ARPA-E: A New Paradigm in Energy Research

www.arpa-e.energy.gov

The ARPA Model: Different by design

- ARPA-E is modeled after the first Advanced Research Projects Agency (ARPA), now known as DARPA, at the Department of Defense

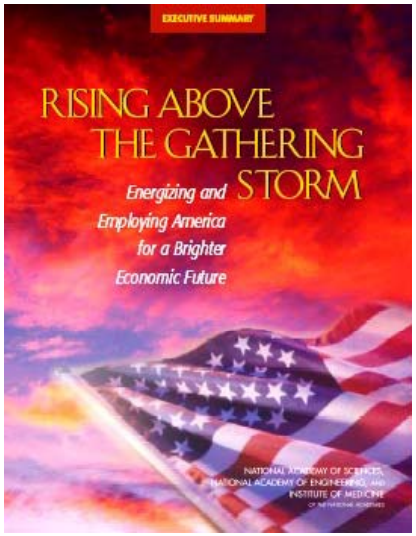
- DARPA was explicitly chartered to be different, so it could do fundamentally different things than had been done by other military service research and development organizations
  - Did not have labs
  - Did not focus on existing military requirements
  - Separate from any other operational or organizational elements

- Using this model, DARPA has enjoyed 50 years of success

Secretary Chu's commitment and funding from the Recovery Act enabled ARPA-E to begin work

Rising Above the Gathering Storm, 2006 (National Academies) specified

- "Creative, out-of-the-box, transformational" energy research
- Spinoff Benefit – Help educate next generation of researchers



America COMPETES Act, 2007

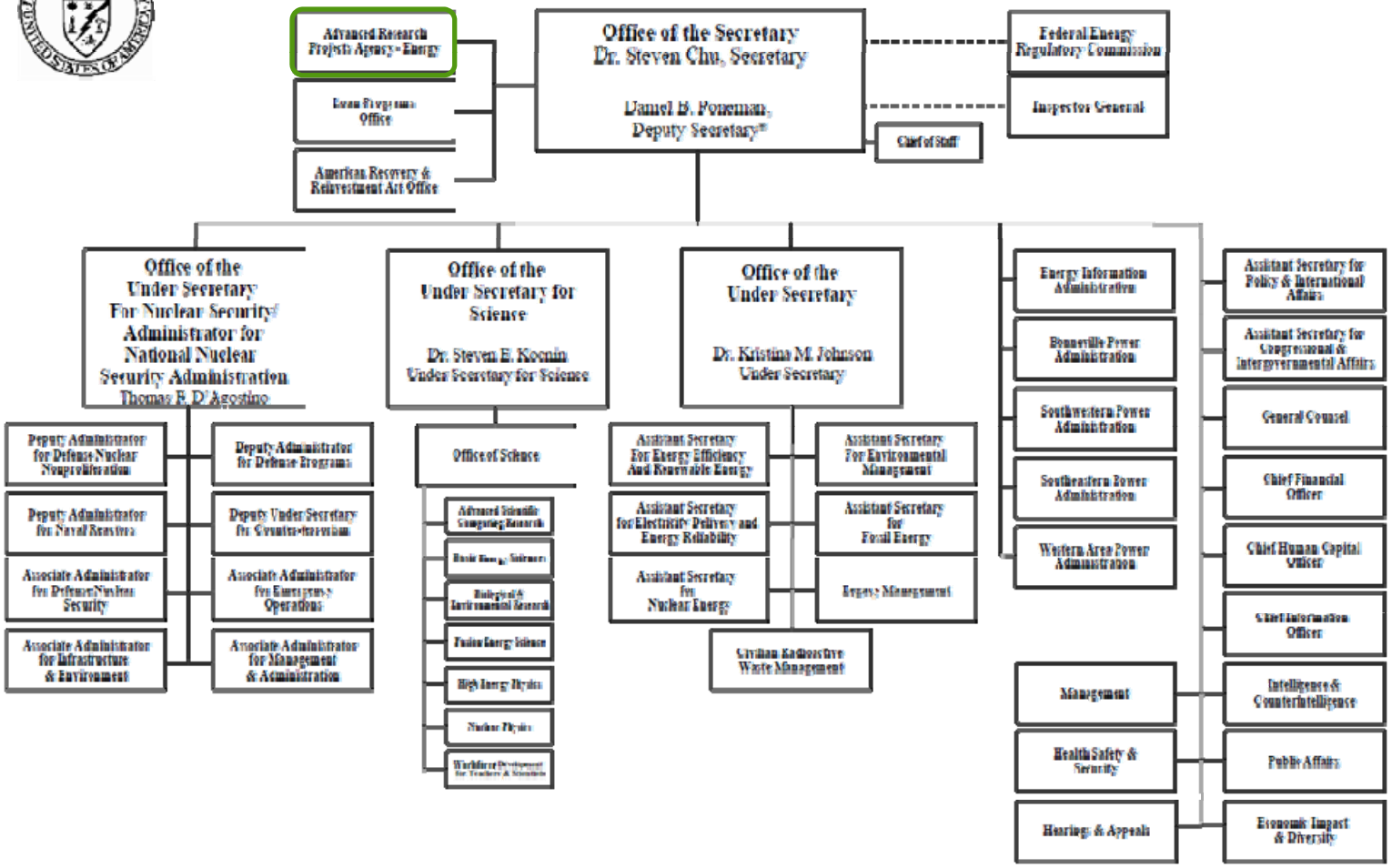
- Authorizes the establishment of ARPA-E

American Recovery and Reinvestment Act of 2009 (Recovery Act)

- $400M appropriated for ARPA-E
- President Obama launches ARPA-E in a speech at the National Academy of Sciences on April 27, 2009

