GRIDSCALE RAMPABLE INTERMITTENT DISPATCHABLE STORAGE (GRIDS) PROGRAM

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PROGRAM DIRECTOR

DOE Annual Storage R&D Review Meeting
ARPA-E and OE

November 2010

www.arpa-e.energy.gov

Overview of ARPA-E as an Agency

Overview of GRIDS Storage Program

Technical Progress in Energy Storage

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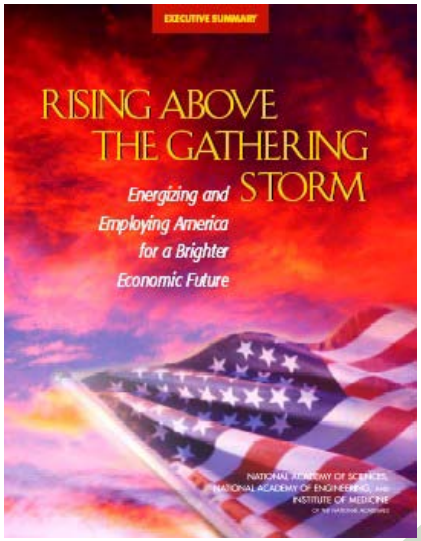
ARPA-E: Applying The ARPA Model To Energy



2006
Rising Above the Gathering Storm
(National Academies)

2007
America COMPETES Act

American Recovery and Reinvestment Act of 2009 (Recovery Act)

$400M appropriated for ARPA-E
President Obama launches ARPA-E in a speech at NAS on April 27, 2009

ARPA-E's Distinct Culture

- Excellence
- Openness
- Integrity
- Speed
- Metrics Driven
- Flat and Nimble

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Fulfilling ARPA-E's Mission

- **Find and fund high-risk, high-impact projects**
- **Identify and promote revolutionary advances in fundamental sciences**
- **Accelerate transformational technologies or create new technologies where none currently exist**
- **Translate scientific discoveries and cutting-edge inventions into technological innovations**
- **Bridge gaps in the energy innovation pipeline**

Revolutionary Technologies Developed By DARPA over the Years

The Internet

GPS

Stealth Technology

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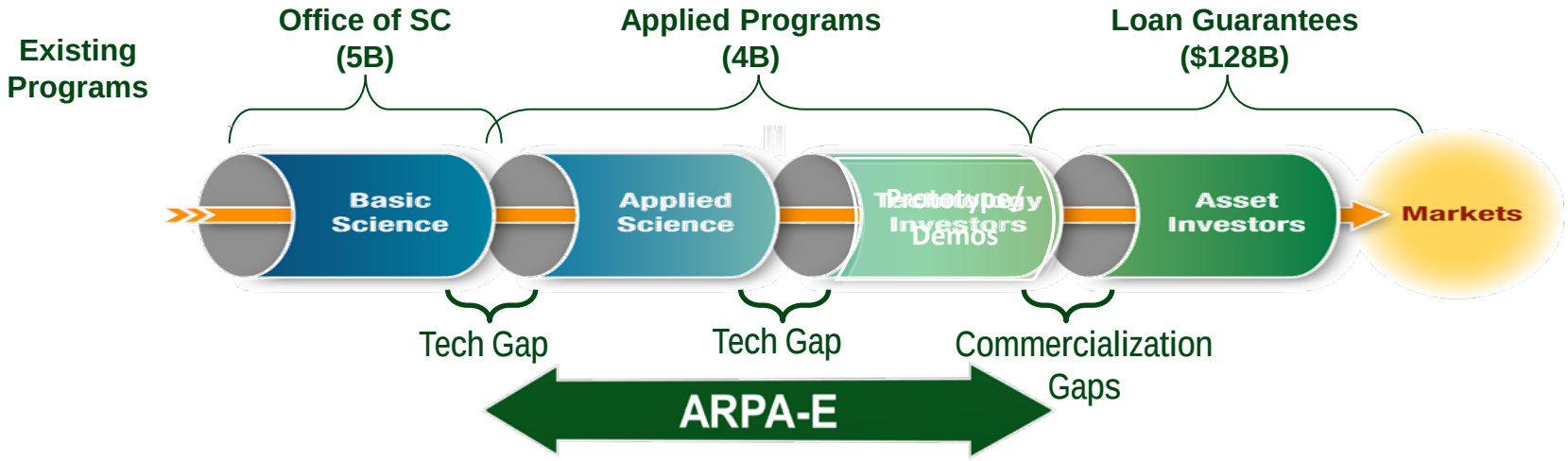
ARPA-E to bridge gaps in the energy innovation pipeline



what ARPA-E will do

- Seek high impact science and engineering projects
- Invest in the best ideas & teams
- Will tolerate and manage high technical risk
- Accelerate translation from science to markets
- Proof of concept and prototyping

