Emerging Renewable Energy Technologies for On-Site Power

JONATHAN BURBAUM

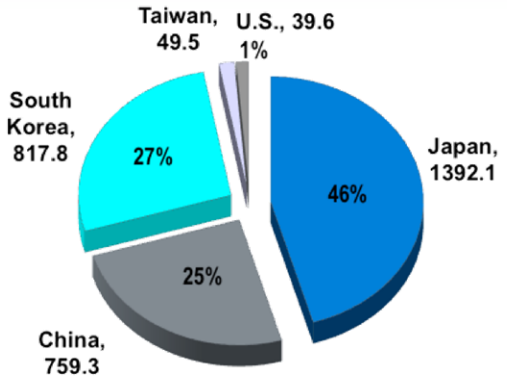
FEDERAL FACILITIES COUNCIL

Renewable Energy Workshop

April 15, 2011

Wake Up Call

Lithium-ion battery manufacturing volumes in 2009
(millions of cells/year)

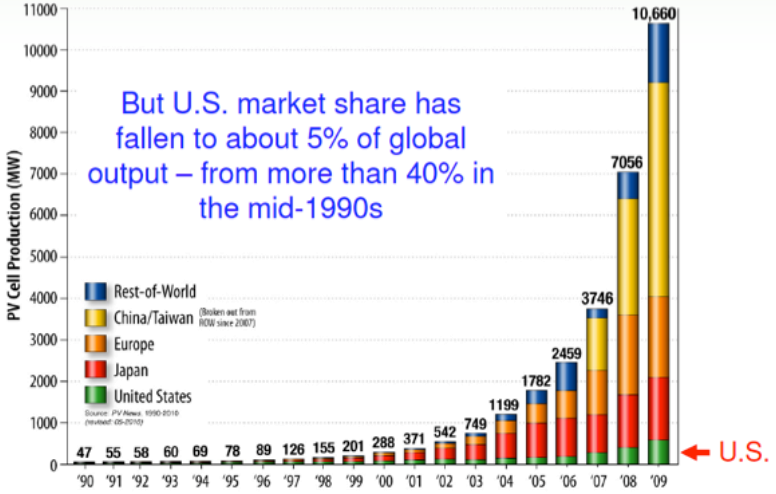


THE ENRICO FERMI AWARD

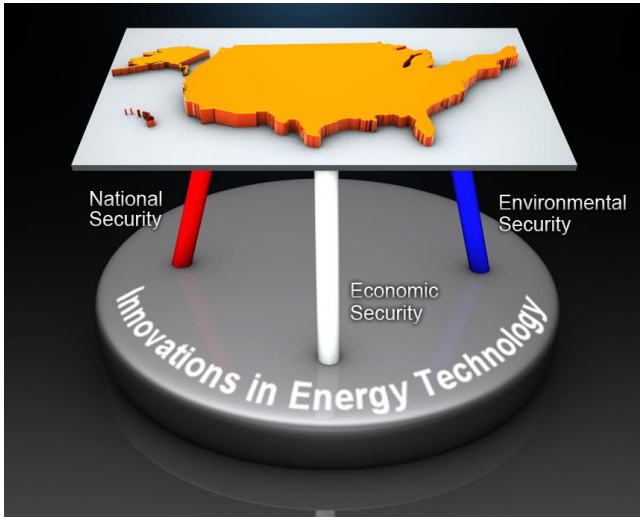
2009

John Goodenough, U. Texas at Austin

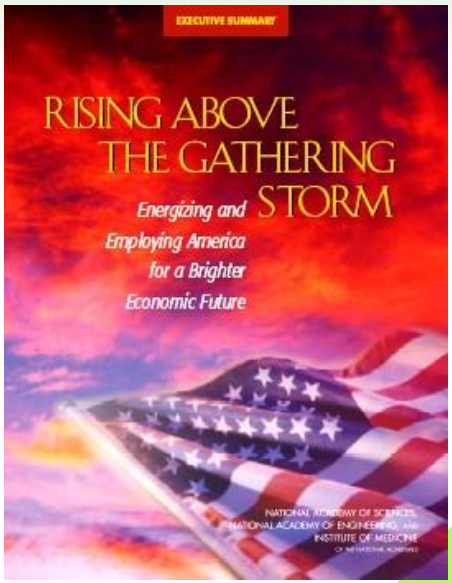
Solar PV is a booming global industry



Worldwide production of solar photovoltaics – in Megawatts



Creation & Launching of ARPA-E



2009
American Recovery and Reinvestment Act
($400M appropriated for ARPA-E)

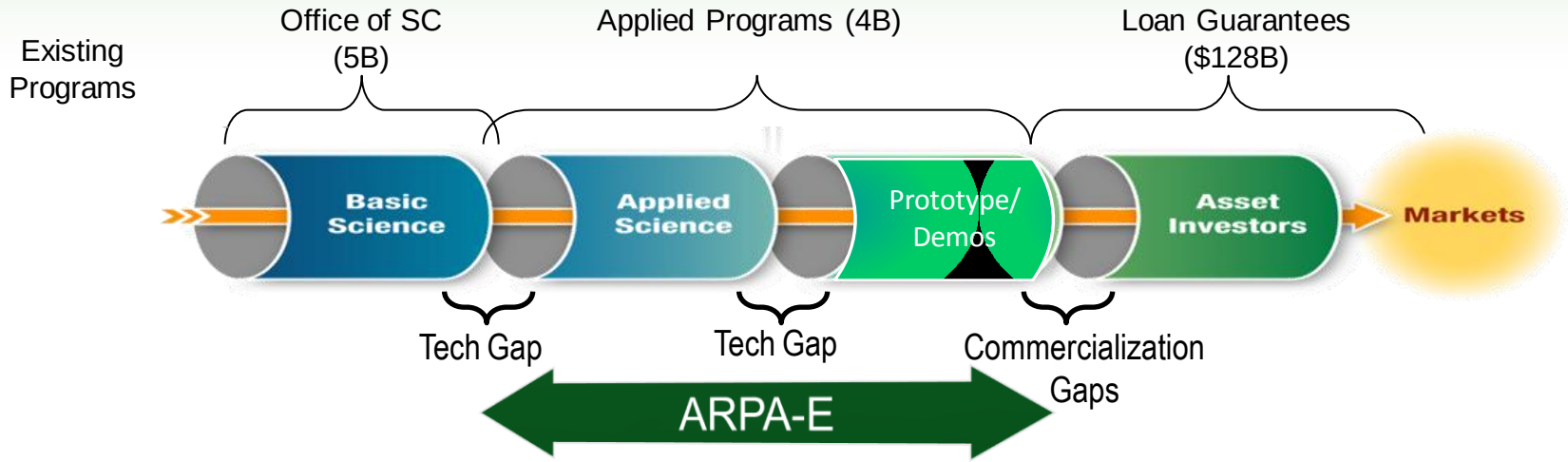
2007
America COMPETES Act

2006
Rising Above the Gathering Storm
(National Academies)

President Obama launches ARPA-E at National Academies on April 27, 2009

Innovation based on science and engineering will be primary driver of our future prosperity & security

ARPA-E was created with a vision to bridge gaps in the energy innovation pipeline



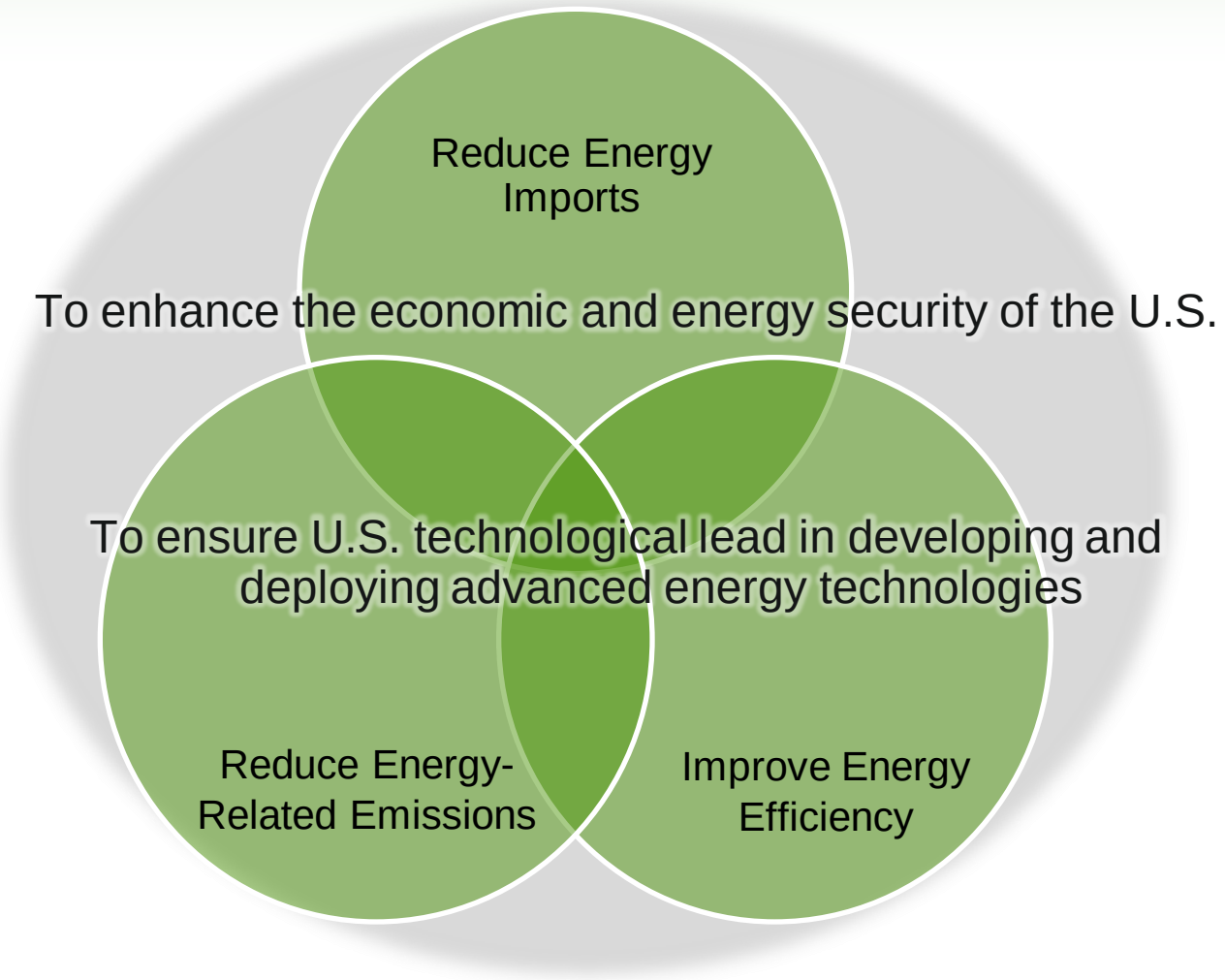
what ARPA-E will do

- 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

ARPA-E's Mission and Means



To overcome the long-term and high-risk technological barriers in the development of energy technologies.