ARPA-E's director reports directly to the Secretary of Energy

DEPARTMENT OF ENERGY



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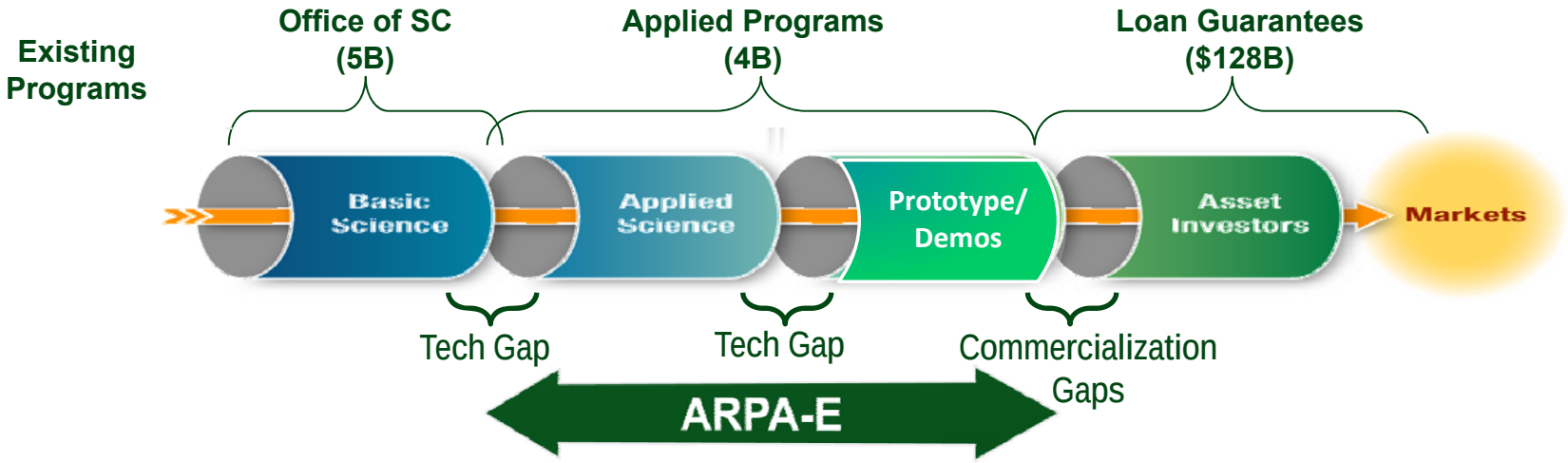
* The Deputy Secretary also serves as the Chief Operating Officer

ARPA-E was created with a vision 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 and 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

What is an ARPA-E Project?

High impact on ARPA-E mission areas

Disruptive, innovative technical approaches & new learning curves

- Best-in-class people & teams containing scientists and engineers;
- Attract the U.S. intellectual horsepower to energy R&D

Strong impact of ARPA-E funding relative to private sector

ARPA-E now funds 121 projects in 7 program areas with $363 million federal dollars ($518 million total project cost)

arpa·e TIMELINE

2006
The National Academies release report, "Rising Above the Gathering Storm"

AUG 9, 2007
President George W. Bush signed into law the America COMPETES Act that codified many of the recommendations in the National Academies report, thus creating ARPA-E.

SEPT 18, 2009
President Barack Obama announced his intent to nominate Dr. Arun Majumdar, as Director of ARPA-E.National Academies report, thus creating ARPA-E.

APR 27, 2009
President Barack Obama allocated $400 million in funding to ARPA-E from the American Recovery and Reinvestment Act of 2009.

OCT 22, 2009
Senate confirmed Dr. Arun Majumdar as ARPA-E's first Director. National Academies report, thus creating ARPA-E.

OCT 26, 2009
Department of Energy awarded $151 million in Recovery Act funds for 37 energy research projects under ARPA-E's first Funding Opportunity Announcement.

DEC 7, 2009
U.S. Secretary of Energy Steven Chu announced ARPA-E's second round of funding opportunities in the areas of "Electrofuels", "Innovative Materials & Processes for Advanced Carbon Capture Technologies (IMPACCT)" and "Batteries for Electrical Energy Storage in Transportation (BEEST)."

MAR 1 – 3, 2010
ARPA-E hosted the inaugural "Energy Innovation Summit," which attracted over 1,700 participants

MAR 2, 2010
U.S. Secretary of Energy Steven Chu announced ARPA-E's third round of funding opportunity in the areas of "Grid-Scale Rampable Intermitten Dispatchable Storage (GRIDS)," "Agile Delivery of Electrical Power Technology (ADEPT)" and "Building Energy Efficiency Through Innovative Thermodevices (BEET-IT)."

APR 29, 2010
Vice President Joe Biden announced 37 awarded projects under ARPA-E's second funding opportunity.

JUL 12, 2010
Department of Energy Awarded $92 Million for 43 cutting-edge research projects under ARPA-E's third funding opportunity.