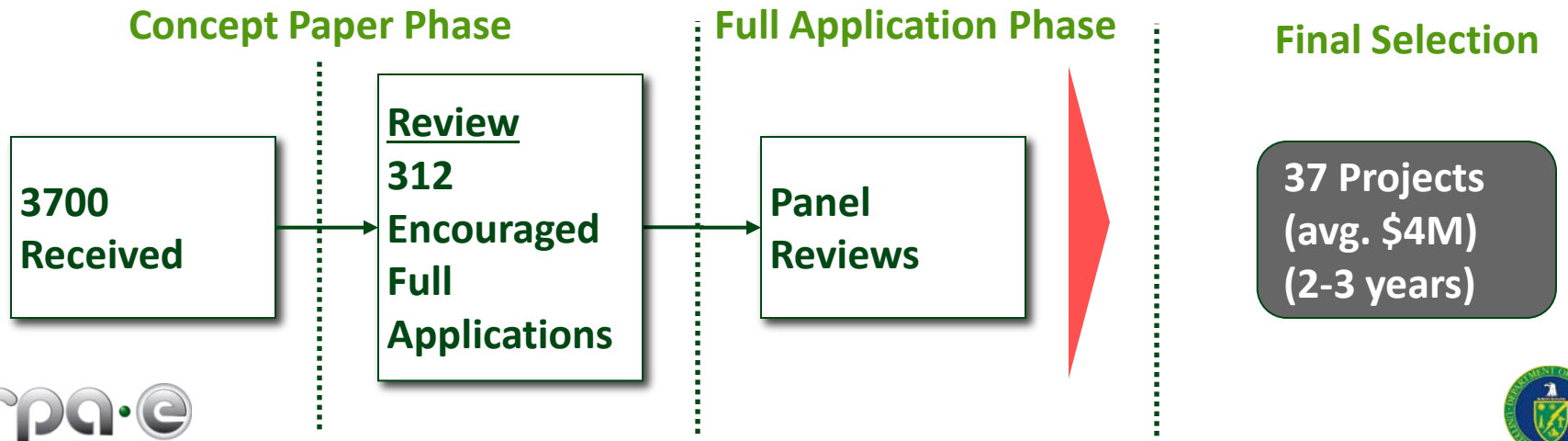
what ARPA-E will *NOT* do

- Incremental improvements
- Basic research
- Long term projects or block grants
- Large-scale demonstration projects

FOA Round 1

- ARPA-E's First Funding Opportunity
  - Announced April 2009, Selections Oct 2009
  - 3,700 proposals to 37 project selections ($151M)

- In ARPA-E's inaugural program, funding was open to all energy ideas and technologies, but focused on applicants who already had well-formed research and development plans for potentially high-impact concepts or new technologies



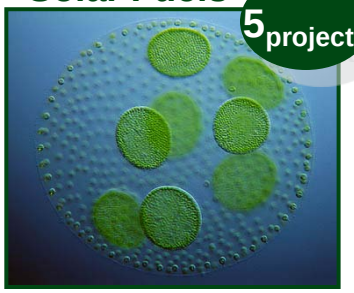
FOA-1 Projects Span 10 Areas

Energy Storage
6 projects

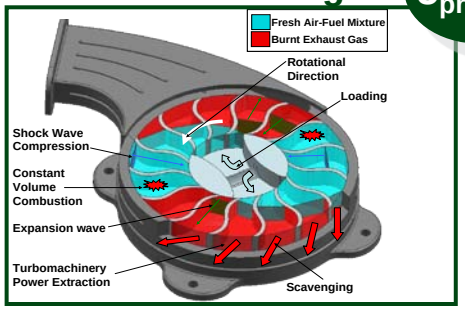
Biomass Energy
5 projects

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

FOA-2: Funding for 3 Program Areas

Batteries for Electrical Energy Storage in Transportation (BEEST)

Developing a new generation of energy-dense, low-cost battery technologies for plug-in and hybrid electric vehicles

Could give electric vehicles the range, performance, lifetime, and cost required to shift transportation energy from oil to the U.S. electric grid

Electrofuels

Exploring using microorganisms to harness energy and convert carbon dioxide into liquid fuels

Theoretically, this could be10 times more efficient than current approaches

Innovative Materials & Processes for Advanced Carbon Capture Technologies (IMPAACT)

Revolutionizing technologies that prevent carbon dioxide produced by coal-fired power plants from entering the atmosphere

Could dramatically reduce the amount of carbon dioxide emissions that contribute to global warming

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FOA-3: Funding for 3 Program Areas

Agile Delivery of Electrical Power Technology (ADEPT)

Exploring materials that will increase performance and lower costs of computers and other electronics

Could reduce energy consumption by up to 30 percent – or 12 percent of total U.S. energy consumption

Building Energy Efficiency Through Innovative Thermodevices (BEETIT)

Developing efficient air conditioners and building-cooling technologies that use less energy and release less greenhouse gases

Could reduce emissions and significantly increase the U.S. technological lead in rapidly emerging clean energy industries

Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)

Developing affordable, large-scale energy storage that enables the widespread use of two key renewable energy sources: wind and solar power

These technologies will position the U.S. to lead the technology and manufacturing of stationary electricity storage infrastructure in the emerging global market

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Attributes Of ARPA-E Projects

High Impact on ARPA-E Mission Areas –

- Reduction in energy imports
- Improvement in energy efficiency
- Reduction in energy-related emissions, including greenhouse gases
- To “ensure” U.S. “technological lead in developing and deploying advanced energy technologies