(A) identifying and promoting revolutionary advances in fundamental sciences; **AND**

(B) translating scientific discoveries and cutting-edge inventions into technological innovations; **AND**

(C) accelerating transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty.

Dr. Arun Majumdar
ARPA-E Director

(MechE/Matl Sci, UCB/LBL)

(Econ, Albany)

Shane Kosinski
Deputy Director of Operations

Dr. Eric Toone
Deputy Director of Technology

(Chemistry, Duke)

Operations Team

Matt Dunne (JD, Georgetown)
Acting Chief Counsel
Michael Saretsky (JD, GWU)
Christina England (JD, Vanderbilt)

John Harris
Patricia Espinoza
Contracting Officers

Antony DiGiovanni (U. Mich)
Budget Officer
Eli Levine (JD, Wash. U St. Louis)

Commercialization & Strategic Outreach Teams

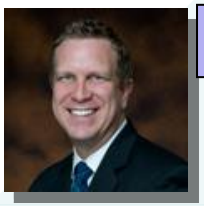
Commercialization:
Sanjay Wagle (Harvard/UCB)
Dr. Srinivas Mirmira (TAMU/Chicago)
Leshika Samarsinghe (Stanford/Harvard)

Strategic Outreach:
Peder Maarberg

Program Team

ARPA-E Fellows
Dr. Karma Sawyer (Chem, UCB)
Dr. Nicholas Cizek (Phys, Stanford)
Dr. Robert Conrado (Chem E, Cornell)

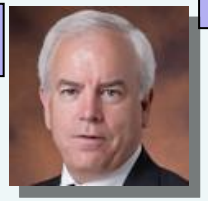
Dr. Dave Danielson



(Matl Sci, MIT, Gen. Cat.)

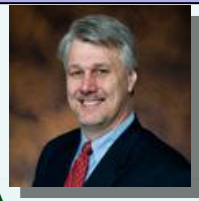
Dr. Eric Toone

Dr. Mark Hartney



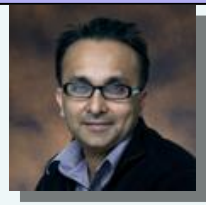
(Chem E, DARPA, FlexTech)

Dr. Mark Johnson



(Matl Sci, NCSU)

Dr. Ravi Prasher



(MechE, ASU, Intel)

Dr. Rajeev Ram

(EECS, MIT)

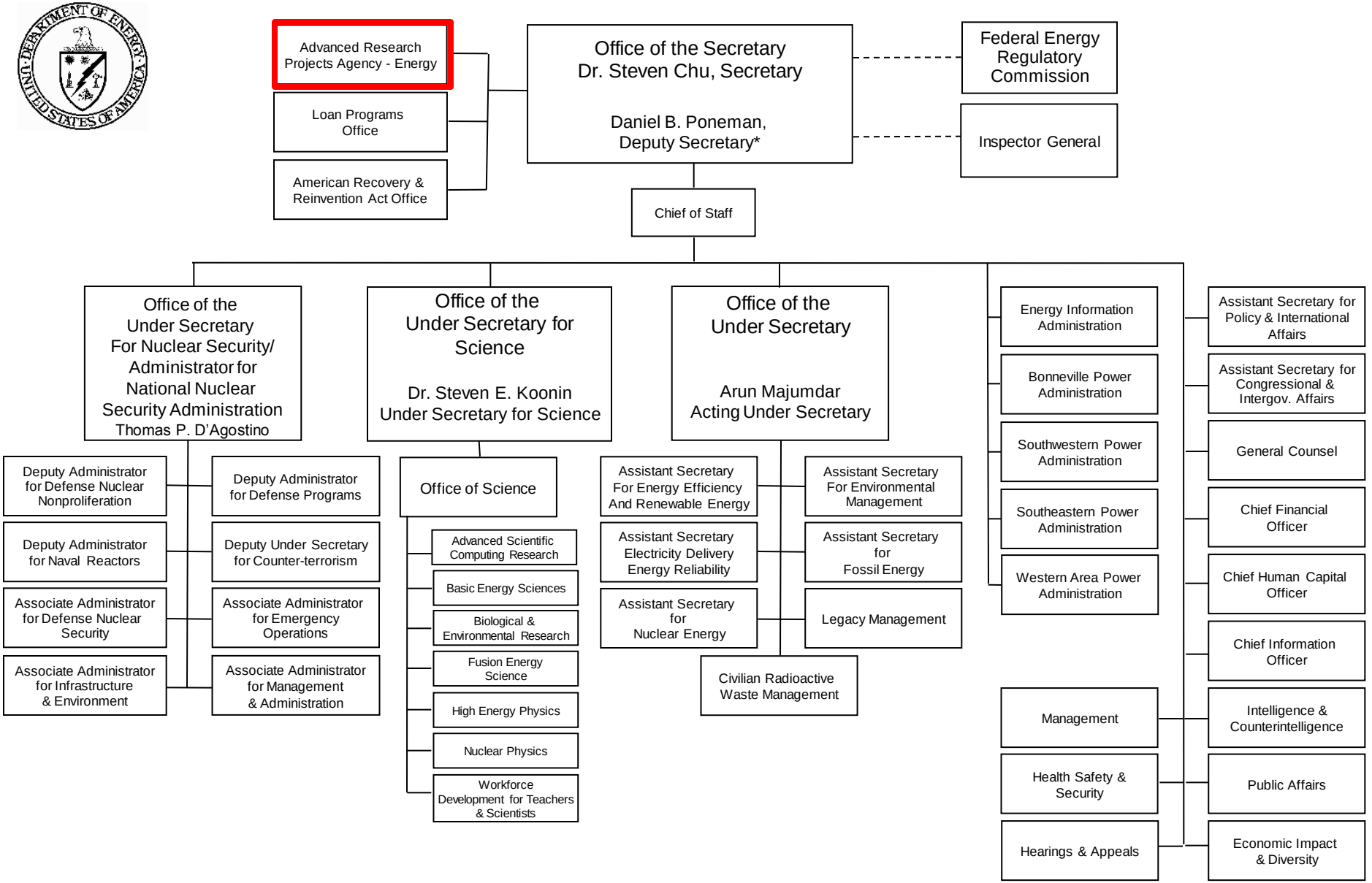
Dr. Jonathan Burbaum

(Biochem, Merck, Pharmacopeia)

Dr. David Shum

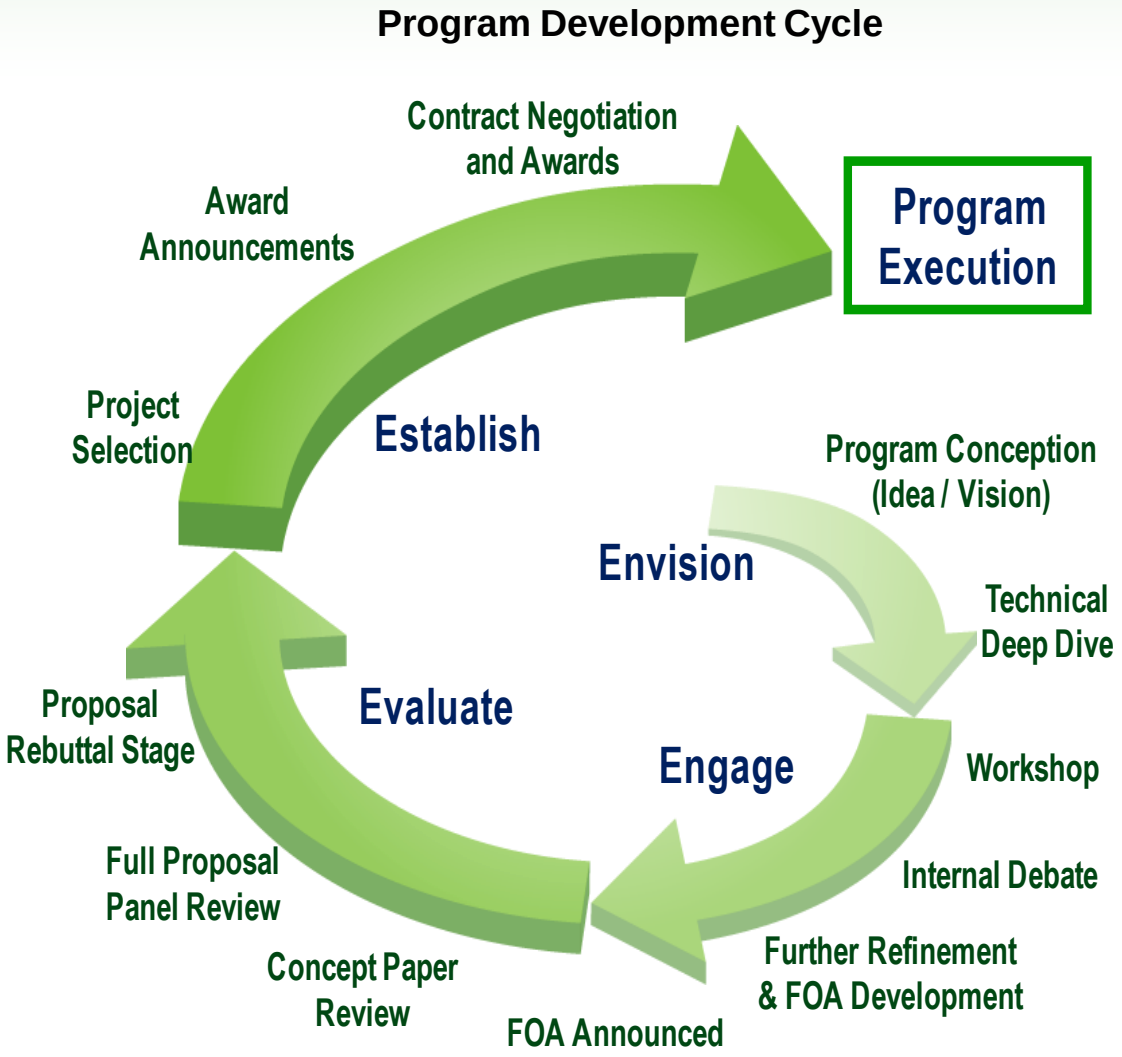
(MechE, Harvard, St. Gobain

DOE ORGANIZATIONAL CHART



* The Deputy Secretary also serves as the Chief Operating Officer

ARPA-E's program development process is extremely fast



From Program Conception to Execution in 6-8 Months

An ARPA-E Project has four main attributes

IMPACT

If successful, project could have:

- High impact on ARPA-E mission areas
- Large commercial application

BREAKTHROUGH TECHNOLOGY

Technologies that:

- Do not exist in today's energy market
- Are not just incremental improvements; could make today's technologies obsolete

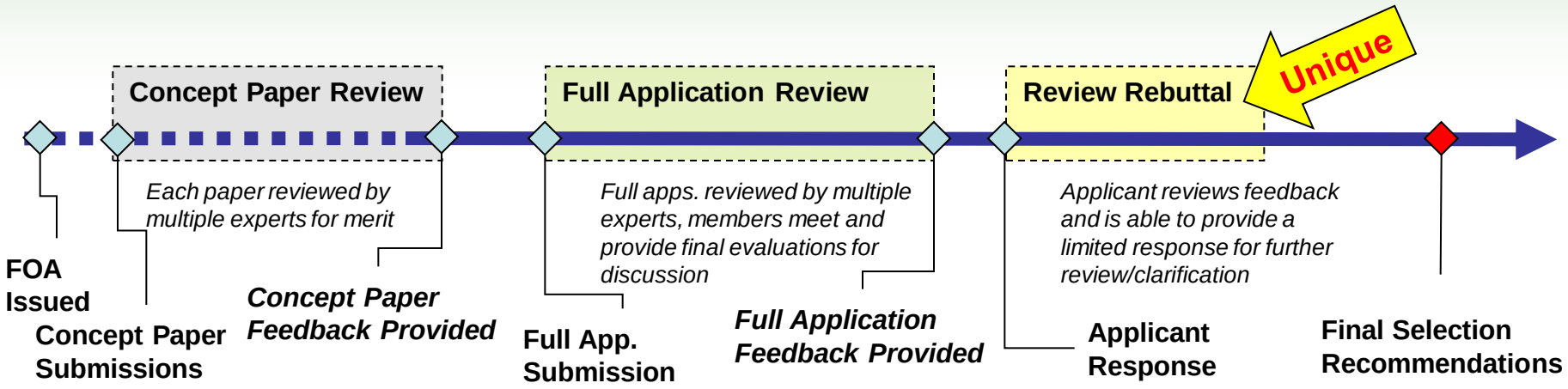
ADDITIONALITY

- Difficult to move forward without ARPA-E funding
- But able to attract cost share and follow-on funding
- Not already being researched or funded by others

PEOPLE

- Best-in-class people
- Teams with both scientists and engineers
- Brings new people, talent and skill sets to energy R&D

The Funding Opportunity Announcement (FOA) process is fast-paced, but deliberative



- 5-7 page summary
- Limits applicant expenses
- Reviewer comments provided to applicants

- Review by external, leading experts in the field
- External reviews critical to decision making – but scores do not get rack and stacked

- Applicants respond to reviews before selections
- Clarification improves final decisions

A streamlined contract negotiation and award process allows projects to begin promptly

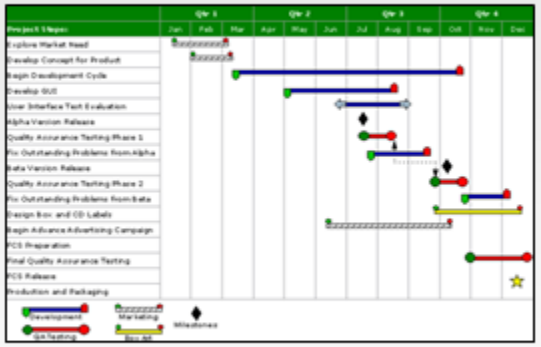
- Aggressive internal and external deadlines established – move at the pace of business
- ARPA-E Technical, Contracting and Legal teams co-located – limits bureaucracy
- ARPA-E developed user-friendly negotiation guide and materials provided
- Jointly develop challenging technical milestones

"ARPA-E has consistently impressed and surprised us with the speed of their evaluation and contracting process, and the high caliber of their staff…We wish all R&D programs could adopt this degree of efficiency and professionalism" – ARPA-E Performer

ARPA-E's active program management promotes eventual project success

Program Management Tools

SCHEDULE



COST

TECHNICAL NOTES

Task 1: Chip Fabrication			
	Subtask	*Milestone*	*Technical Notes*
	1.1: Deposit high capacitance materials	Q3: 20 microfarad capacitance achieved on 45 cm^2 sample	Best capacitance to-date is 12 µF; new oxide material was proposed at last meeting to achieve target
	1.2: Improve etch performance	Q4: New etching tool installed	On-track: PO made last week, delivery set for Nov.

Active Program Management

- ARPA-E has a vested interest in the success of the project, we do not just provide a check
- Regular contact – at least two site visits per year, and formal quarterly reviews
- Help identify and resolve technical issues
- Annual community meetings

ARPA-E Currently has six focused programs plus a broad portfolio of projects from its first solicitation

Broad Solicitation

Transportation

Electrofuels

BEEST

End-Use Efficiency

BEETIT

Stationary Power

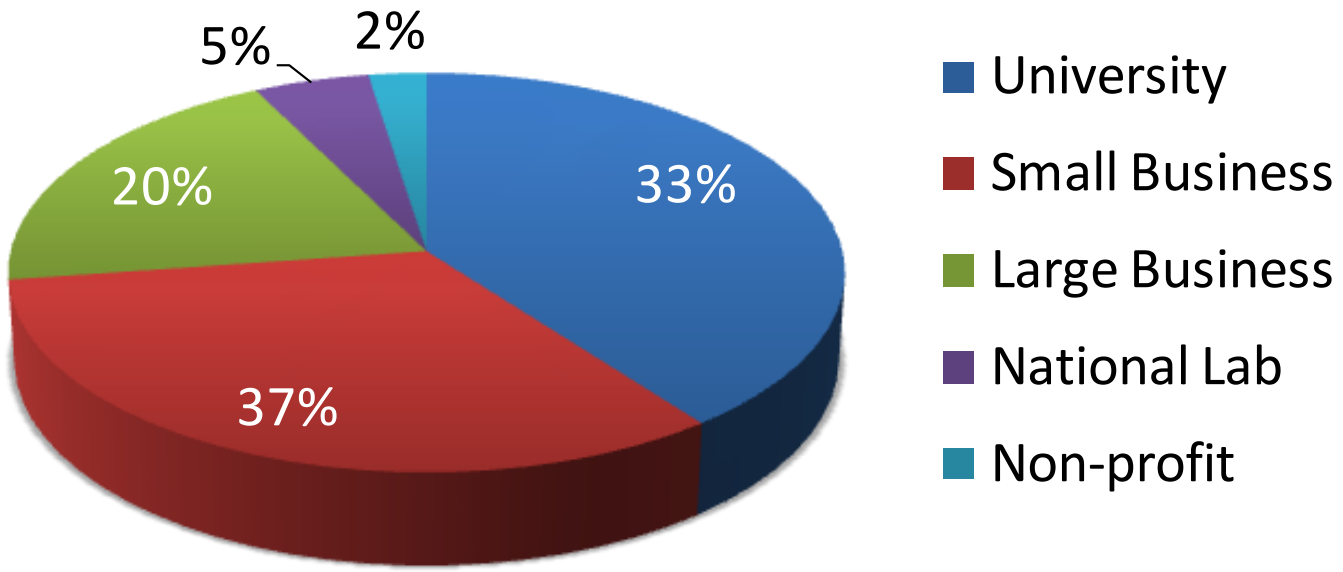
ADEPT

IMPACCT

GRIDS

To date ARPA-E has made 121 awards from seven FOAs to a wide variety of organizations

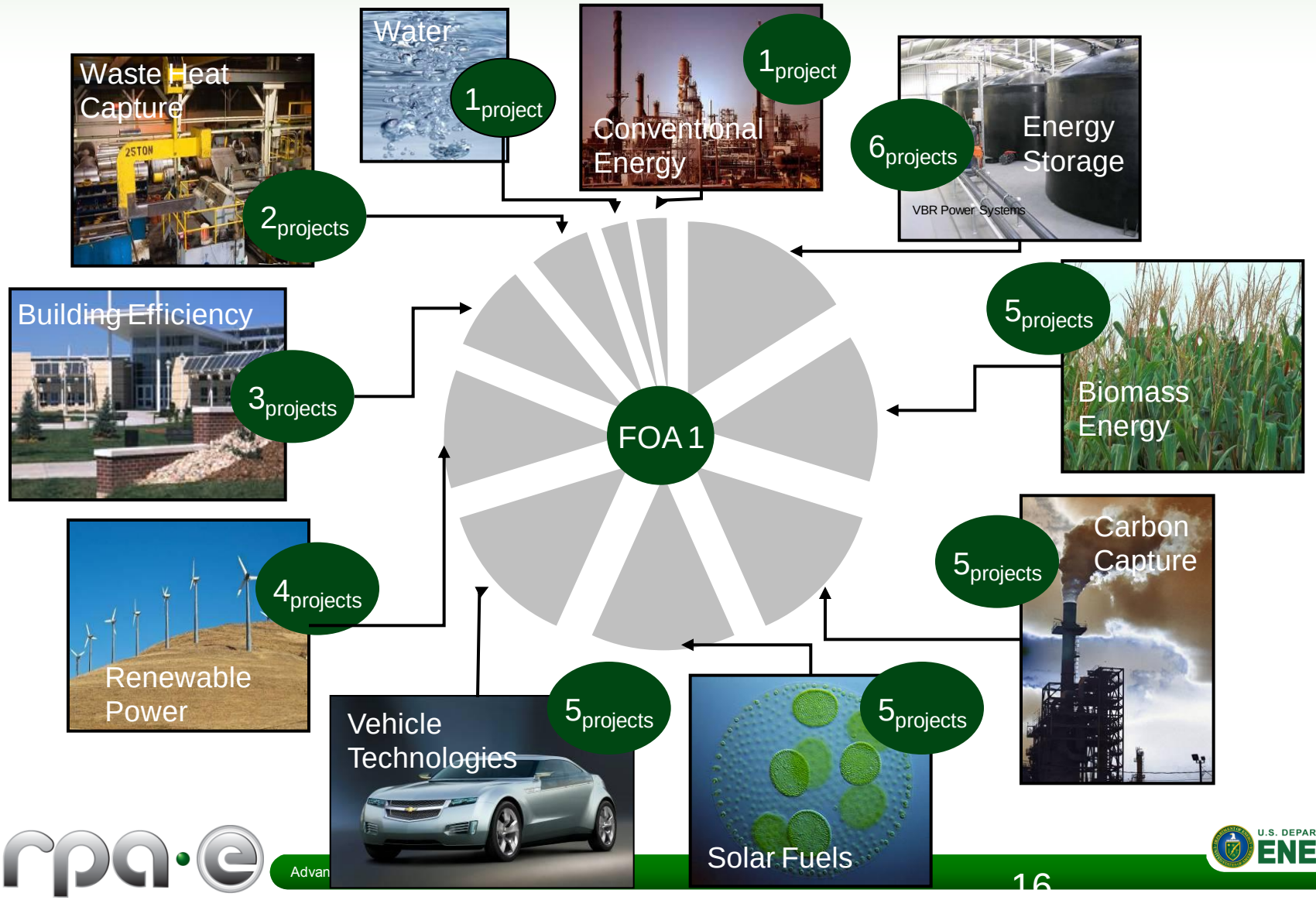
Project Breakdown by Lead Organization Type (% based on award value)*



