

# **Advanced Research Projects Agency – Energy (ARPA-E)**

**Dr. Arun Majumdar**

**Director, ARPA-E**

**U.S. Department of Energy**

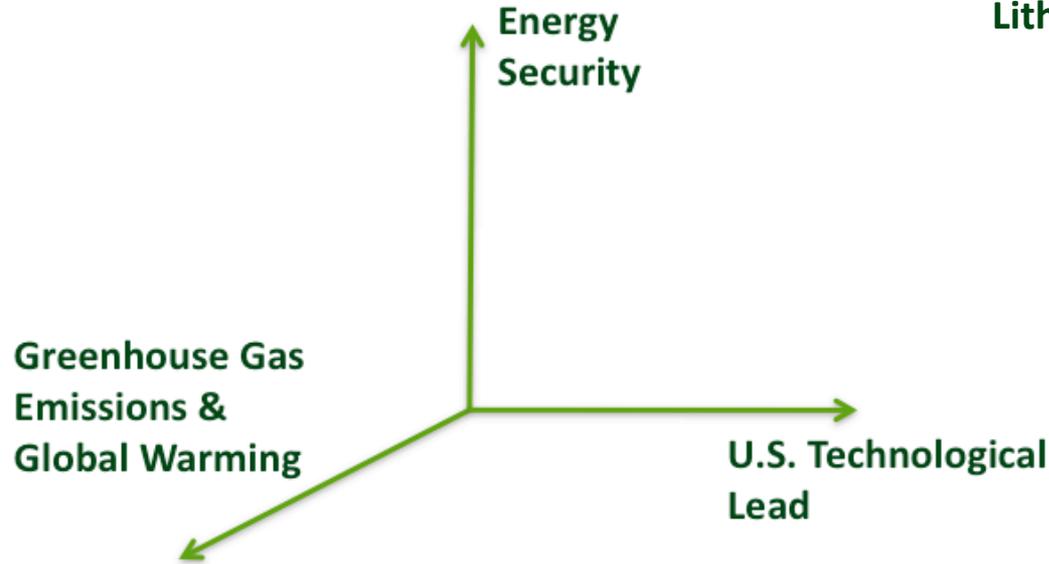
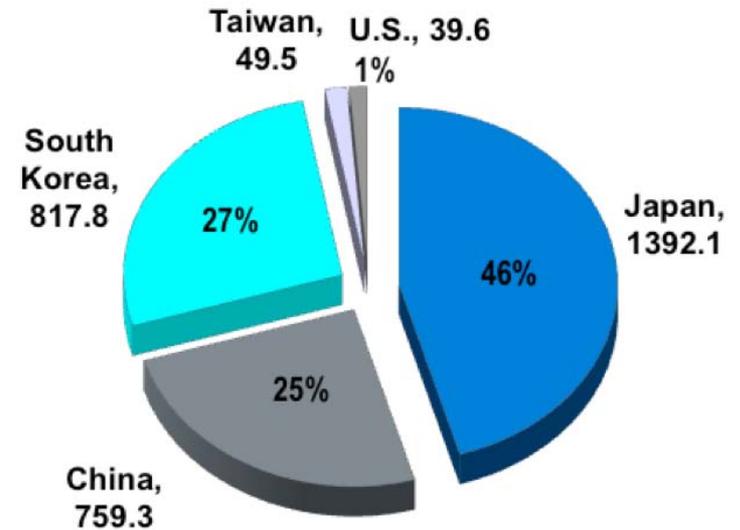
**<http://arpa-e.energy.gov/>**