ARPA-E PROGRAMS

FOA1

Electrofuels

BEEST

IMPACCT

ADEPT

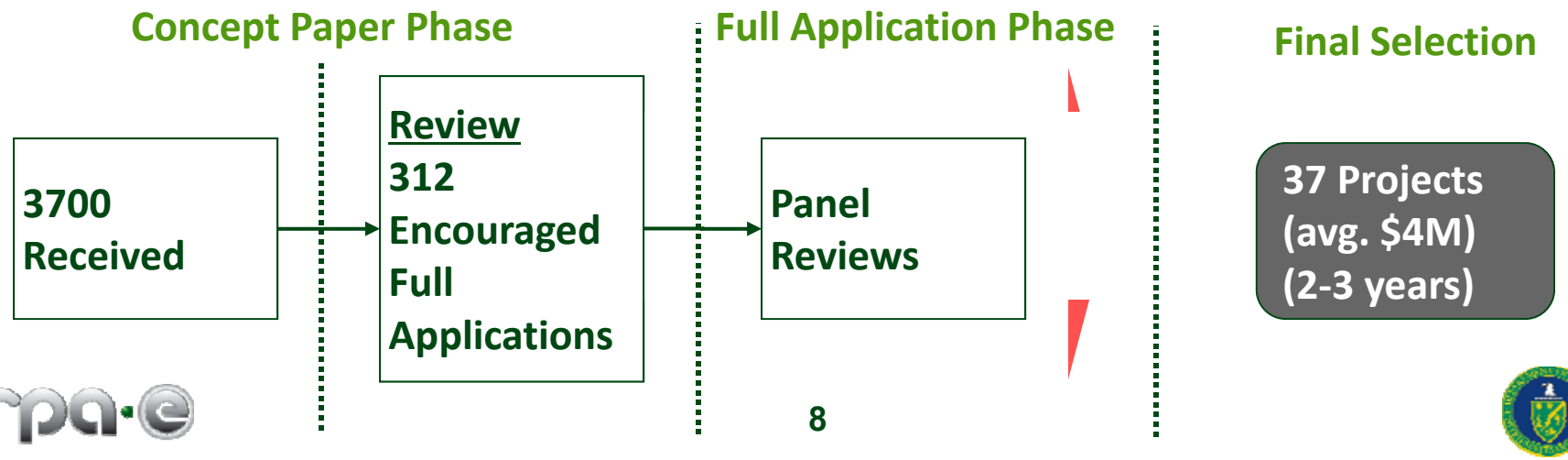
BEETIT

GRIDS

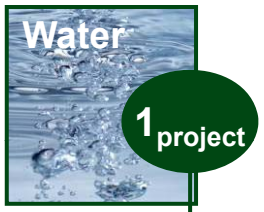
FOA ROUND 1

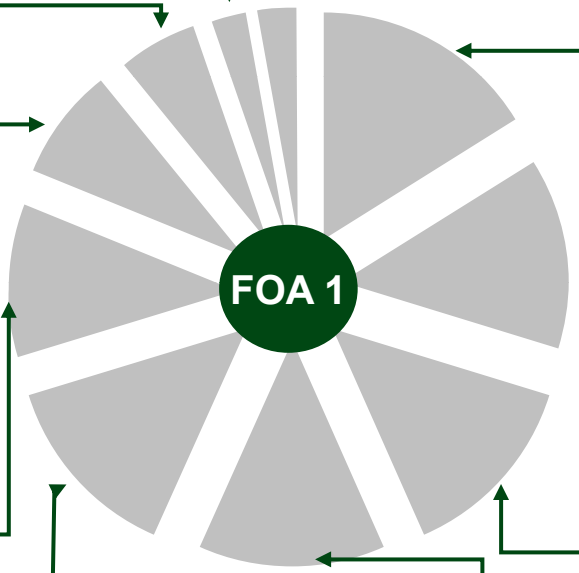
- ARPA-E's First Funding Opportunity
  - Announced April 2009, Selections Oct 2009
  - 3,700 proposals to 37 project selections ($151M)

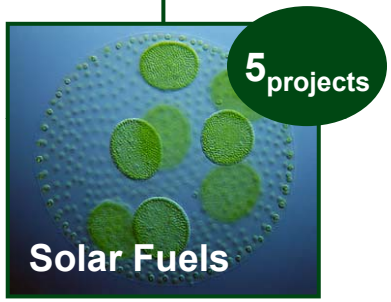
- As ARPA-E's inaugural program, this funding opportunity was open to all energy ideas and technologies, but focused on applicants who already had well-formed research and development plans for potentially high-impact concepts or new technologies



ARPA-E FOA 1 projects can be categorized into one of ten energy technology areas

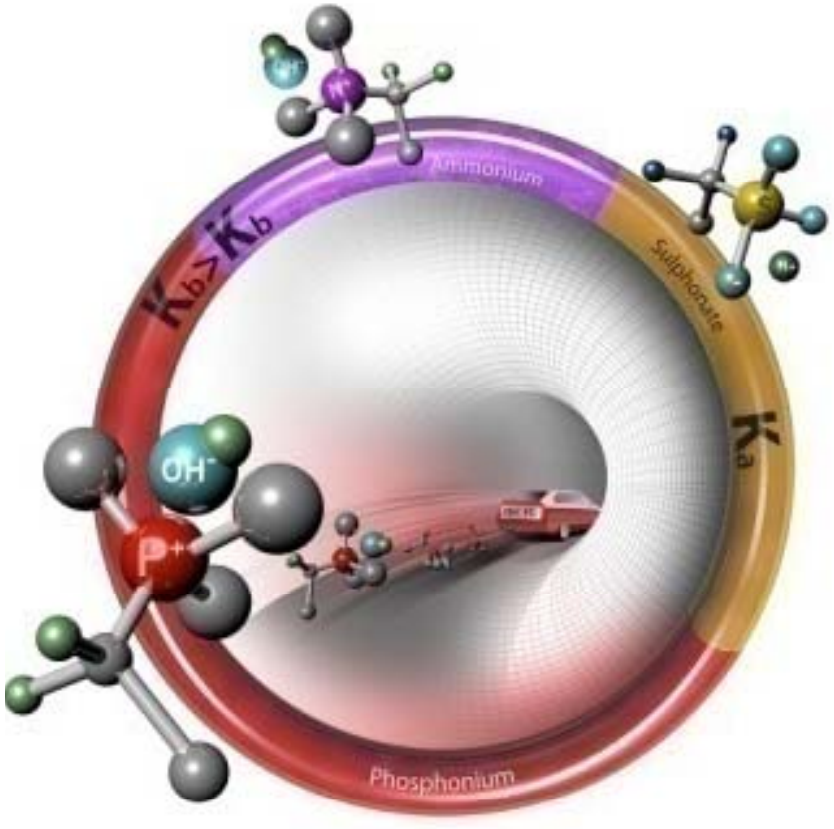






New membranes enabling non-platinum catalysts

University of California - Riverside	$0.74M cost share - 36 mo.