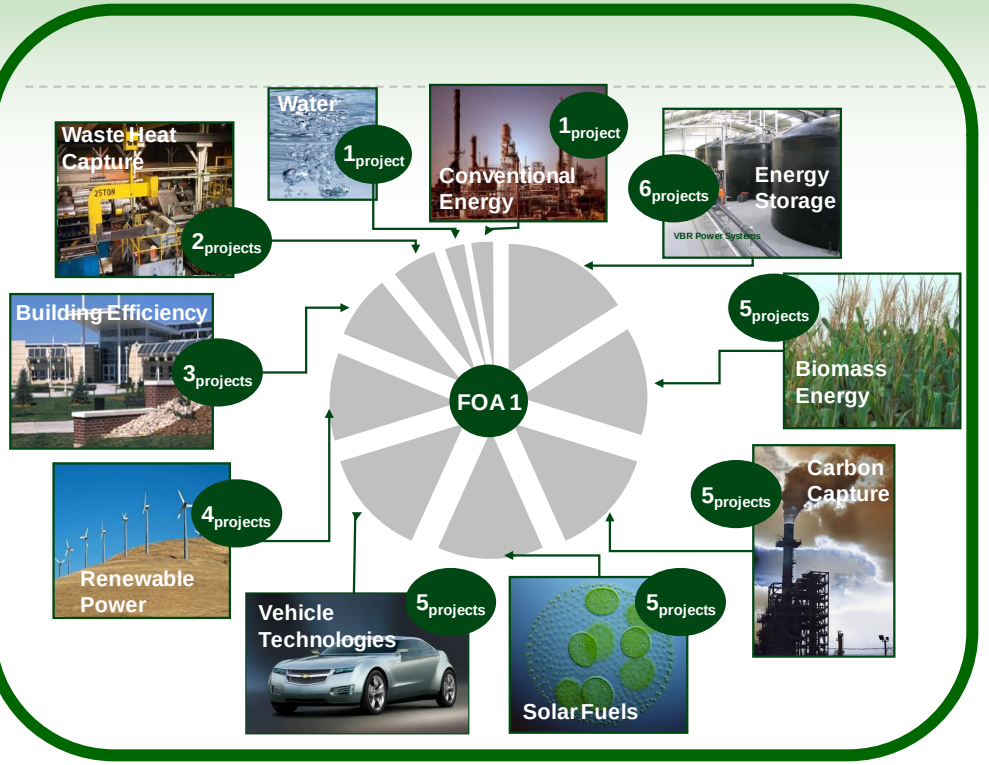
*Total Value of Awards = $366 million

Currently Funded Programs

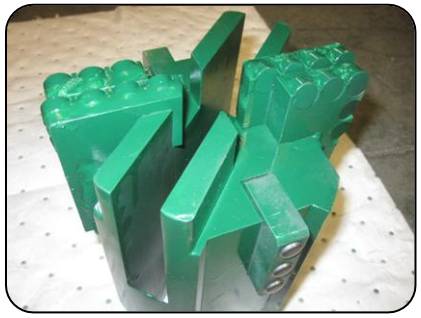
ARPA-E FOA 1 projects can be categorized into one of ten energy technology areas



FOA1



Low-contact drilling technology to enable economical geothermal wells



FORO ENERGY

Dr. Dave Danielson

ARPA-E Currently has six focused programs plus a broad portfolio of projects from its first solicitation

Broad Solicitation

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GRIDS

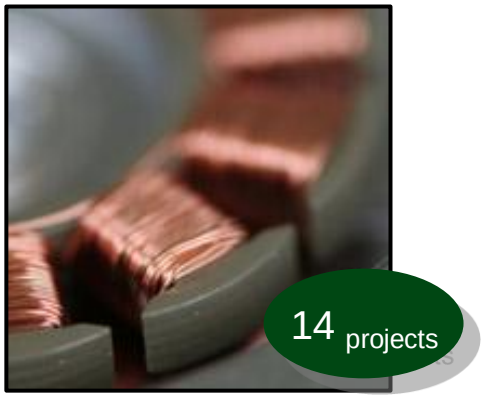
ARPA-E programs that enable on-site renewables

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

Agile Delivery of Electrical Power Technology (ADEPT)

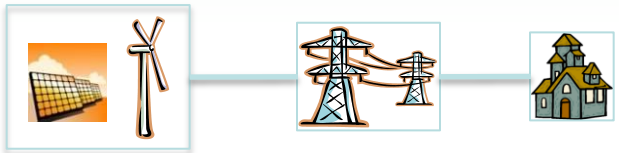


Exploring materials that will increase performance and lower costs of power conversion equipment

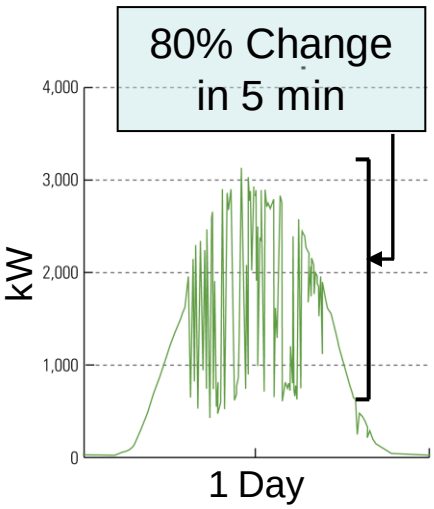
Could reduce energy consumption by up to 30 percent – or 12 percent of total U.S. energy consumption

Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)

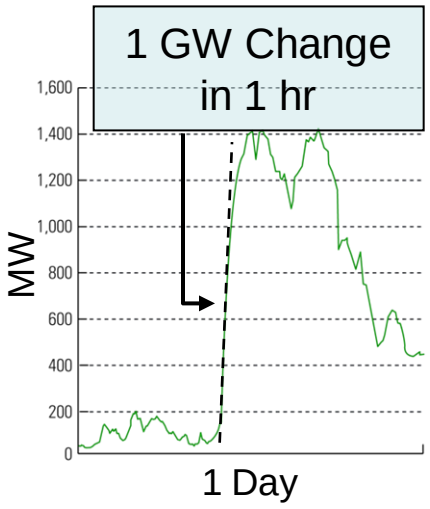
Renewables Today



Solar PV in AZ (TEP)

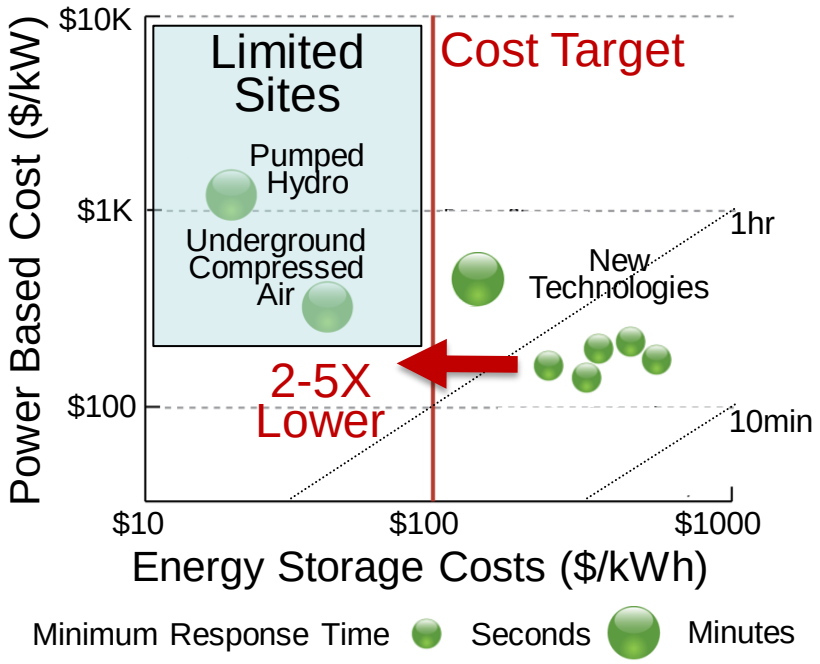


Wind in OR (BPA)



Problem:
Minutes-to-Hours Changes in Power

Storage for Renewables Tomorrow



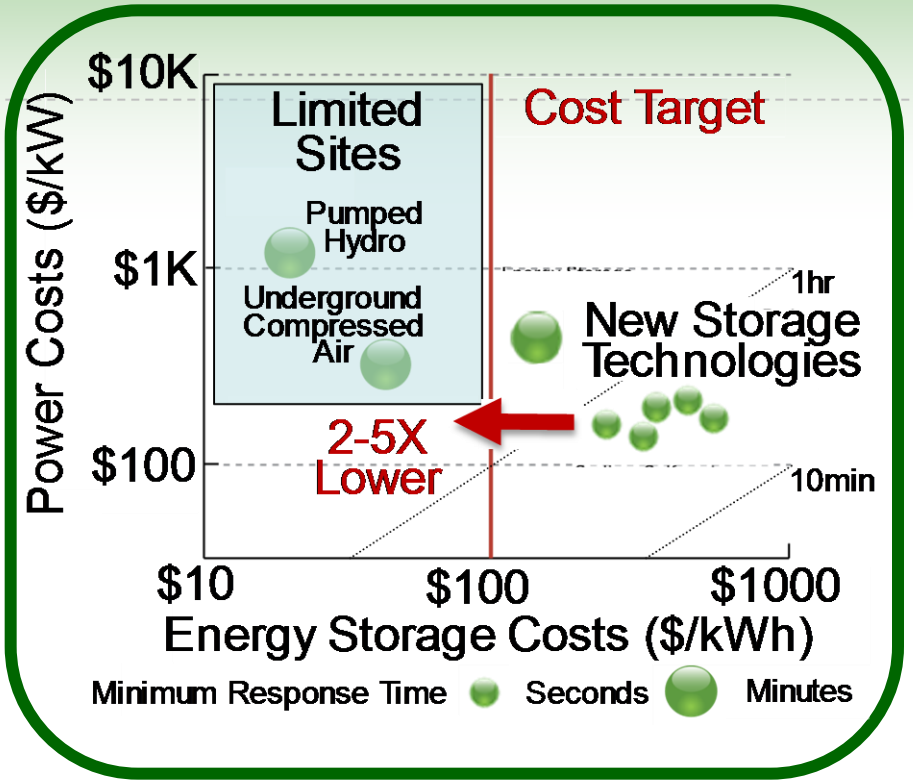
Need: Innovative Technologies for Cost-Effective Energy Storage