# SPUTNIK MOMENT OF OUR GENERATION



## EXAMPLE

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



THE ENRICO FERMI AWARD

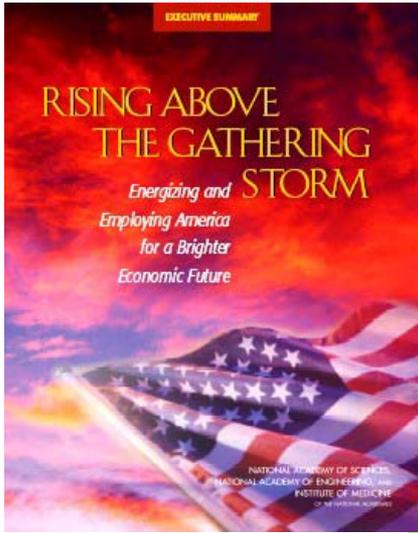
2009



John Goodenough, U. Texas at Austin



# CREATION OF ARPA-E

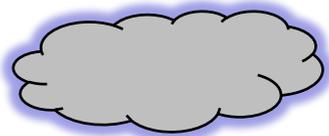


## American Recovery and Reinvestment Act of 2009 (Recovery Act)

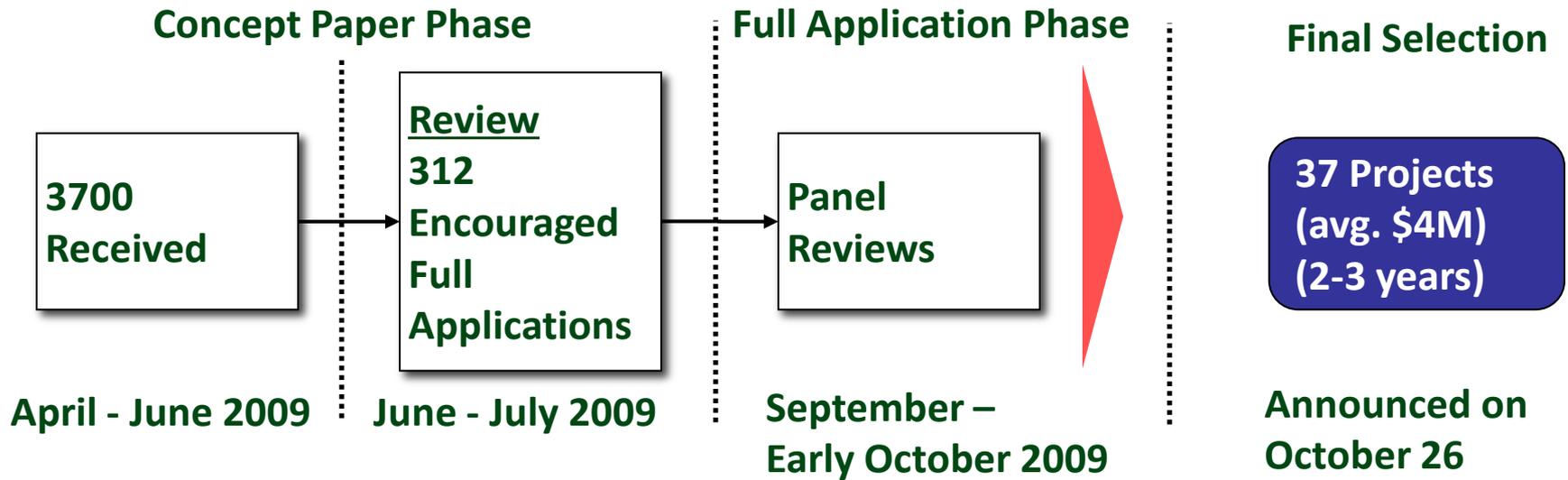
2007  
**America COMPETES Act**

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

2006  
*Rising Above the Gathering Storm*  
(National Academies)



# FIRST ROUND OF FUNDING



**Award Negotiations Completed in 3 months including 3 Uses of Other Transaction Authorities**

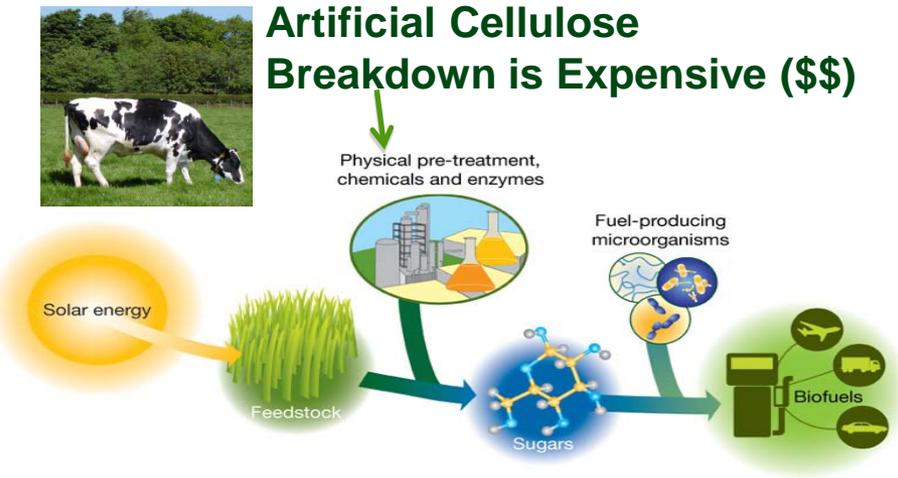
“In my 30 years of doing Government contracting.....I have never seen any government project move from selection to contracts and to actual work with such speed anywhere near what we are seeing out of ARPA-E.....” CEO, Diversified Energy Corporation, Gilbert, AZ - 01/27/10

# EXAMPLES FROM FIRST ROUND OF FUNDING



## Cellulosic Biofuels

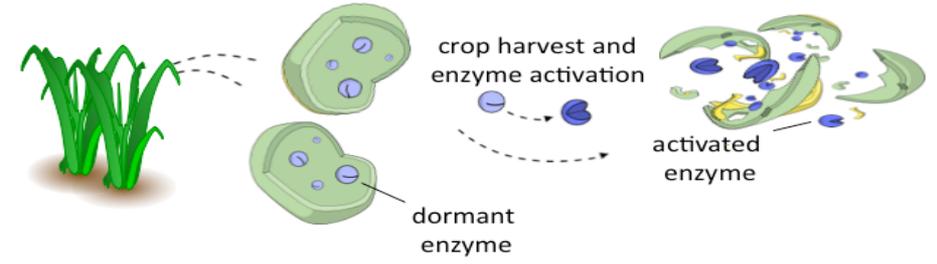
### Artificial Cellulose Breakdown is Expensive (\$\$)