- By switching from an acidic medium to a basic one, hydroxide (OH) exchange membrane fuel cells (HEMFCs) have the potential to solve the problems of catalyst cost and durability while achieving high power and energy density.
- In a basic environment, the cathode oxygen reduction over-potential can be significantly reduced, leading to high fuel cell efficiency, and catalysts in basic medium are also more durable.[1]
- In addition, the facile cathode kinetics allows non-precious metals to be used as catalysts, thus drastically reducing the cost of the fuel cell

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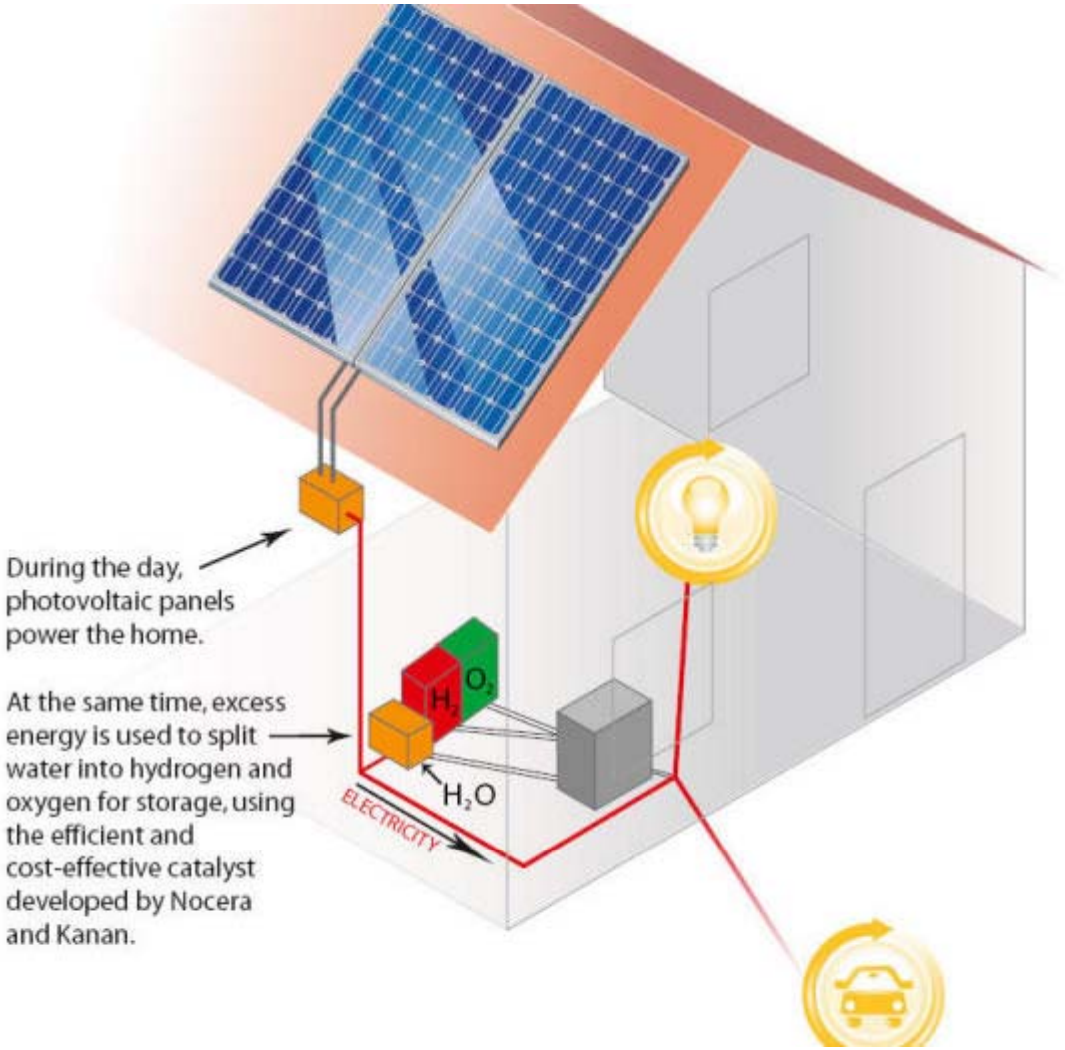
[1] G. F. McLean, T. Niet, S. Prince-Richard, N. Djilali, Int. J. Hydrogen Energy 2002, 27, 507 – 526.

Affordable water from energy and sunlight

Sun Catalytix	$4.14M + cost share - 24 mo.



Sun Catalytix aims to design and develop a new class of electrolyzer and photo-electrochemical cell (PEC) devices, including an inexpensive 100 Watt electrolyzer and a direct solar-to-fuel PEC module

ARPA-E PROGRAMS

Electrofuels

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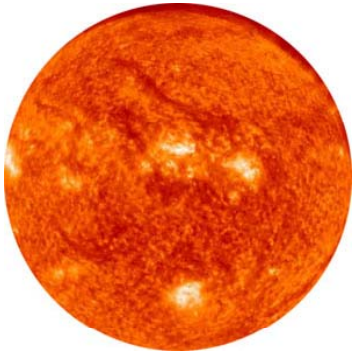
ARPA-E's Electrofuels program seeks to address U.S. oil dependence with significantly more efficient biofuels

The Electrofuels program is anticipated to open up a new area of research and path to biofuels



Photosynthesis

Electrons/
Reducing equivalents

Biomass

Algae

Chemical Catalysis

Biological Catalysis

EtOH Advanced biofuels

Pyrolysis oils

Biodiesel Advanced biofuels

Syngas
CH_3OH
CH_4
Advanced fuels?