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

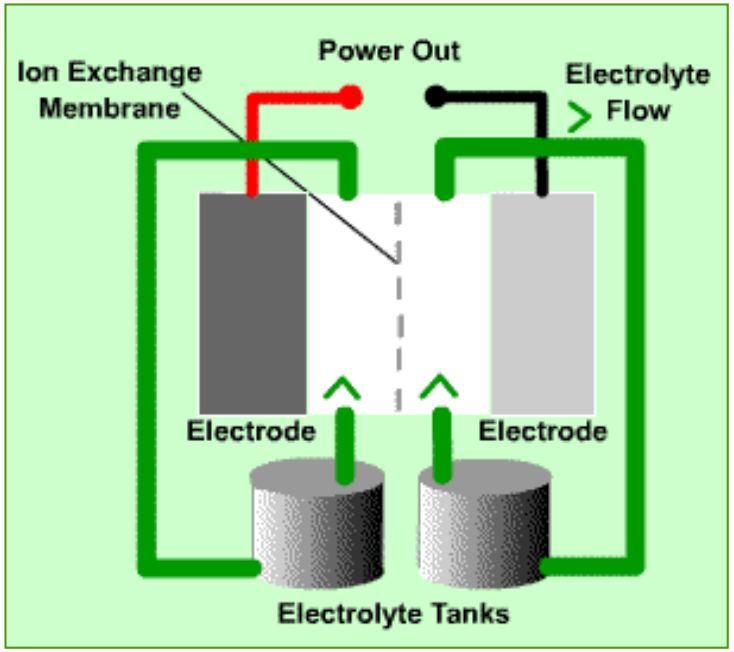
arpa

U.S. DEPARTMENT OF ENERGY

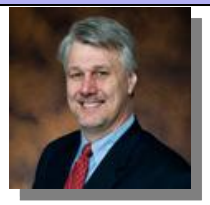
GRIDS

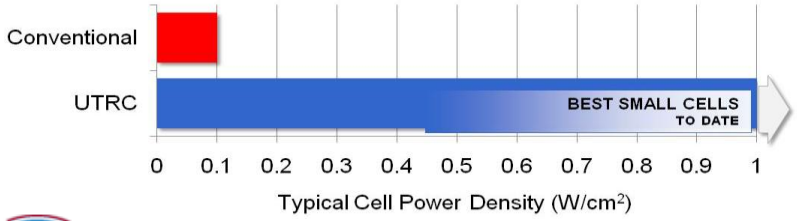


Transformative Electrochemical Flow Storage System



Dr. Mark Johnson





United Technologies Research Center

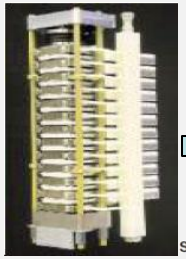
Clipper

Pratt & Whitney
A United Technologies Company

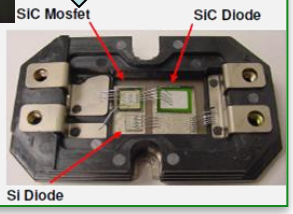
Pratt & Whitney Rocketdyne, Inc.

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

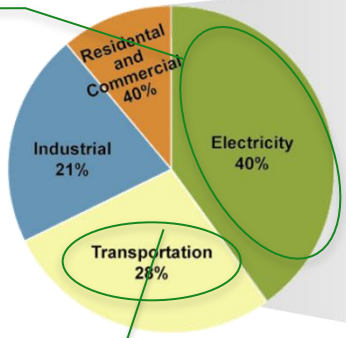
Distribution & Transmission



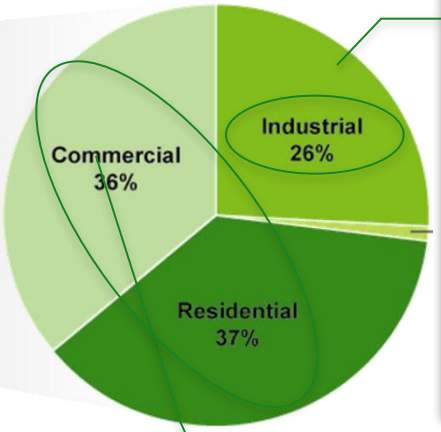
>13 kV, 50kHz SiC transistors



Primary Energy Use by Sector, 2008

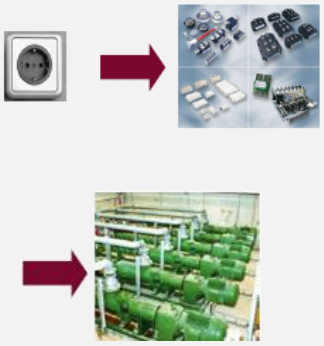


Share of Electricity Consumed by Major Sectors of the Economy, 2008

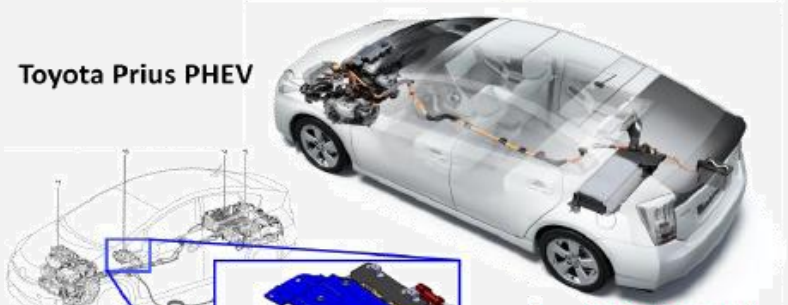


Industrial

Inverter drives motor



Automotive



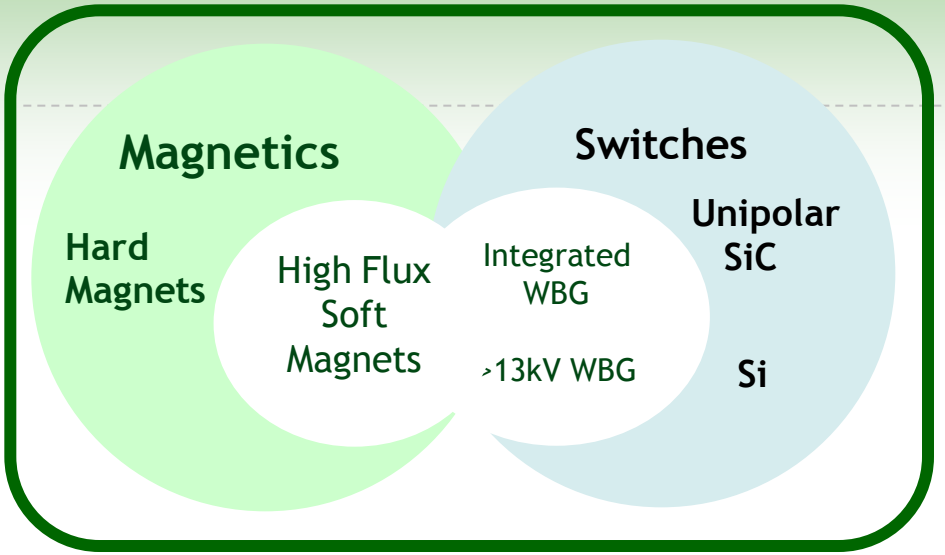
Lighting

Existing 25 W AC-DC SSL Driver

130 mm x 45 mm x 25 mm

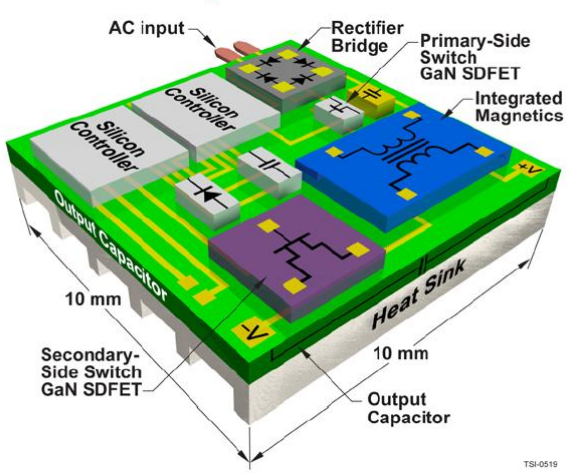
300X reduction in power stage volume

ADEPT



Chip-scale LED Driver for Commercial Lighting

25 Watt LED Electronics



300x reduction in power stage volume

Integrated Circuits for Power Systems

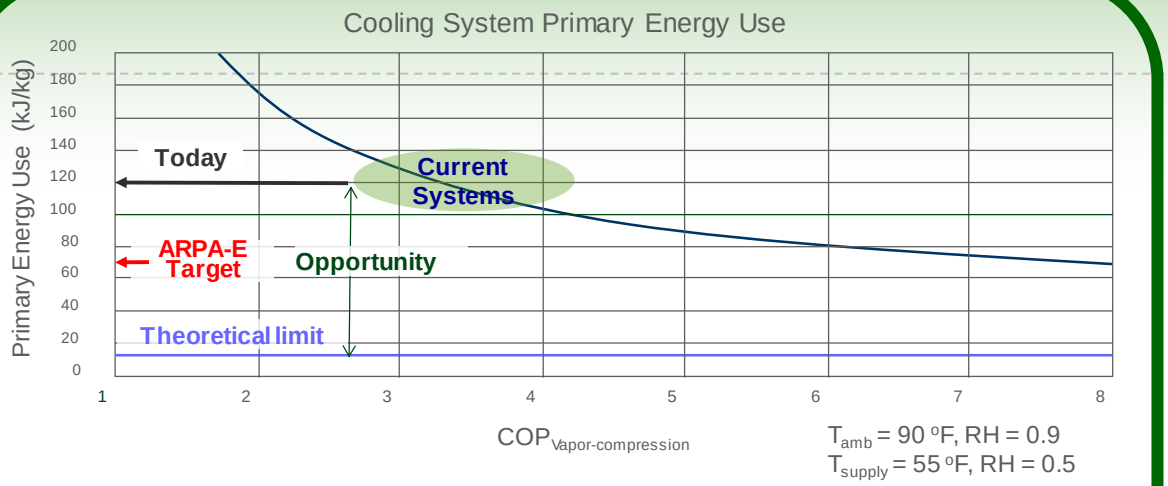
- On-chip inductors and transformers
- High-voltage transistors
- High-energy capacitors