## AgriVida

## GreenGenes™ Technology

### Putting the cow inside the plant!



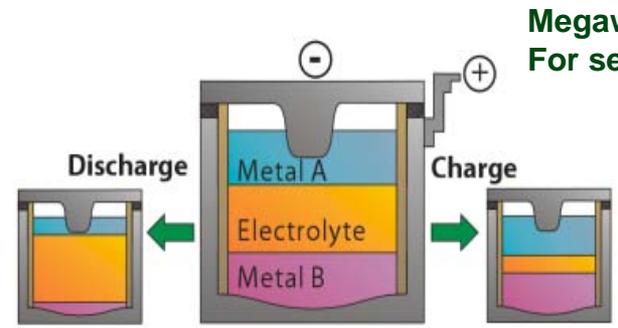
**Plant produces all the enzymes & chews itself from the inside!!**

## Breakthrough High Efficiency Mixer/Ejector Wind Turbine (MEWT) – FloDesign Wind Turbine Corp.



- Mimic jet engines, not propellers, for wind turbine
- 40% lower cost expected vs. horizontal axis wind turbines (HAWT)

## Grid-Level Electricity Storage - MIT



**Megawatts of storage For several hours**

**Potential Cost: \$50/kW-hr**

Lithium Ion Laptop Battery: \$2000/kW-hr  
Lithium Ion Car Battery: \$1000/kW-hr



# 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; Attract the US  
Intellectual Horsepower  
to Energy**

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

# BATTERIES FOR ELECTRICAL ENERGY STORAGE FOR TRANSPORTATION (BEEST)



Recapping Stanford (Capacitive)

**Program Director:** David Danielson (PhD Materials Sci, MIT; General Catalyst)

Upside ↑

- Cell-level energy density: 400 W-hr/kg (2.5X higher)
- Cost: \$250/kW-hr (4X lower)
- New architectures & manufacturing processes

Ultra-High Energy

**Sion Power (Li-S)**  
**ReVolt (Zn-Air Flow)**  
**PolyPlus (Li-Air)**  
**Missouri Inst of Sci/Tech**

MIT (Flow Batt)

Pellion (Mg-Ion)

Mfg Innovations

**Planar Energy Devices (Solid State Li-Ion)**  
**AMAT/A123/LBNL (Li Ion Mfg)**

Infrastructure Compatible High Energy Materials

Time to Market →



# INNOVATIVE MATERIALS AND PROCESSES FOR ADVANCED CARBON CAPTURE TECHNOLOGIES (IMPACCT)



**Program Director:** Mark Hartney (PhD Chem Engr, UC Berkeley, DARPA, Lincoln Labs, Bell Labs, Flex Tech)

**Today:**  $\text{CO}_2 +$



**Amine Chemistry**

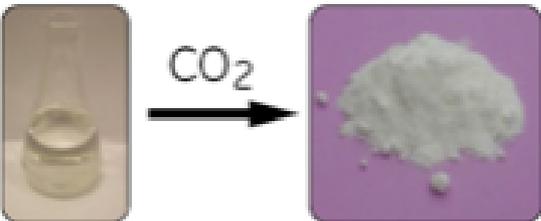
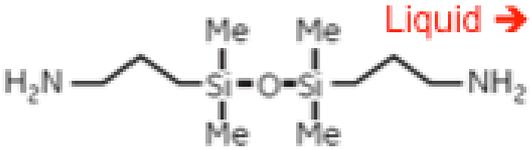
**Bind, Isolate & Release**

**Cost: \$70-100/tCO<sub>2</sub>**  
**Cost Above Price = Loss!**

**High-Temperature Heat**

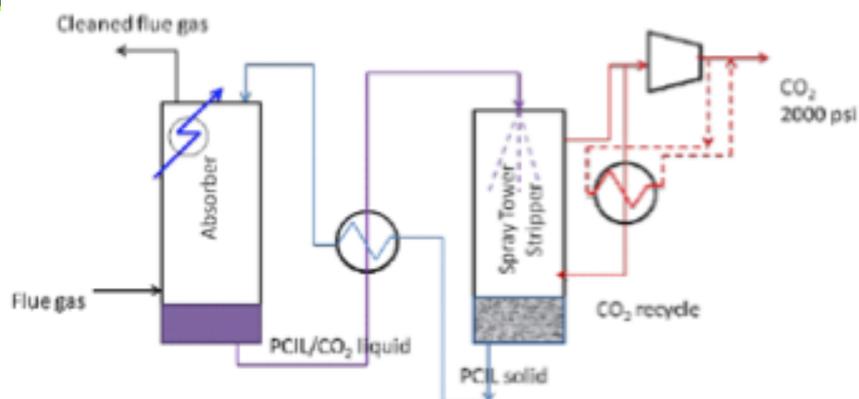
**Market Price of CO<sub>2</sub>: ≈ \$30/tCO<sub>2</sub>**