Disruptive, Innovative Technical Approach –

- ARPA-E is focused on high risk/high reward R&D
- Interested in –
  - New technical approaches that move to entirely new learning curves
  - Fundamentally new areas of research with uncharted white space

Best-in-class People & Teams

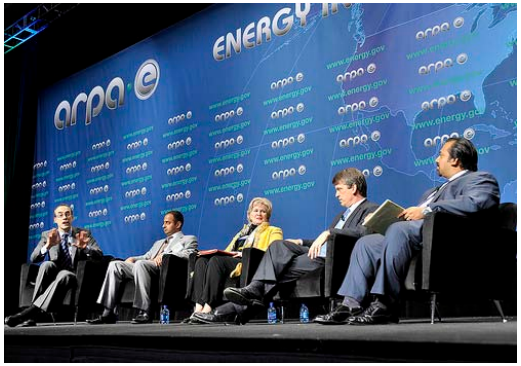
- Complementary, cross-discipline skill sets
- Strong interest to bring in new, talented scientists and engineers to energy technology research
- Break down barriers between science and engineering

Strong Impact of ARPA-E Funding Relative to Private Sector –

- Invest in areas too risky for the private sector
- ARPA-E investments de-risk technologies and catalyze follow- on private sector investments

ARPA-E Commercialization Program

- $162M in cost share funding and follow-on investments from FOA-1: equivalent to 107% of ARPA-E funding
  - $63M cost share
  - $98.5M additional funding
- 13 new patent applications filed
- 4 major business milestones/partnerships
- 2 new spinouts formed
- Over a dozen senior executives and scientists hired
- ARPA-E Energy Innovation Summit: February 28 - March 2



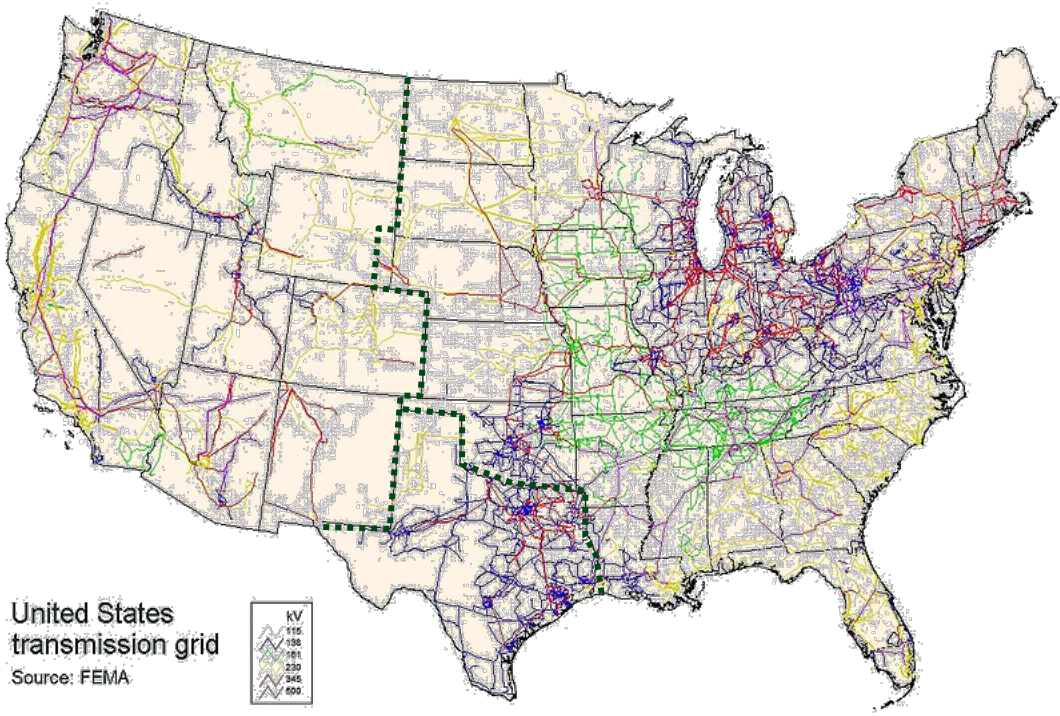
Overview of ARPA-E as an Agency

Overview of GRIDS Storage Program

Technical Progress in Energy Storage

POWER GRID: LARGE SUPPLY CHAIN WITH NO WAREHOUSE

- Electrification: Premier Engineering Accomplishment of the 20th Century
- Harnessing Renewable Power: #1 Challenge for 21st Century



“Storage Changes Everything for the Grid”