TELEDYNE SCIENTIFIC & IMAGING, LLC
A Teledyne Technologies Company

Dr. Rajeev Ram

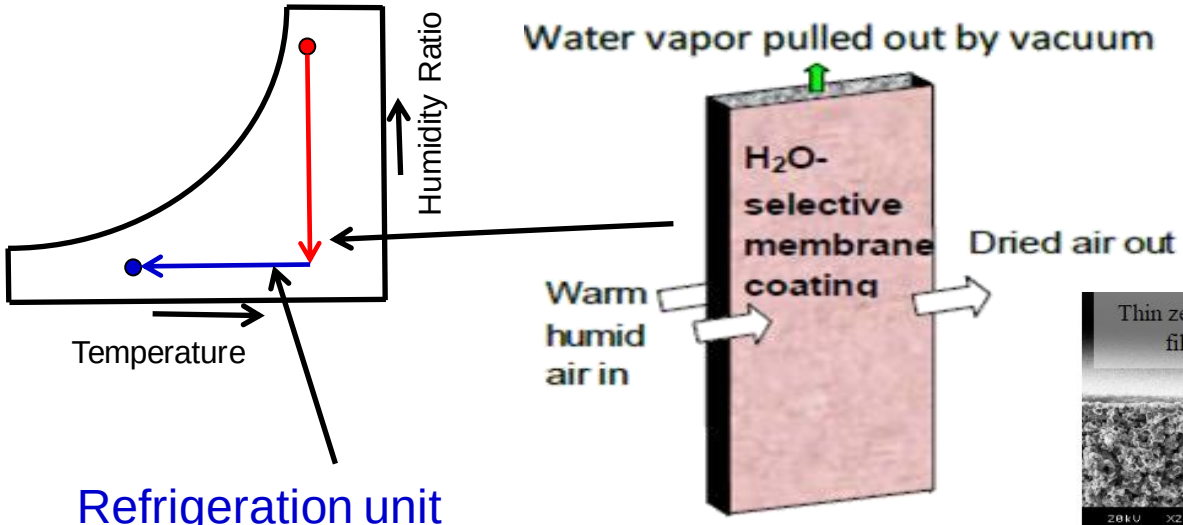
BEETIT

Dr. Ravi Prasher

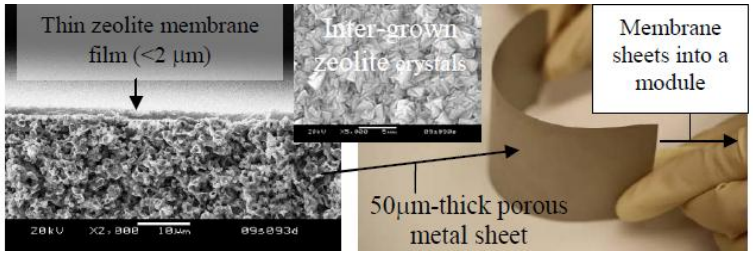


Reduce primary energy consumption by ~ 40 – 50%

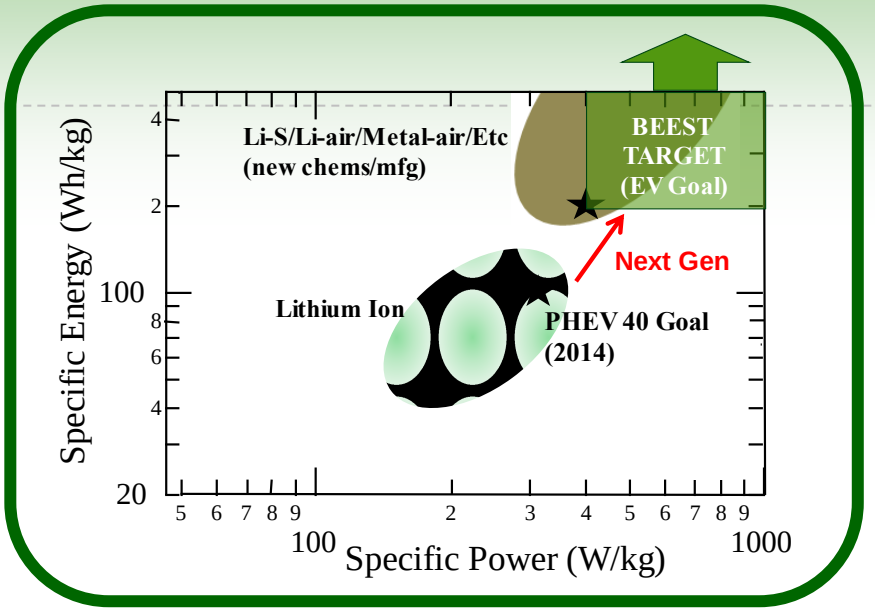
High-Efficiency, on-Line Membrane Air Dehumidifier Enabling Sensible Cooling for Warm and Humid Climates



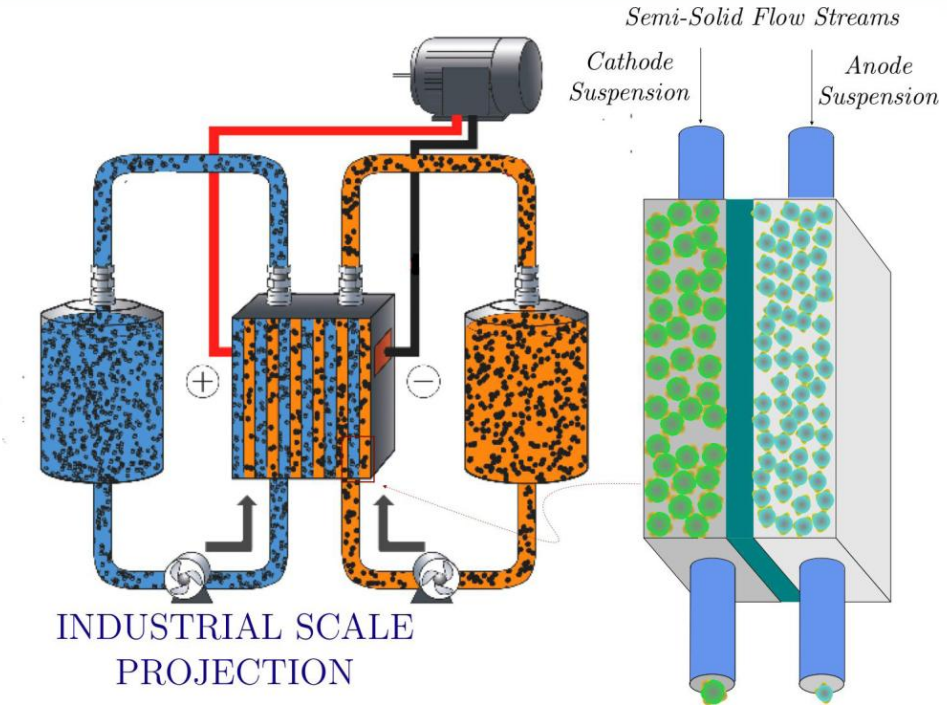
ADMA ADVANCE MATERIALS



BEEST



The Semi Solid Flow Cell (SSFC): Flow Batteries meet Solid Batteries



24M

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

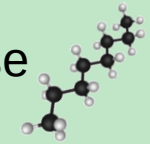
Dr. Dave Danielson

	Redox Density (M)	Voltage (V)
Aqueous Flow Battery	~ 2	~1
50% Solids SSFC	10-25	~3.5