Advanced Fuels

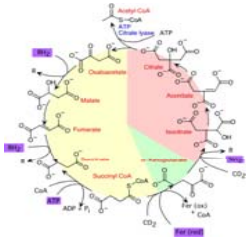
Electrofuels approach is non-photosynthetic, modular, and solutions can be mixed- and- matched

Assimilate Reducing Equivalents

Reducing equivalents: *other than reduced carbon or products from Photosystems I & II*

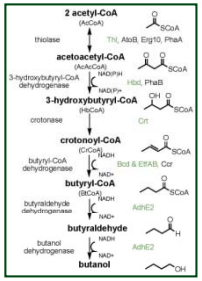
H_2S H_2 Direct Current NH_3 Fe^{2+}

Fix CO_2 for Biosynthesis

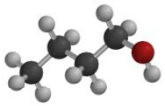


Pathway for carbon fixation: *reverse TCA, Calvin- Benson, Wood-Ljungdahl, hydroxpropionate/hydroxybutyrate, or newly designed biochemical pathways*

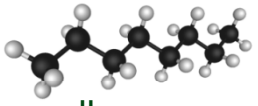
Generate Energy Dense Liquid Fuel



Fuel synthesis *metabolic engineering to direct carbon flux to fuel products*



butanol



alkanes

+ numerous possibilities

ARPA-E PROGRAMS

Electrofuels

BEEST

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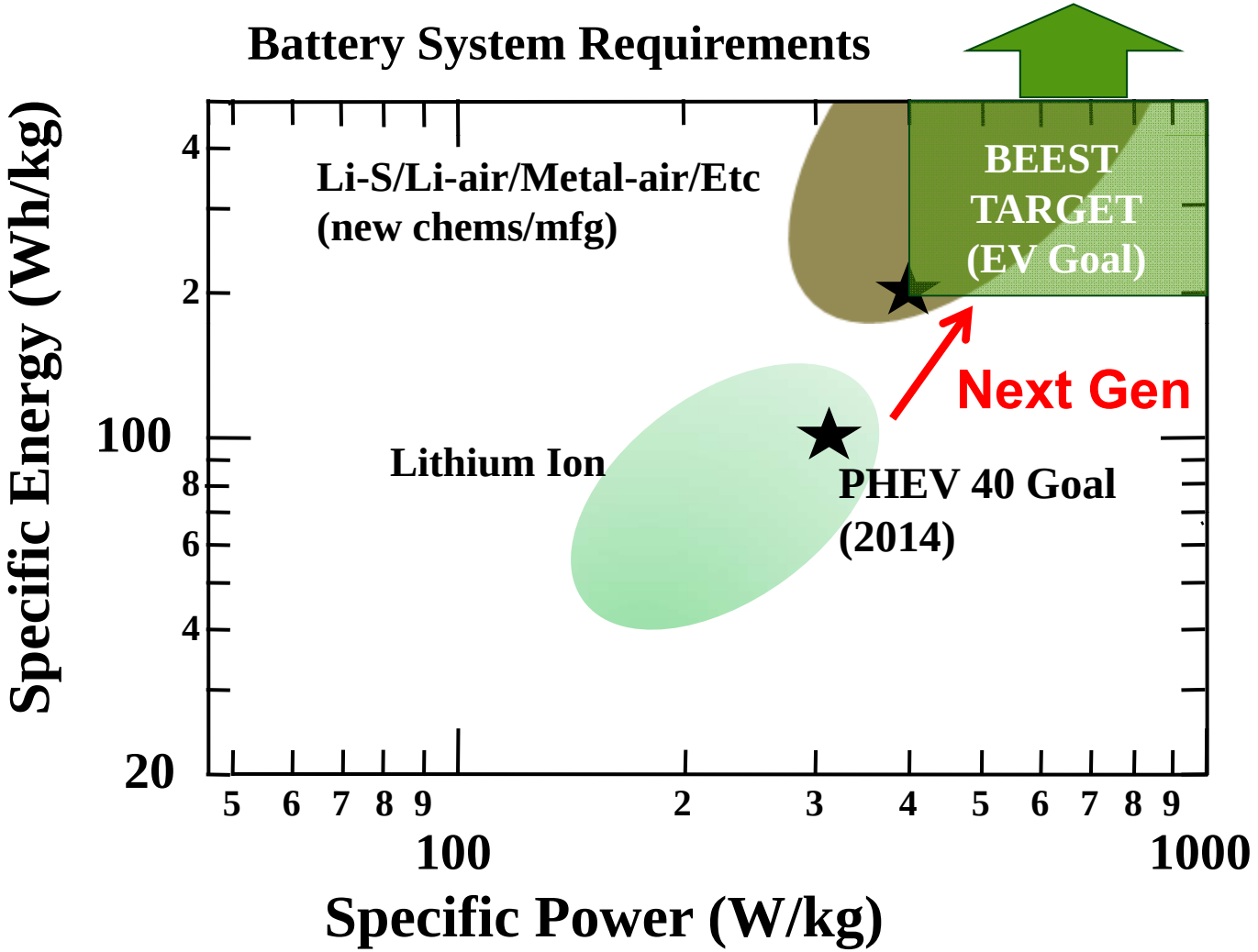
BEEST GOAL : Develop Next generation of ultra-high energy, low cost batteries for PHEV-100+ and EV's



Source: David Howell, DOE Office of Vehicle Technologies, 2009.

BEEST Program Targets

Primary Technical Requirements

System Level	Now	BEEST Goals	Multiple
Energy Density (Wh/kg)	100 →	200	2X
Cost ($/kWh)	1000 →	250	4X

Goal: Doubling battery energy density while decreasing the system cost by a factor of 4

Secondary Technical Requirements
(power density, cycle life, round trip efficiency, self-discharge rate, safety, etc.)