**ARPA-E High-Risk/Phase Changing Absorbents**



**(GE, U. Pittsburgh)**

**Phase Changing Ionic Liquids**



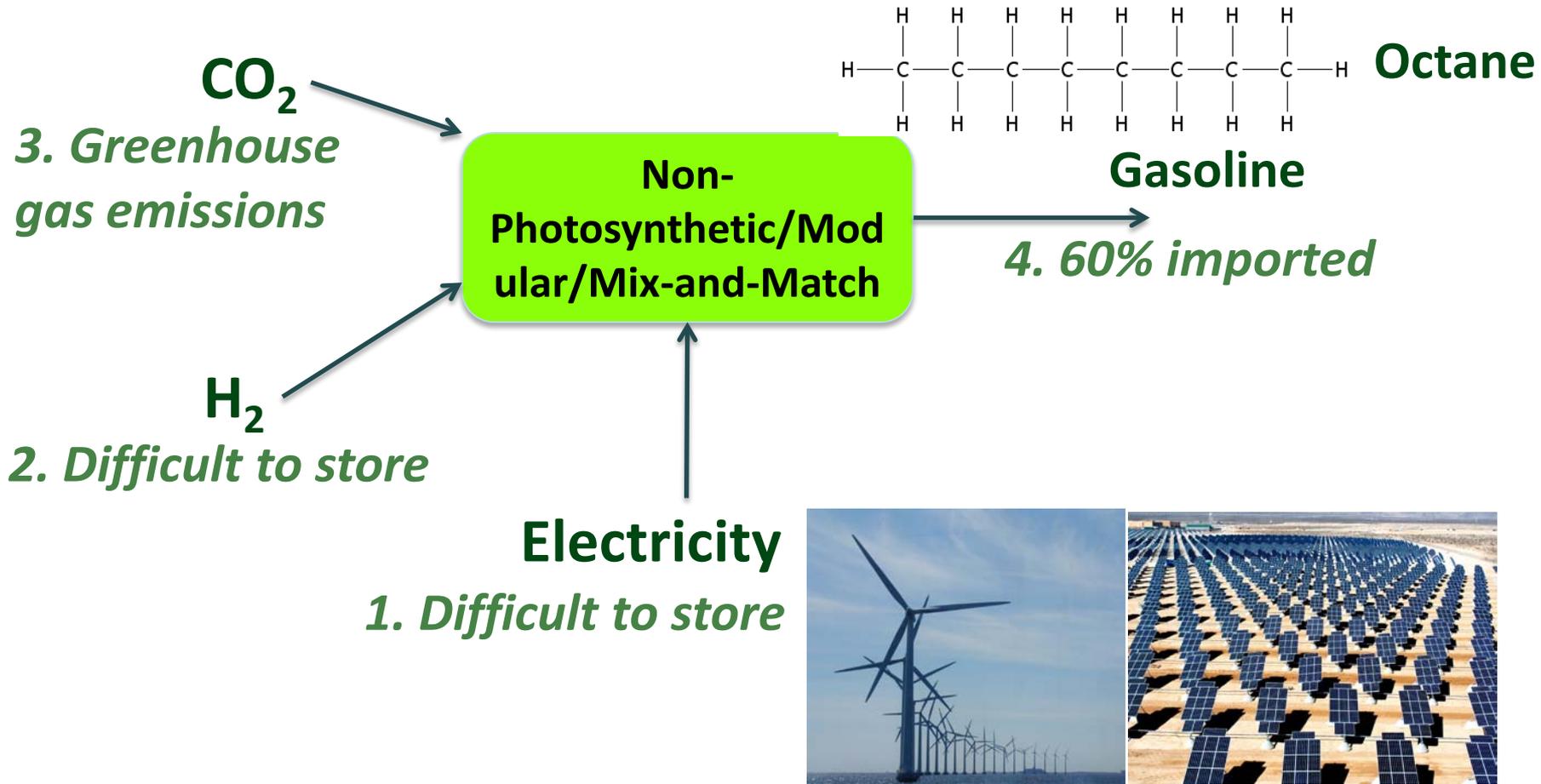
**Joan Brennecke (2009 Lawrence Awardee) (U. Notre Dame, MATRIC)**



# ELECTROFUELS



**Program Director:** Eric Toone (Robert Bass Prof of Chemistry, Duke; PhD-Toronto; Post-Doc - Harvard)

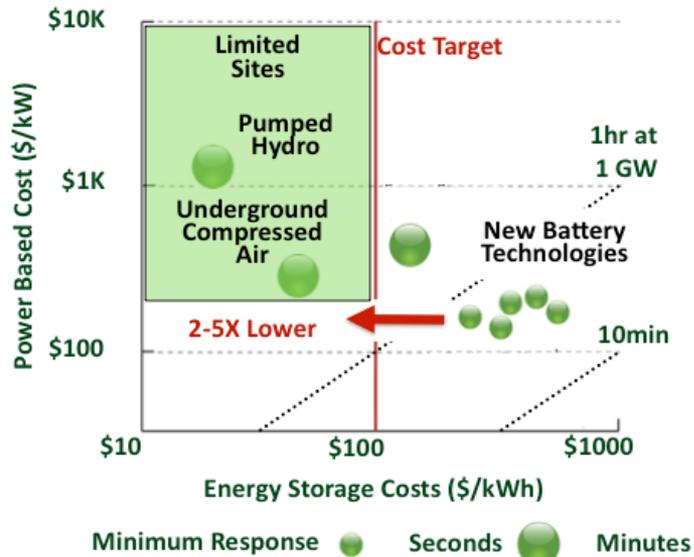


PIs: David Baker (U. Washington), Jay Keasling (Berkeley), Pam Silver (Harvard), ....