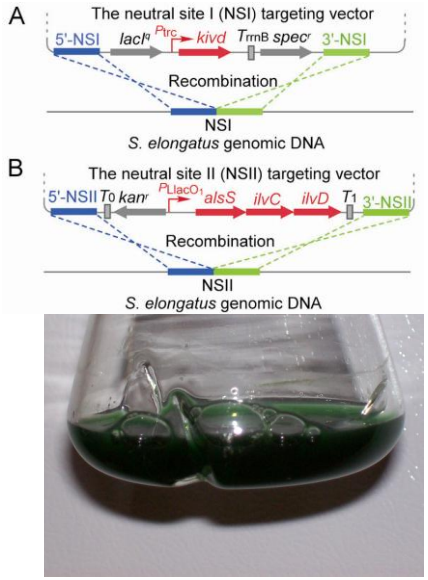
Electrofuels

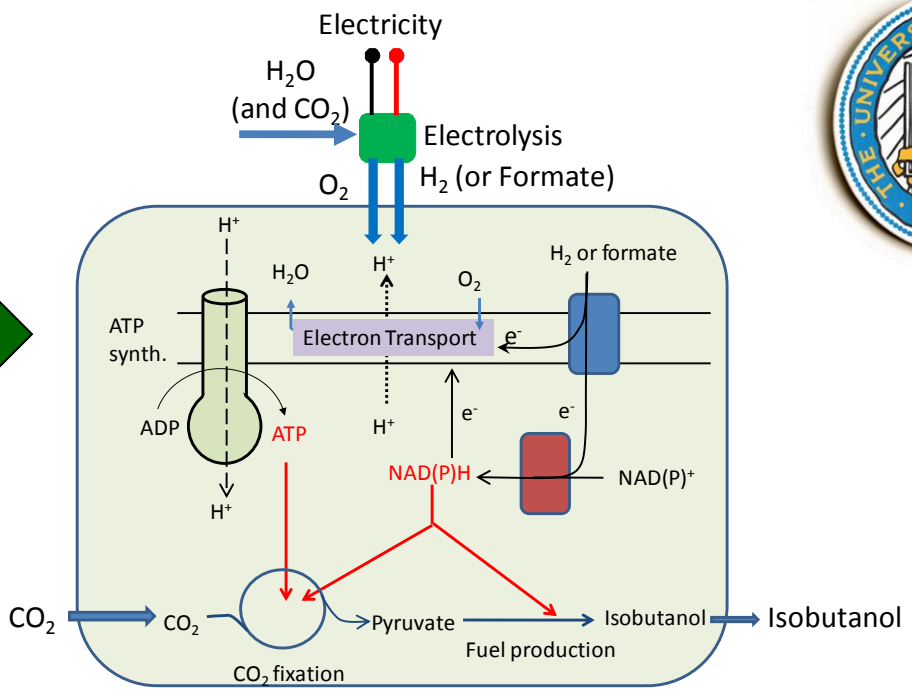
1. Assimilate Reducing Equivalents 

2. Fix CO_2 for Biosynthesis 

3. Generate Energy Dense Liquid Fuel 

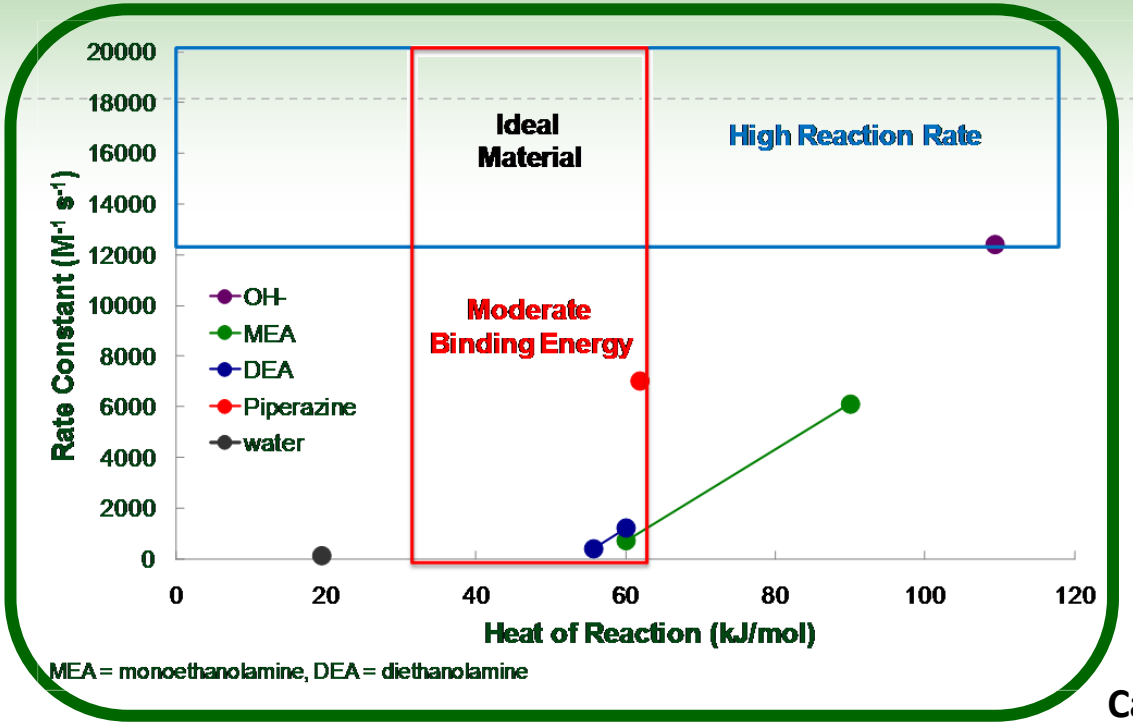
Electro-Autotrophic Synthesis of Higher Alcohols





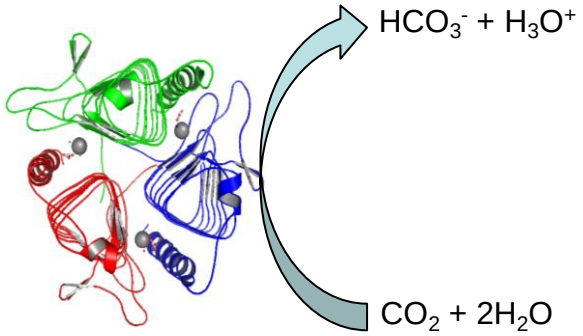
Dr. Eric Toone

IMPACCT



MEA = monoethanolamine, DEA = diethanolamine

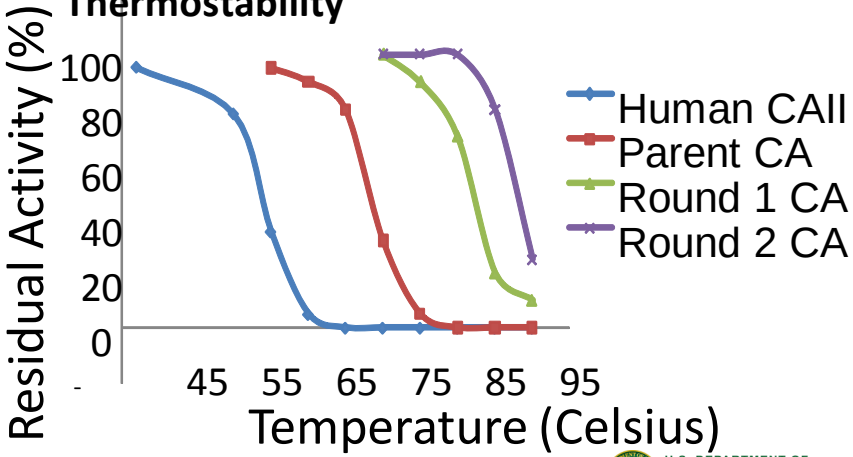
Low-Cost Biological Catalyst to Enable Efficient CO_2 Capture



Dr. Mark Hartney

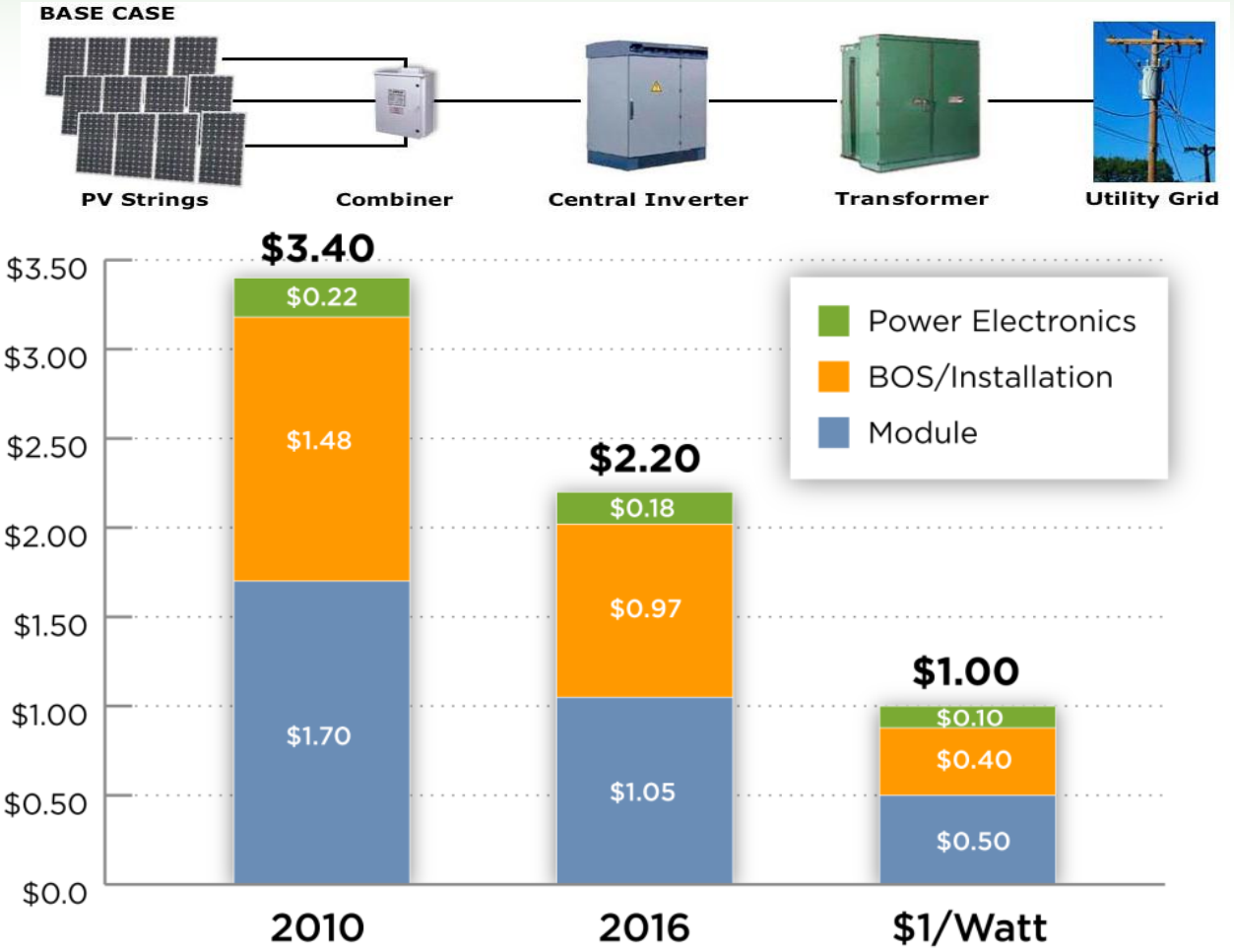
CODEXIS®

Carbonic Anhydrase (CA) Thermostability



Workshops

Power Electronics in Photovoltaic Systems (2/8/11)



5-6¢/kWh fully installed at the MW scale by 2020

High Density Thermal Energy Storage (1/31/11)