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Innovative Materials and Processes for Advanced Carbon Capture Technologies (IMPACCT)

The Need: The state-of-the-art CO_2 capture technology, aqueous amine solvents, imposes a ~25-30% parasitic power load on a coal-fired power plant, increasing levelized cost of electricity by ~80%

The Goal: Develop *materials* and *processes* that drastically reduce the parasitic energy penalty required for CO_2 capture from a coal-fired power plant

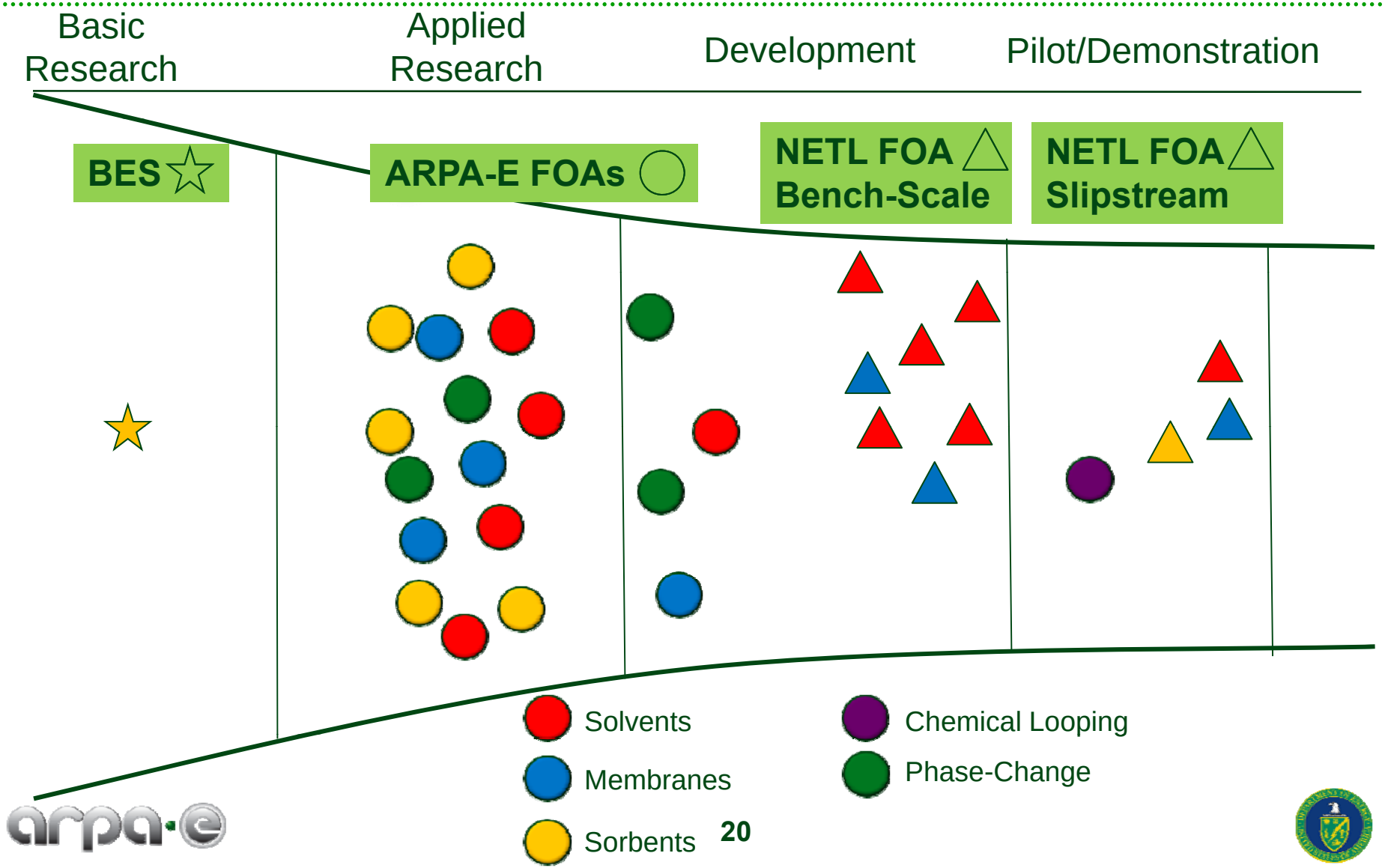
Approx. 80% of the capital costs of carbon capture and storage arise from the capture process

Capture	Transport	Storage
• Post Combustion	• Pipelines	• Saline Aquifers
• Oxy-fuel	• Tankers	• EOR
• Pre Combustion		• Deep Sea

Example areas of interest

- Low-cost catalysts to enable systems with superior thermodynamics that are not currently practical due to slow kinetics
- Robust materials that resist degradation from caustic contaminants in flue gas
- Advanced capture processes, such as processes that utilize thermodynamic inputs other than temperature or pressure

CCS technology pipeline and DOE program coordination



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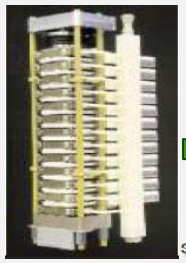
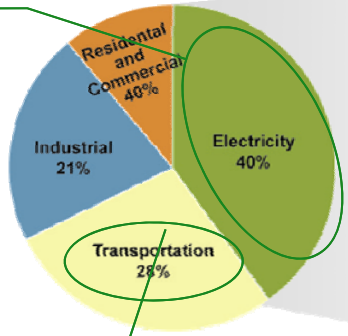
Power electronics need improvement in applications across the entire energy sector (ADEPT)