# ROUND 3 PROGRAMS



## Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)



**Program Director:** Mark Johnson  
(Prof. of Mat Sci, NCSU)

## Building Energy Efficiency Through Innovative Thermo-devices (BEETIT)



**Program Director:** Ravi Prasher (Formerly Intel, PhD-ASU)

Announced: March 2, 2010  
Awardees Selected: July, 2010  
All Awards Made: September, 2010

## Power Electronics

*...results in low-cost, higher performance power electronics across many applications.*

Fully integrated, chip scale power converters (10-50W, >100V)




Solid State Lighting      Computers

Kilowatt scale package integrated power converters (3-10 kW, >600V)





Inverters      Motors

Lightweight, solid state, medium voltage energy conversion (1MW, 13kV)

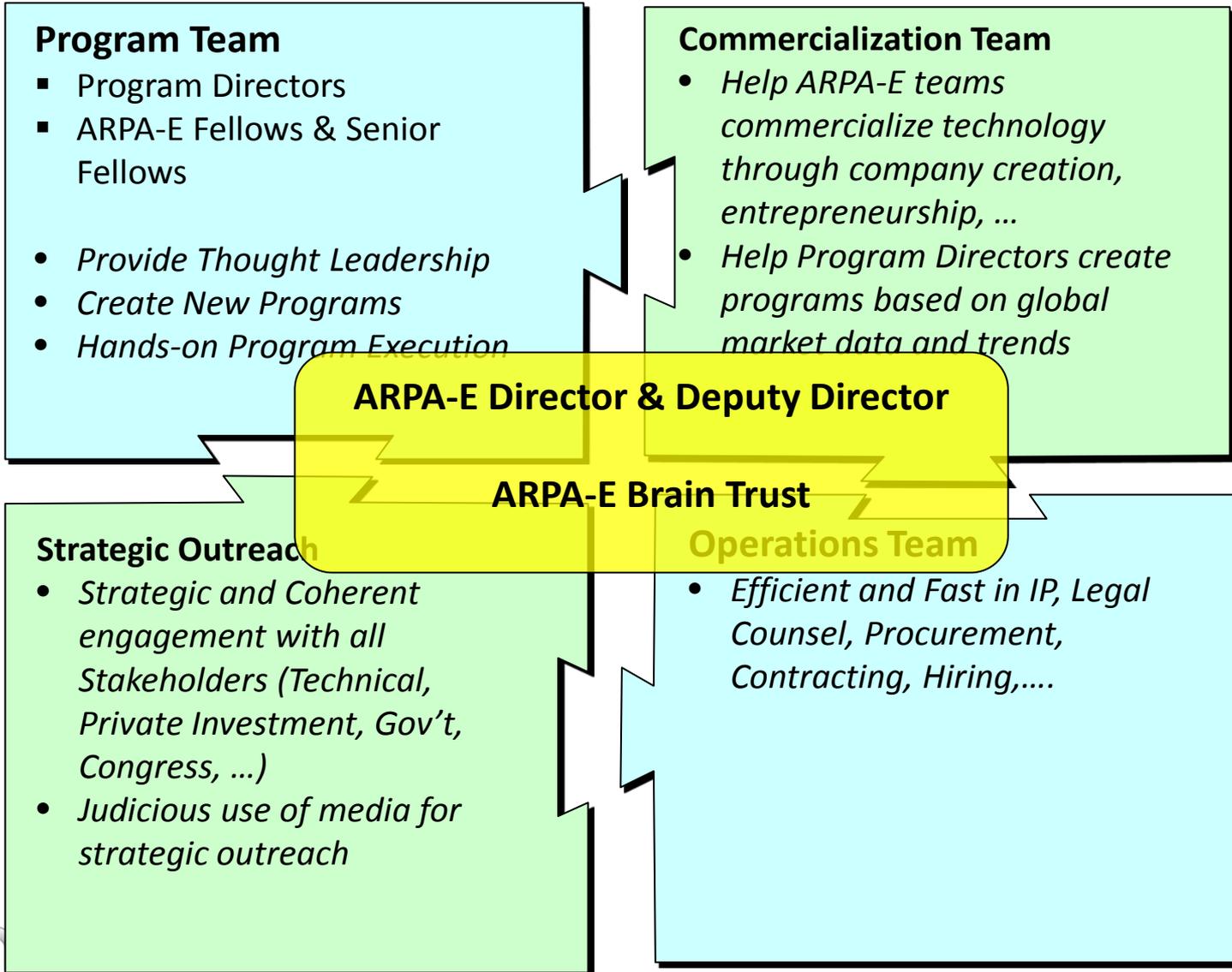



Solid-state electrical substations      Wind turbines

**Program Director:** Rajiv Ram (Professor, EECS Dept, MIT)

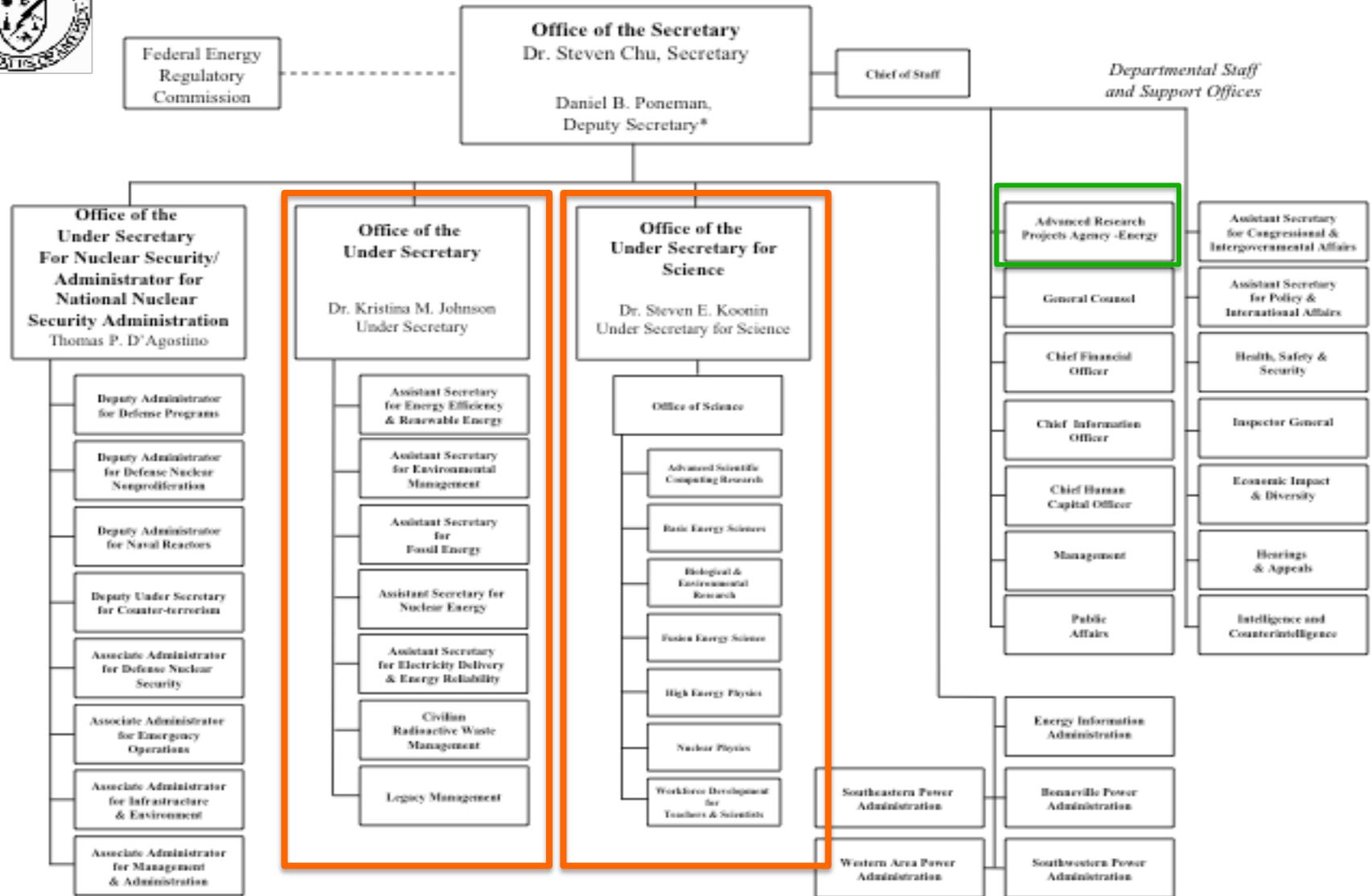


# ARPA-E TEAM





# DEPARTMENT OF ENERGY



\* The Deputy Secretary also serves as the Chief Operating Officer

# MANAGING EXPECTATIONS



**NOW**

**3 - 5 YRS**

**10+ YRS**

- Attracting the best minds to energy R&D
- Follow on investment post ARPA-E award (\$)
- Increase in enterprise value of company (\$)
- Companies created (#)
- Initiating new technology-business ecosystems
- Accelerated market entry - Products to market (#) / Product sales (\$)
- Patents filed and licensed (#)
- Papers published in top journals (#)
- World Record-setting “best-in-class” performance (#)