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ENERGY STORAGE CAN PROVIDE A VARIETY OF BENEFITS

Generation - Supply Side

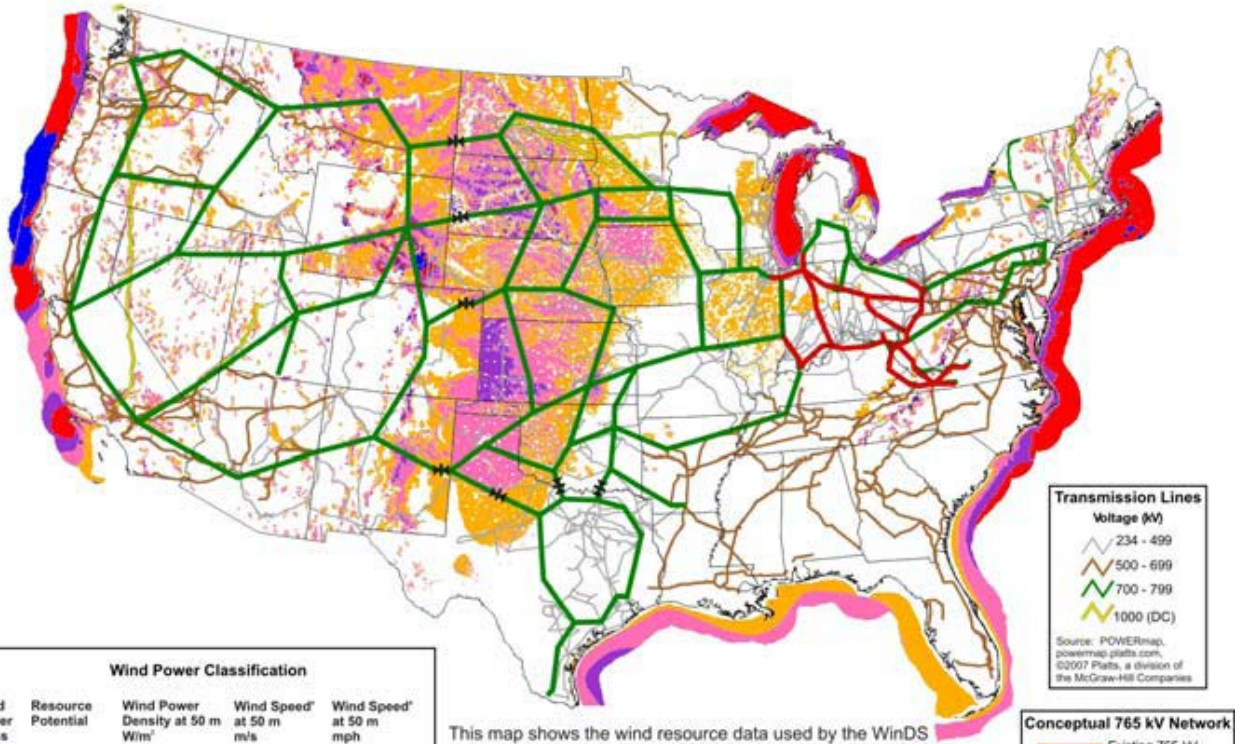
- Renewables Integration
- Rate Optimization
- Price Arbitrage / Peak Shaving
- Capacity Value
- Cycling Cost Management
- Ancillary Services

Delivery – Transmission and Distribution

- T&D Network Investment Deferral
- T&D Component Life Extension
- Transmission Access / Congestion Charge Management
- T&D Asset Utilization
- Reliability
- Power Quality

High Renewable Scenarios (>20%) Could Require Massive Transmission Increase without Storage

Conceptual Transmission Expansion Plan to Accommodate 400 Gigawatts (GW) of Wind Power



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m²	Wind Speed* at 50 m m/s	Wind Speed* at 50 m mph
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

* Wind speeds are based on a Weibull k value of 2.0

This map shows the wind resource data used by the WinDS model for the 20% Wind Scenario. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

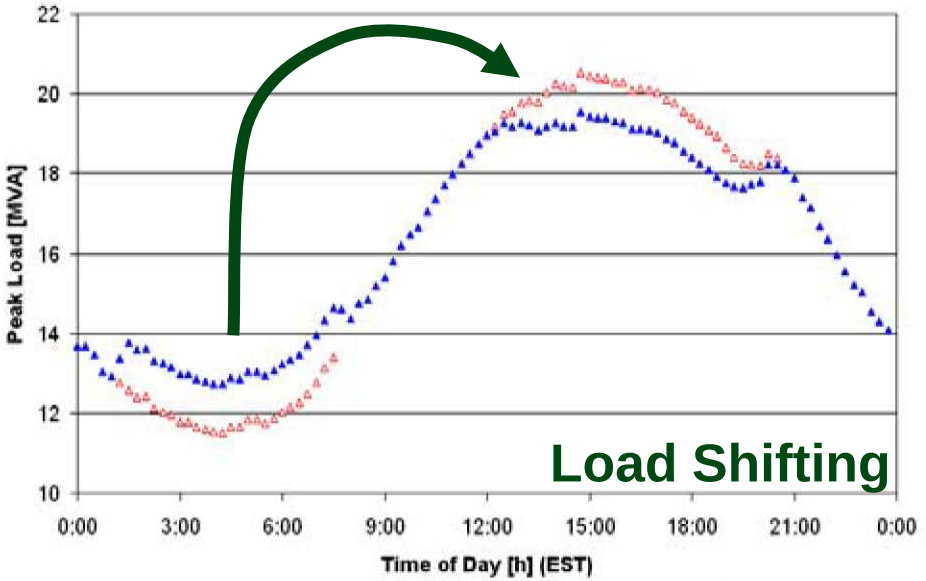
Source: AWEA, “Building a Green Power Superhighway”