Distribution & Transmission

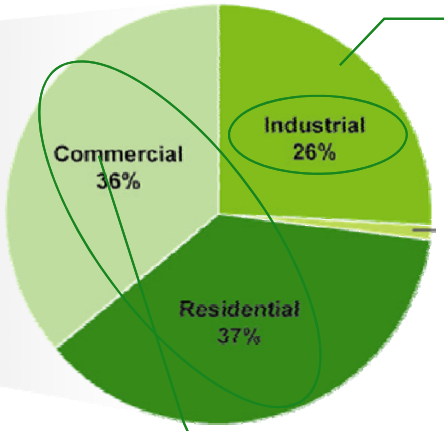


>13 kV, 50kHz SiC transistors

Primary Energy Use by Sector, 2008



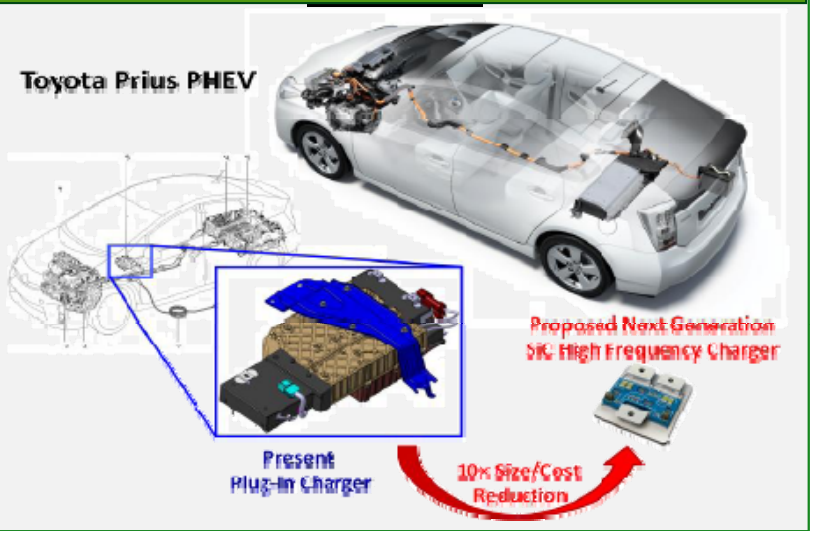
Share of Electricity Consumed by Major Sectors of the Economy, 2008



Industrial

Inverter drives motor

Automotive



Lighting

Existing 25 W AC-DC SSL Driver

130 mm x 45 mm x 25 mm

300X reduction in power stage volume

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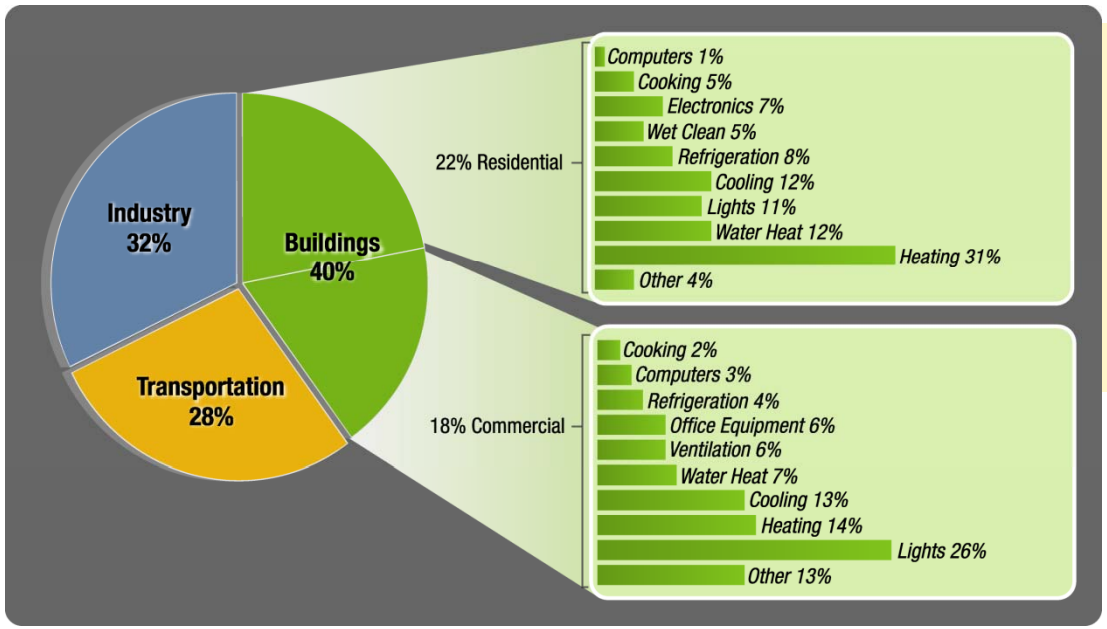
Total buildings energy consumption

Buildings construction/renovation contributed 9.5% to US GDP and employs approximately 8 million people. Buildings' utility bills totaled $370 Billion in 2005.

Buildings use 72% of nation's electricity and 55% of its natural gas.

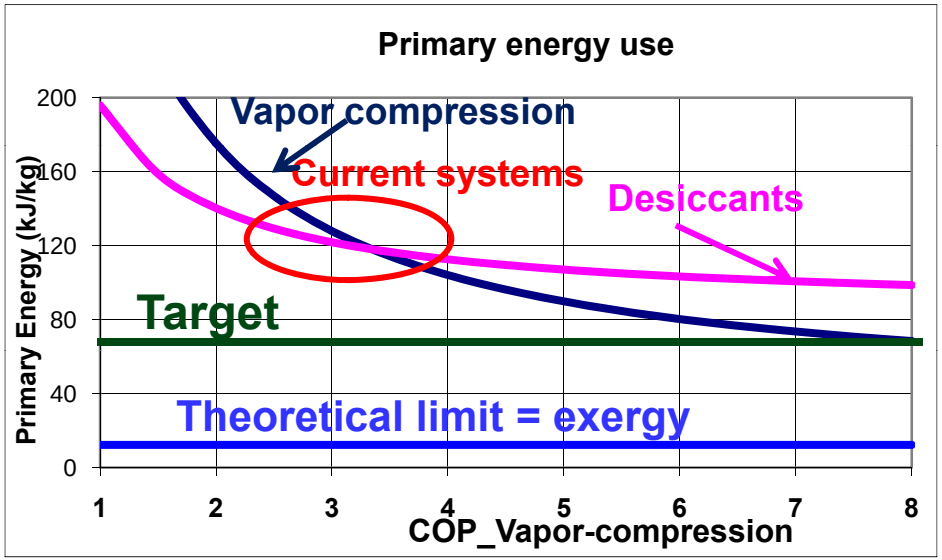


By 2030, Business as Usual

- **16% growth in electricity demand**
- **Additional 200 GW of electricity at cost of $500-1000B, or $25-50B/yr**