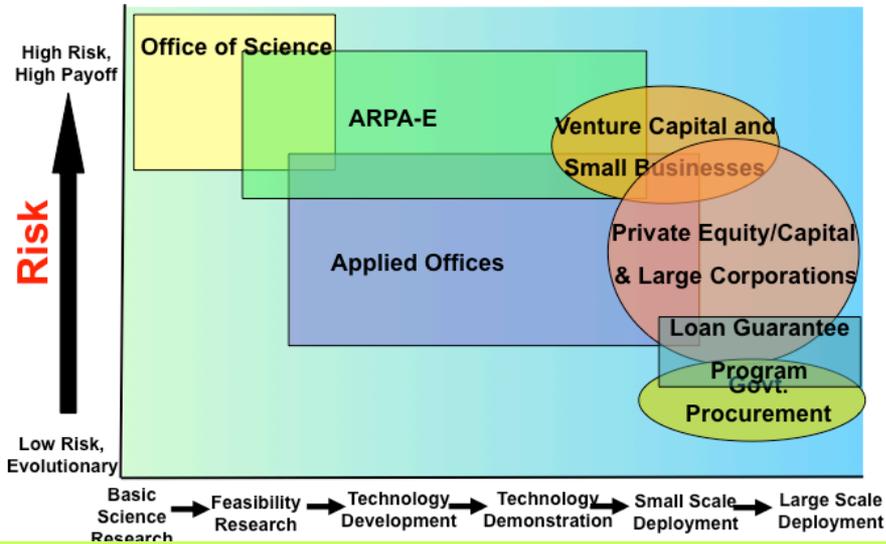
## Home Runs

- Domestic and global sales, US market share (\$)
- Avoided greenhouse gas emissions (tCO<sub>2</sub> equivalent)
- Reduced oil imports (barrels of oil equiv.)
- Creation of new technology/business or new industry ecosystem (#)
- Jobs created (#)
- Beating current projections and trajectories (Moving McKinsey GHG abatement cost curves, EIA & IPCC projections, etc.)

# ENERGY INNOVATION NETWORK – How to scale?



**Historically:** (a) Change is slow; (b) Energy is a ubiquitous commodity; (c) Investments & systems can last a long time



**ARPA-E ENERGY INNOVATION SUMMIT**  
MARCH 1ST – 3RD, 2010  
GAYLORD CONVENTION CENTER  
WASHINGTON, DC



- 2 months preparation; 1700 attendees
- Summit acting as a “catalyst” by integrating relevant communities
- Technology showcase

“Probably the best conference I have ever attended with extremely high caliber speakers and panelists. Great job!”  
– *Executive from large corporation*

“It was great to see a fast paced, entrepreneurial mentality applied to energy.” – *Technology company executive*

“Great event. Came away with renewed enthusiasm for DOE’s ability to be part of the solution.” – *Academic researcher*

“As an investor, I found the technology showcase to be of tremendous value. Not only in terms of finding prospective investments, but also to get my finger on the pulse of up and coming technologies in the field. This was by far the best part of the conference for me.” – *Investor*

# Issues Related to Starting Up



- Direct reporting to and engagement of the Secretary, and thereby some nurturing and care from above
- Clarity of mission and clearly defined role within the DOE
- Budget with a positive slope is critical
- Special hiring authority of personnel
  - *Civil service laws*
  - *Finite tenure of program directors and exit strategy for programs/projects*
- Support from within the DOE on operations & programs
  - *Legal; Contracting/Procurement; HR; IT,...*
- Innovations in Process
  - *Aggressive timelines (ARRA-induced creativity), contracting/procurement, reviews, absorb and adapt best practices from everywhere...*
  - *Questioning tradition, not afraid to try out new approaches*
- Close coordination and making it a win-win proposition for rest of DOE
  - *Office of Science, Applied Energy Programs*