Scale

Temperature

<100 °C

~ 500 °C

> 800 °C

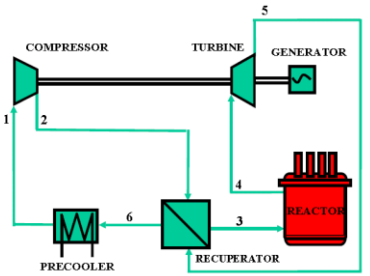
PHEV & EV

Increase EV range by ~ 40%

CHP systems in buildings

Reduces primary consumption ~ 25%

Synergy between Solar and High-Temp Nuclear

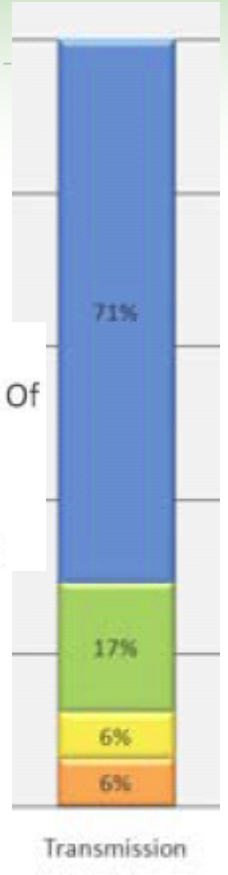


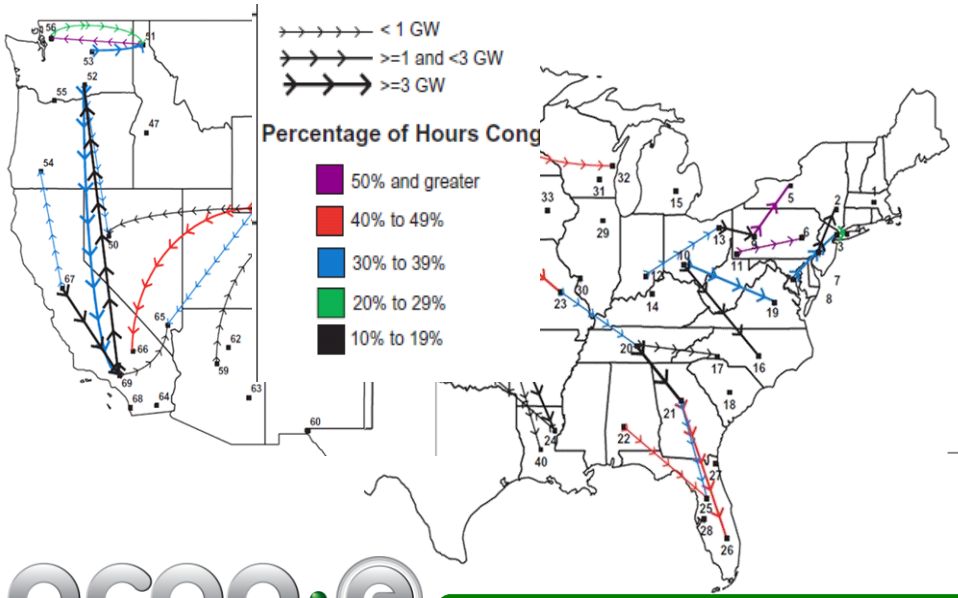
Increase in efficiency > 50% compared to current systems (T ~ 300- 400 °c)

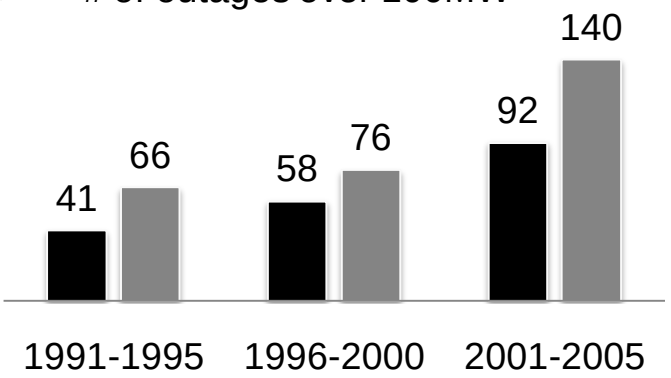
Green Energy Network Integration (12/13/10)

- Congested Lines
- Aging Infrastructure
- Increasingly unreliable
- Increasingly unpredictable

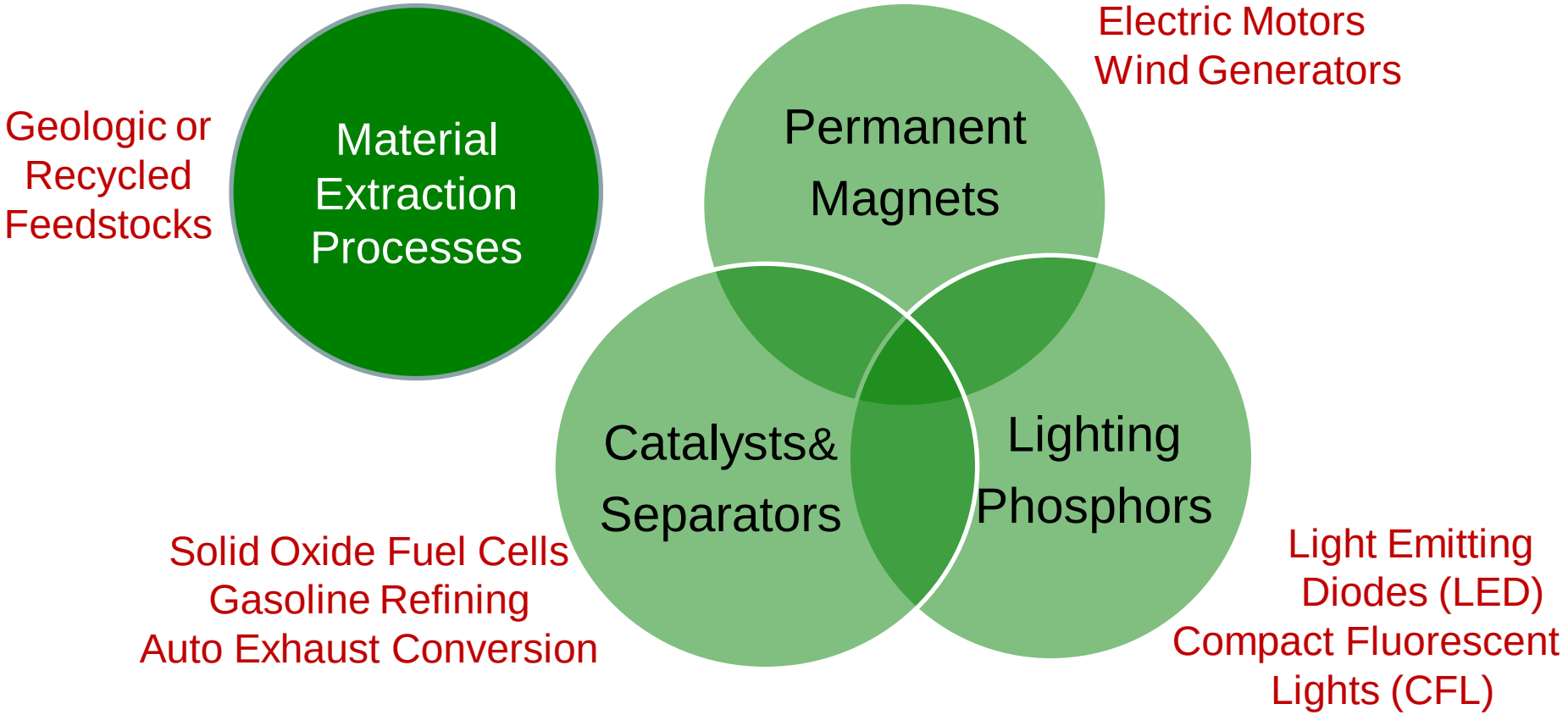
"Today, the average age of a substation transformer is 42, two years more than their expected life span."



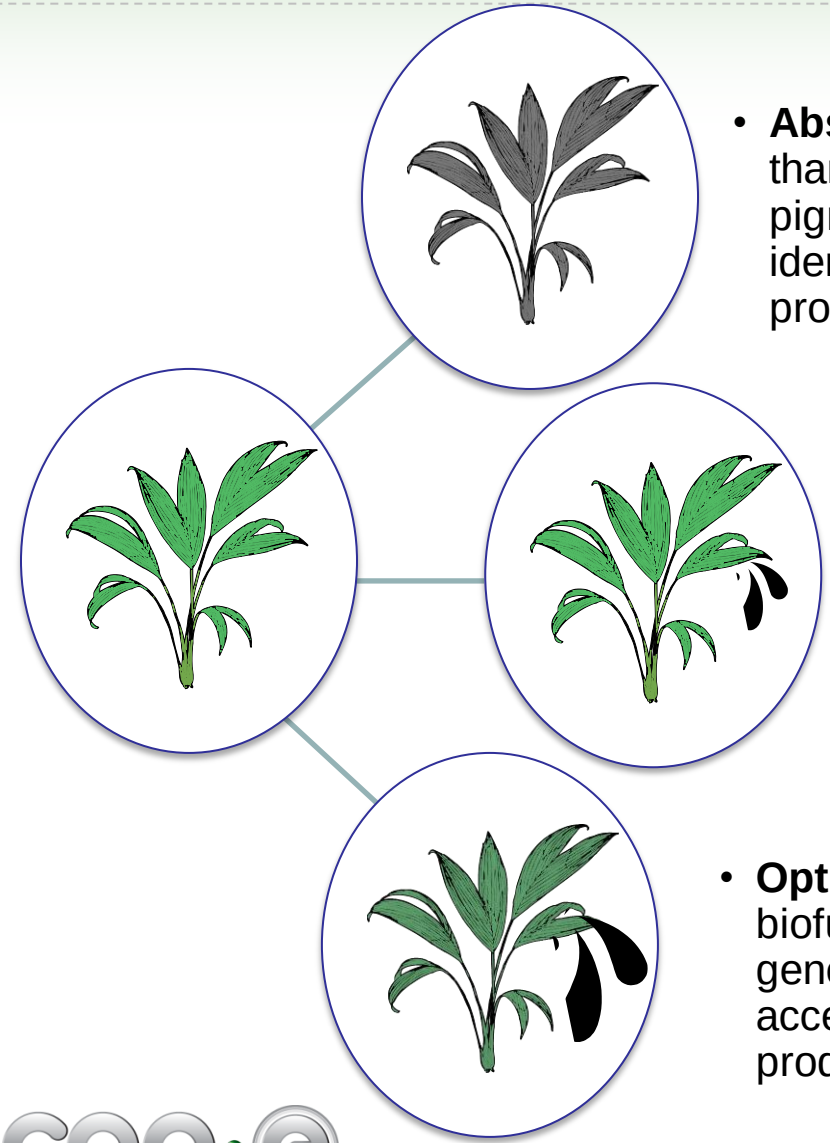




Critical Materials Technology (12/6/10)



Applied Biotechnology for Transportation Fuels (12/2/10)



- **Absorption:** Ordinary photosynthesis uses less than half of the incident light energy. Biological pigments that absorb more energy have been identified, but have not used in biofuel production.

- **Metabolism:** Currently, biofuels are fermented from biologically created materials. The two biological processes are able to be combined into a single process to generate fuel directly.

- **Optimization:** A dedicated source of biofuel is an agricultural crop. Rapid genetic selection can be used to accelerate the development of viable production strains.

Questions