STORAGE AND RENEWABLES

Timing Matters

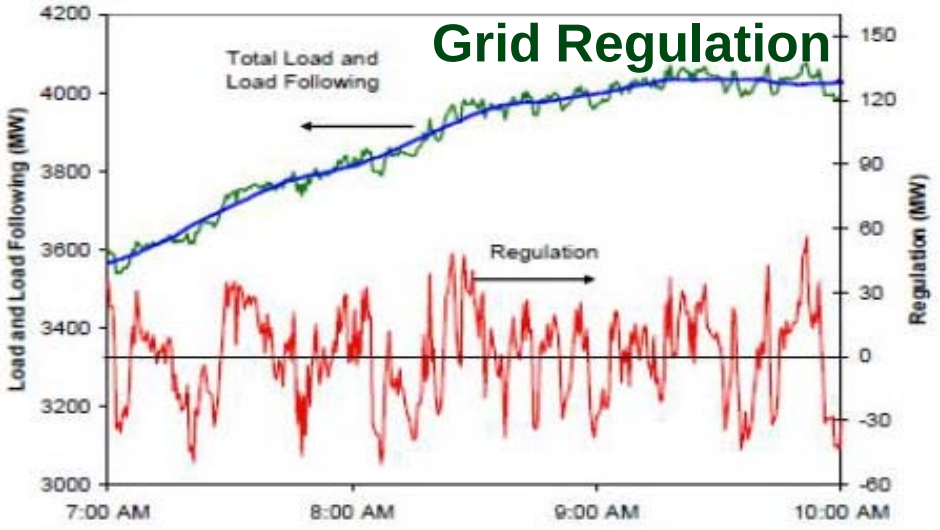
1 minute to hours:

power / energy



1 cycle to 1 minute:

frequency / voltage



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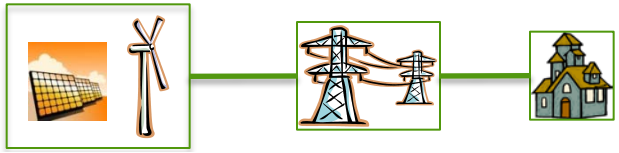
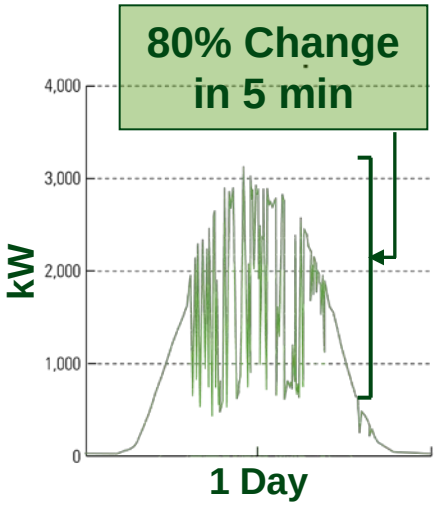
GRID-SCALE RAMPABLE INTERMITTENT DISPATCHABLE STORAGE (GRIDS)

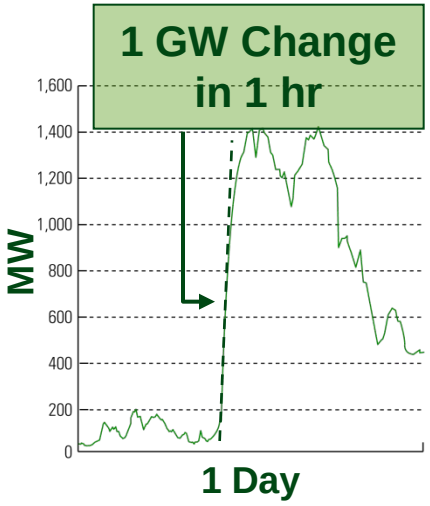
Renewables Today



Solar PV in AZ (TEP)



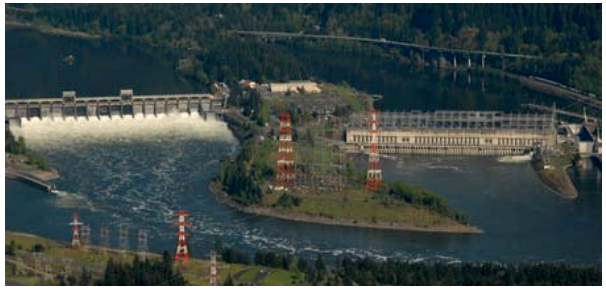
Wind in OR (BPA)