# Issues Related to Starting Up

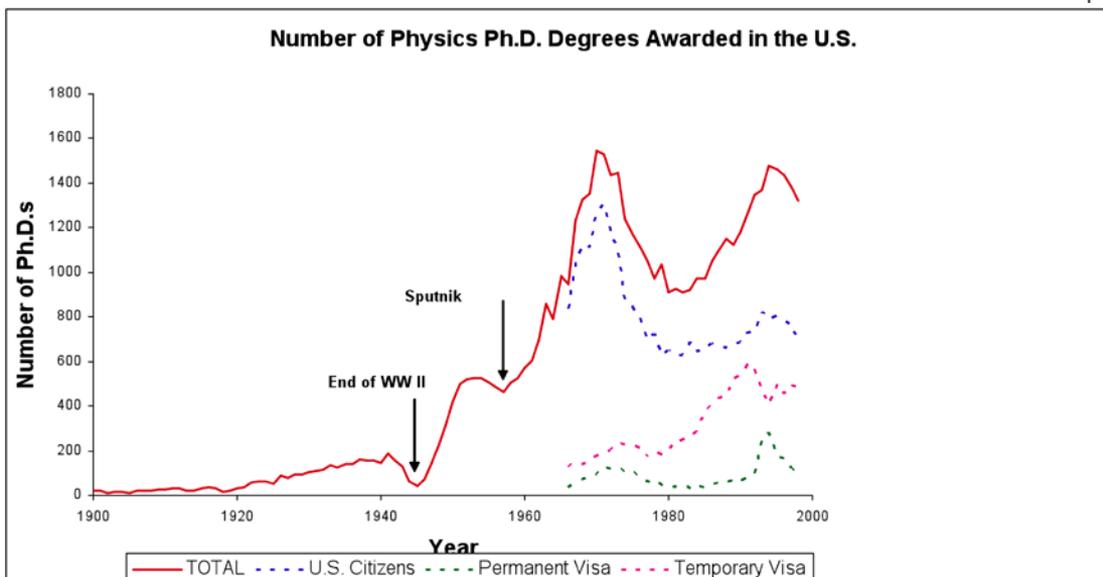
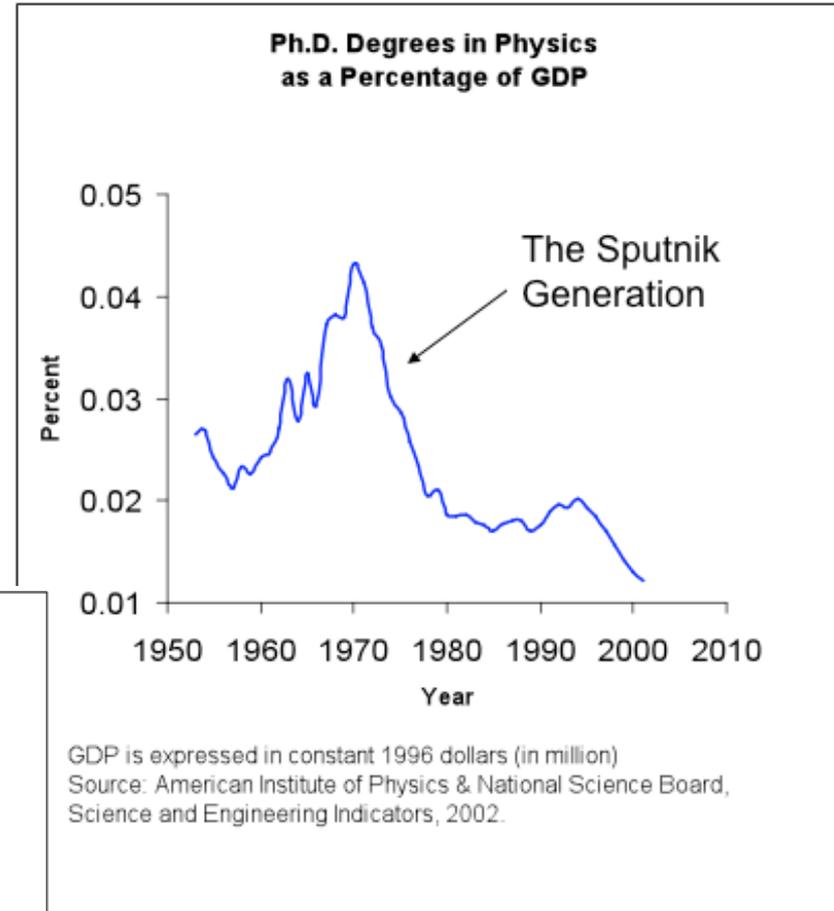


- **Recruiting people**
  - *Scientifically strong and garner instant recognition and respect*
  - *Imaginative, entrepreneurial, collaborative*
  - *Both depth in one relevant field, and breadth in multiple fields*
  - *Intellectually flexible*
- **ARPA-E Team Identity**
  - *Common sense of mission, focus on excellence in every aspect of our work*
  - *Culture of open and friendly debate and “constructive confrontation” to get clarity on issues*
  - *Priority on technical programs*
  - *Both speed and doing things right are important*
  - *Team gelling is critical*
- **Quality of selected projects and focus on best ideas regardless of origin**
- **Close partnership with community and openness to stakeholders**
  - *Workshops, technical review panels, Summit, technology showcase, Congress...*
- **Strategic Plan**
  - *Process of creating one is important – debate/discussion....*
  - *ARPA-E plan part of a national plan*
  - *Engaging all relevant stakeholders*

# STEM Education



- Capitalize on Sputnik Moment
- ARPA-E Fellows Program and their Role in Energy STEM
- Proposal for ARPA-E Challenge: Energy competitions in schools/colleges using private-public partnerships



# ARPA-E and Manufacturing



- Manufacturing R&D embedded in many of our calls to provide US competitiveness (mission impact)
- High-tech/high-quality manufacturing is critical for our R&D and innovation
  - Engagement of thought leaders around the nation
    - *Andy Grove, Norm Augustine, Michael McQuade, Mark Pinto ...*
- **My Oral Statement at House S&T Committee Hearing (01/27/10):**
  - *If I have any concern for the future, it is the following: While ARPA-E's focus is to invest upstream in the energy innovation pipeline, we must keep the scaling of these innovations within the US and thereby create new jobs in the energy sector. The purpose of the ARPA-E Energy Innovation Summit is to explore how to achieve this. In this regard, I may note that the government is the largest energy consumer. I urge Congress to consider using the government's purchasing power to create a demand pull for American innovations, so that our businesses can get a foothold once they meet or exceed market-based performance and cost metrics. This will be critical in scaling up innovations and creating new jobs within the US, especially in manufacturing, and it will enable American taxpayers to reap the benefits of their upstream investments through ARPA-E.*
- **Potential Use of Executive Order for Reducing Federal Energy Use**