Heating & cooling is about 50% of energy consumption

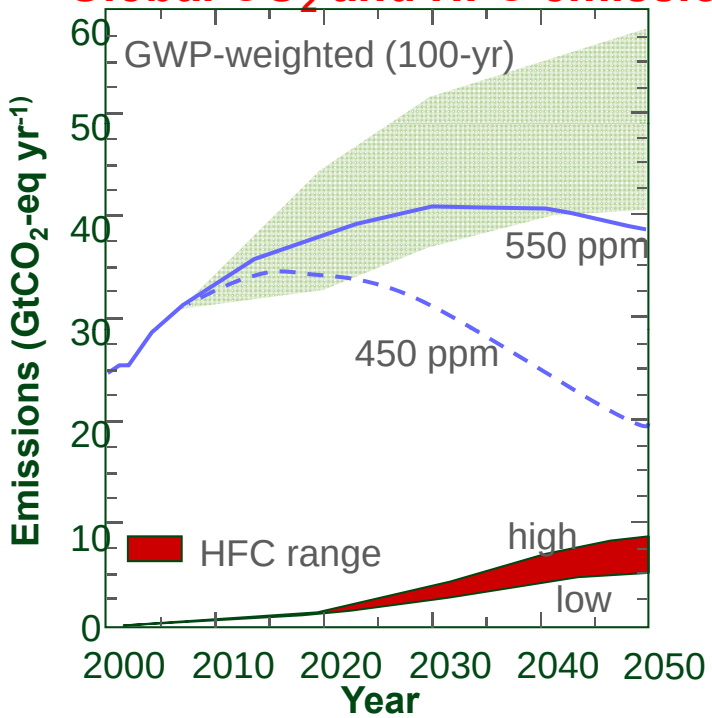
BEET-IT Target



Reduce primary energy consumption by ~ 40 - 50%

- ***Current refrigerants have GWP over 1000 x of CO_2***

Global CO_2 and HFC emissions



Achieve COP > 4 for GWP ≤ 1

Source: Velders et al, PNAS 106, 10949 (2009)

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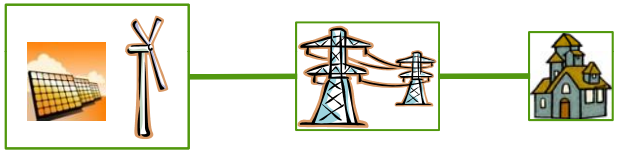
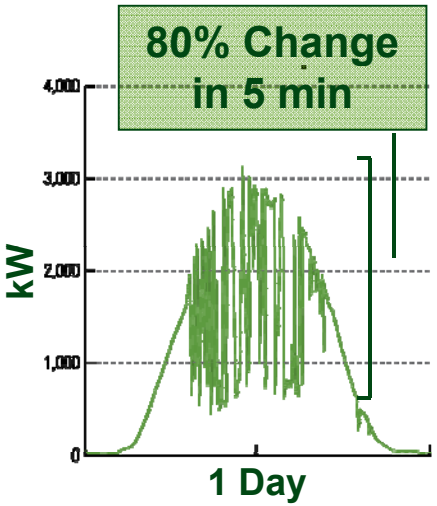
Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)

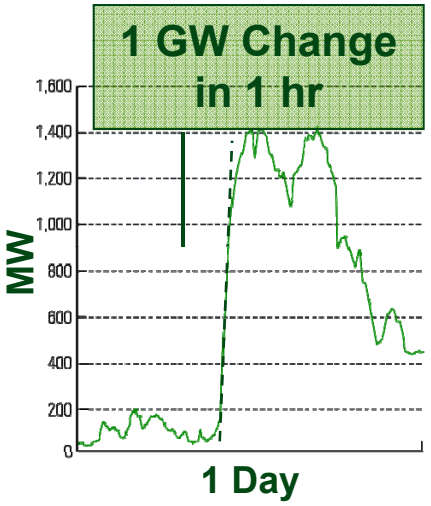
Renewables Today



Solar PV in AZ (TEP)

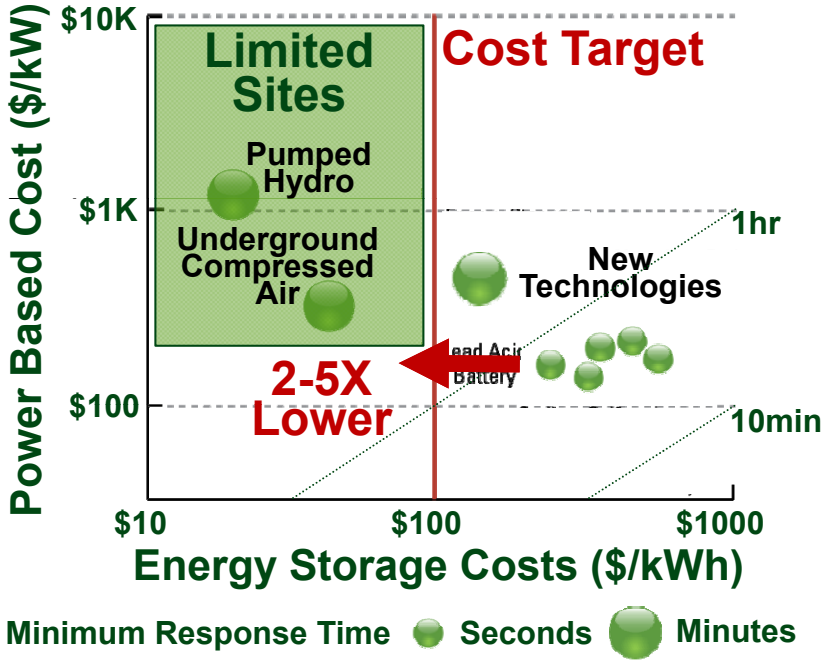


Wind in OR (BPA)



Problem:
Minutes-to-Hours Changes in Power

Storage for Renewables Tomorrow



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

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

Thank you

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