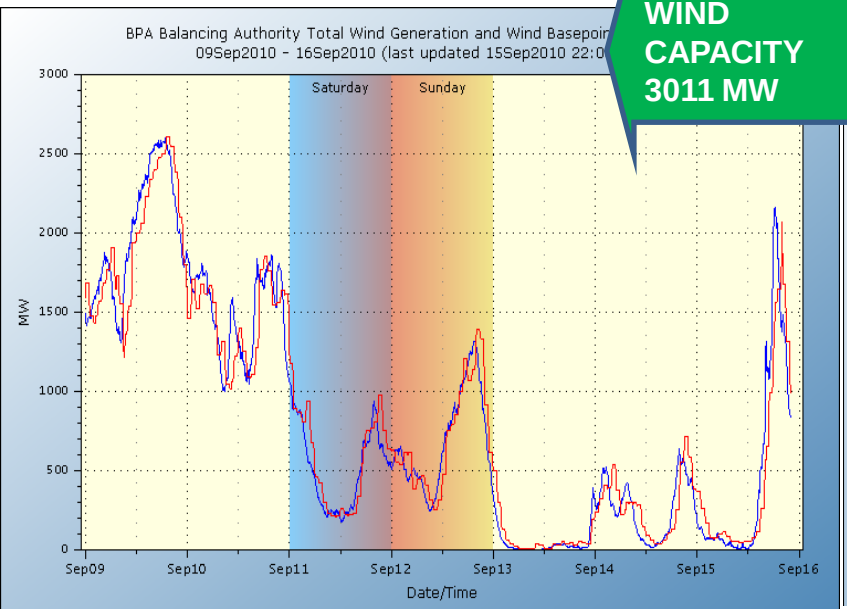


Problem:
Minutes-to-Hours Changes in Power

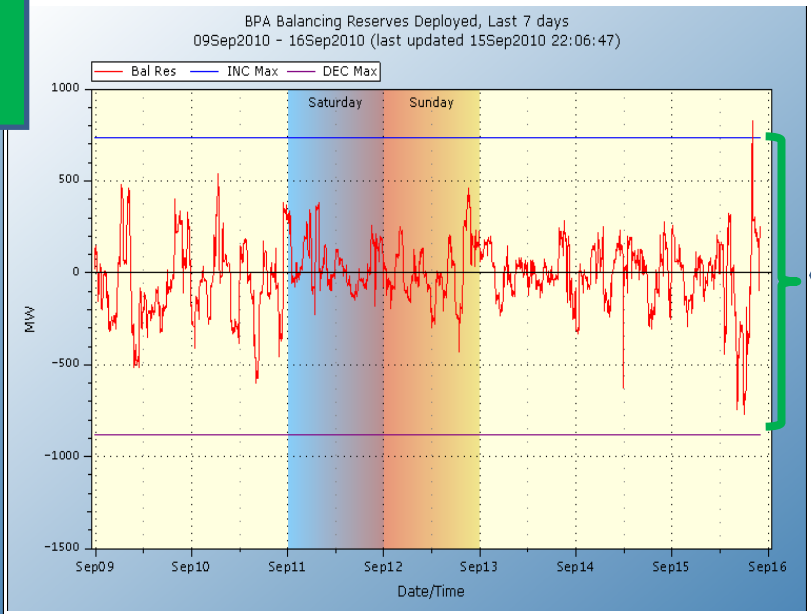
Goal: Grid storage that is dispatchable and rampable
ARPA-E Focus: Transformational approaches to energy storage to enable wide deployment of renewables

