nickel-Cadmium 35 – 60

Nickel-Iron 30 – 40

Lead-Acid 25 – 45

1860 1910 1960 2010 2020 2030

Time of First Introduction

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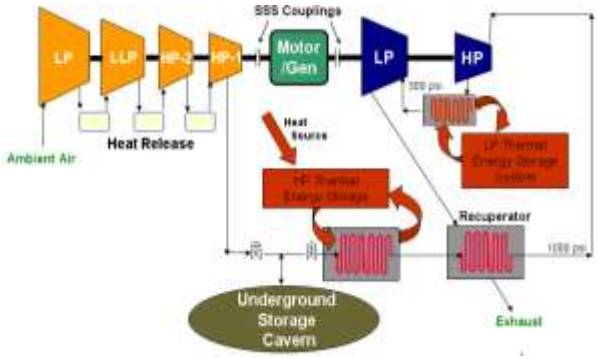
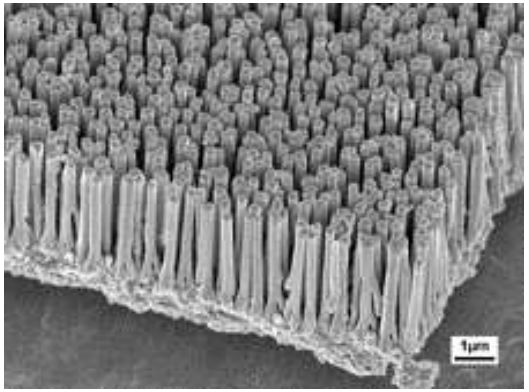
Advanced storage technologies

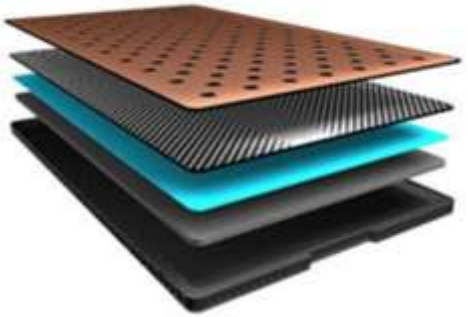


Adiabatic CAES

High Temperature Sodium Batteries

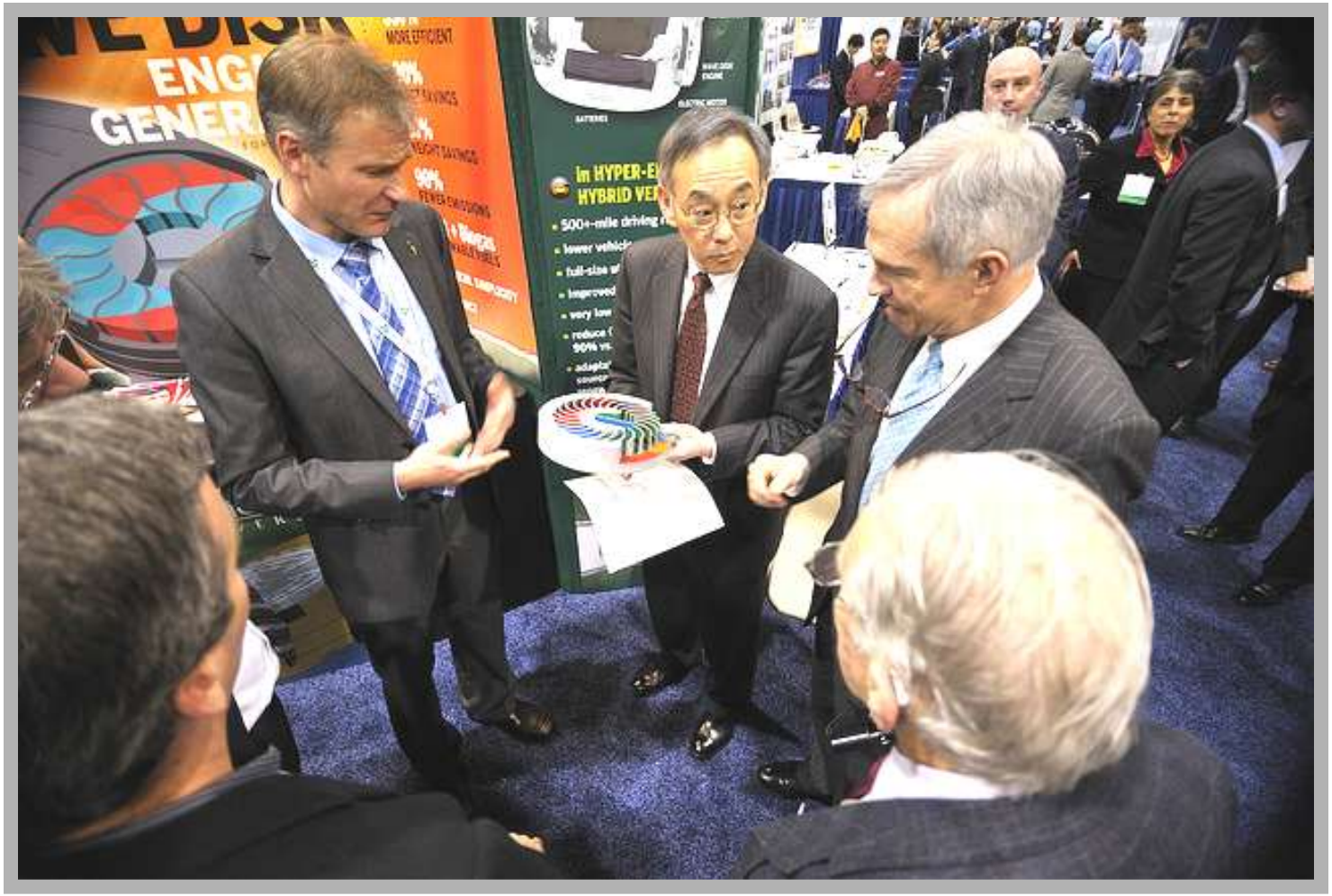


Advanced Lithium Ion



Zinc Air Batteries

ARPA-E Energy Innovation Summit



Together…Shaping the Future of Electricity