Generation and storage data for high renewable penetration area





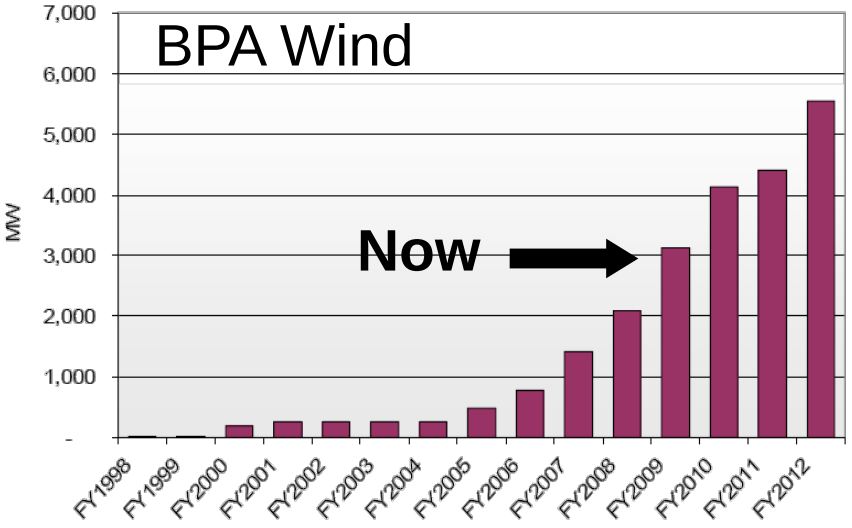
WIND CAPACITY 3011 MW



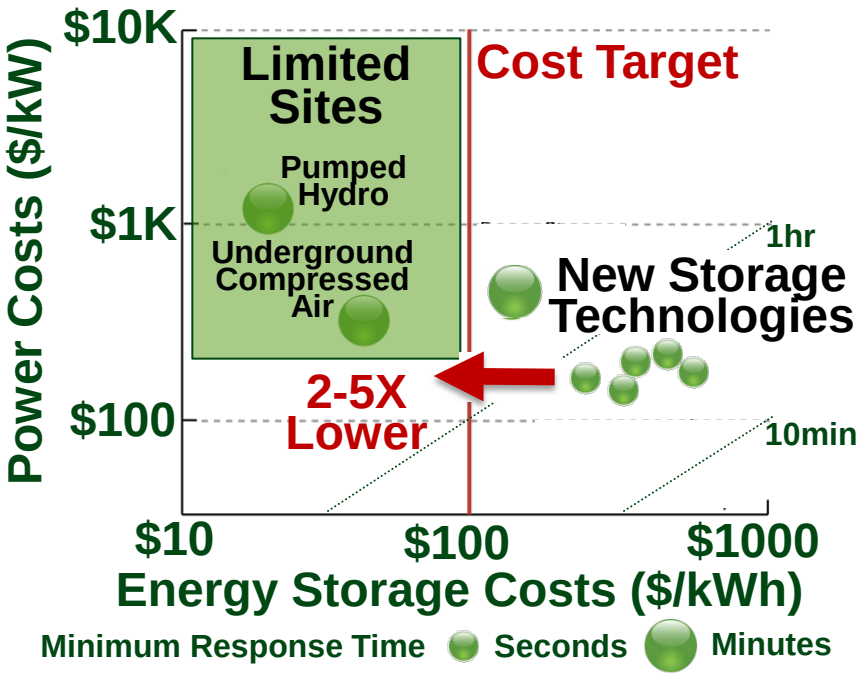
HYDROPOWER RANGE 1600-2000MW

Solving the Renewable Integration Challenge

- Increase Balancing Authority Size
- Increase Transmission Capacity
- Improved Situational Awareness
  - Real Time Knowledge
  - Improved Weather Models
  - Generation Protocols
- New Storage Technologies



Grid-scale Rampable Intermittent Dispatachable Storage (GRIDS)



Need: **Innovative Technologies for Cost-Effective Energy Storage**

Goal: Grid storage that is dispatchable and rampable
Focus: Transformational approaches to energy storage to enable wide deployment at very low cost

GRIDS: Gridscale Renewable Intermittent Dispatchable Storage Program

- Economics of Pumped Hydro - but Deployable Anywhere

- Technology Agnostic – Any Stationary Energy Storage Media

  Electrochemical: Battery, Flow Battery, Re-FC…
  Electromechanical: Flywheel, advanced CAES…
  Electrical: SMES, Ultracap, etc.

- Two Categories: Advanced Systems Prototypes (20kW)

  ~ TRL 3/4 to TRL 6

  Proof-of-Concept Component

  ~ TRL 2/3 to TRL 5

- Connect Across US Gov't and Private Industry for subsequent exit

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Portfolio of Projects

UNIVERSITY/ LAB

USC Viterbi School of Engineering

Rechargable 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

Fuel-Free Isotherma 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

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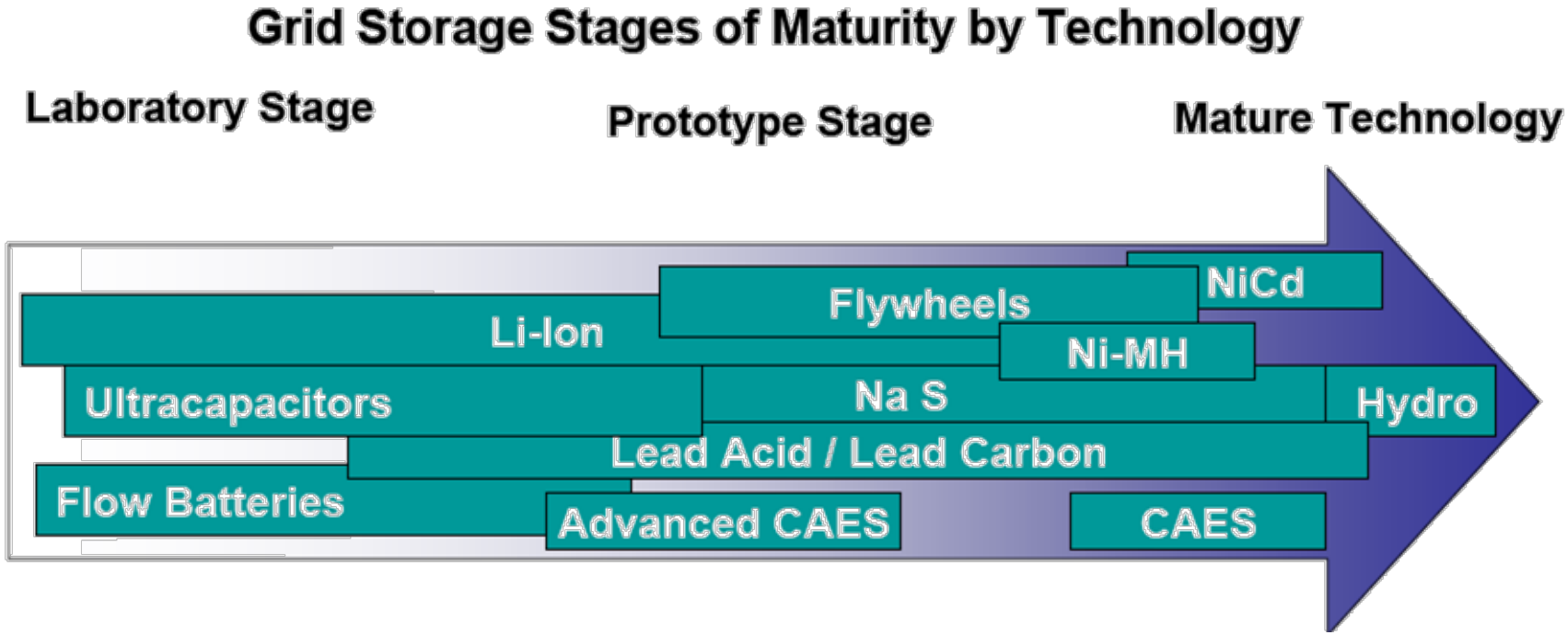
Overview of ARPA-E as an Agency

Overview of GRIDS Storage Program

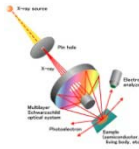
Technical Progress in Energy Storage

GRID-SCALE STORAGE – RANGE OF TECHNOLOGY READINESS LEVELS

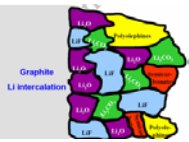


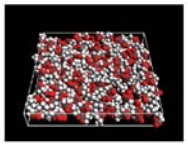
Technology Readiness Level Definitions Related to Energy Storage

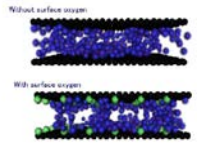
- **TRL-0: Scientific Capability for Research, Possibly Used for Energy Storage**
  - Example: New surface science instrument or supercomputer



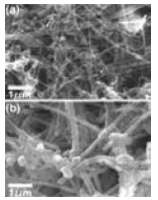
- **TRL-1: Basic Science Investigation**
  - Example: Validation of a new experimental method or insight or simulation of new chemistry or surface functionality

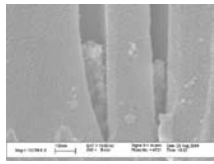




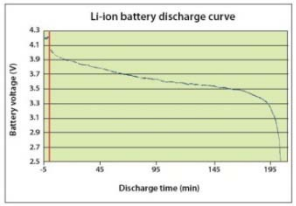


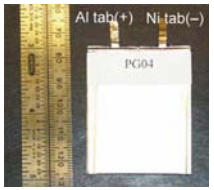
- **TRL-2: Platform Science Demonstrated or Formulated**
  - Example: Design, synthesis and characterization of nanostructures to study interfaces or half-cell tests





- **TRL-3: Proof-of-Concept Device Fabrication and Test**
  - Example: Basic experimental testing of new battery for basic functionality in a full cell configuration

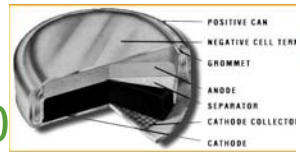




Basic & Exploratory Research

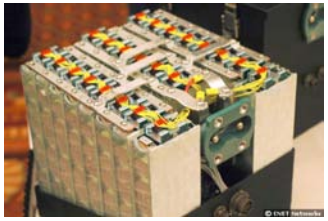
Technology Readiness Level Definitions Related to Energy Storage

- **TRL-4: Component Level Development on Lab Scale**
  - Example: Development and testing of functional storage as proof-of-concept device, for example in coin or 18650 cell size.



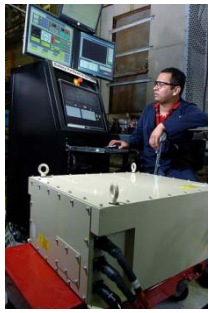
- **TRL-5: Component Development and Test at Prototype Scale**
  - Example: Development of functional prototype storage component at bench scale, for instance 1-25kW power rating, and tested for functionality as system relevant hardware.

- **TRL-6: System / Subsystem Prototype**
  - Example: Development of functional prototype storage system, including power conditioning and control interface, at bench scale. For instance, system of 1-25kW power rating tested in a controlled, use relevant, environment.



Technology Readiness Level Definitions Related to Energy Storage

- **TRL-7**: **System Prototype Validation Testing**
  - Example: Full-scale pilot-testing of a grid-scale storage system as hardware in the loop in a controlled test-bed, with capability for controlled environment testing.



- **TRL-8: Systems Qualification Testing**
  - Example: Full-scale pilot-testing of a grid-scale storage system as hardware on the grid in monitored test-bed under four-season environment conditions

- **TRL-9: Mission Deployment Assessment**
  - Example: Failure analysis or field reliability testing of grid-deployed storage systems.

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Pilot Manufacturing, Testing, and Adoption

POTENTIAL TECHNOLOGY DEVELOPMENT HANDOFFS

Private Sector / Utilities

Basic Research | **Applied Research** | **Development** | **Demonstration**

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Questions?

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