

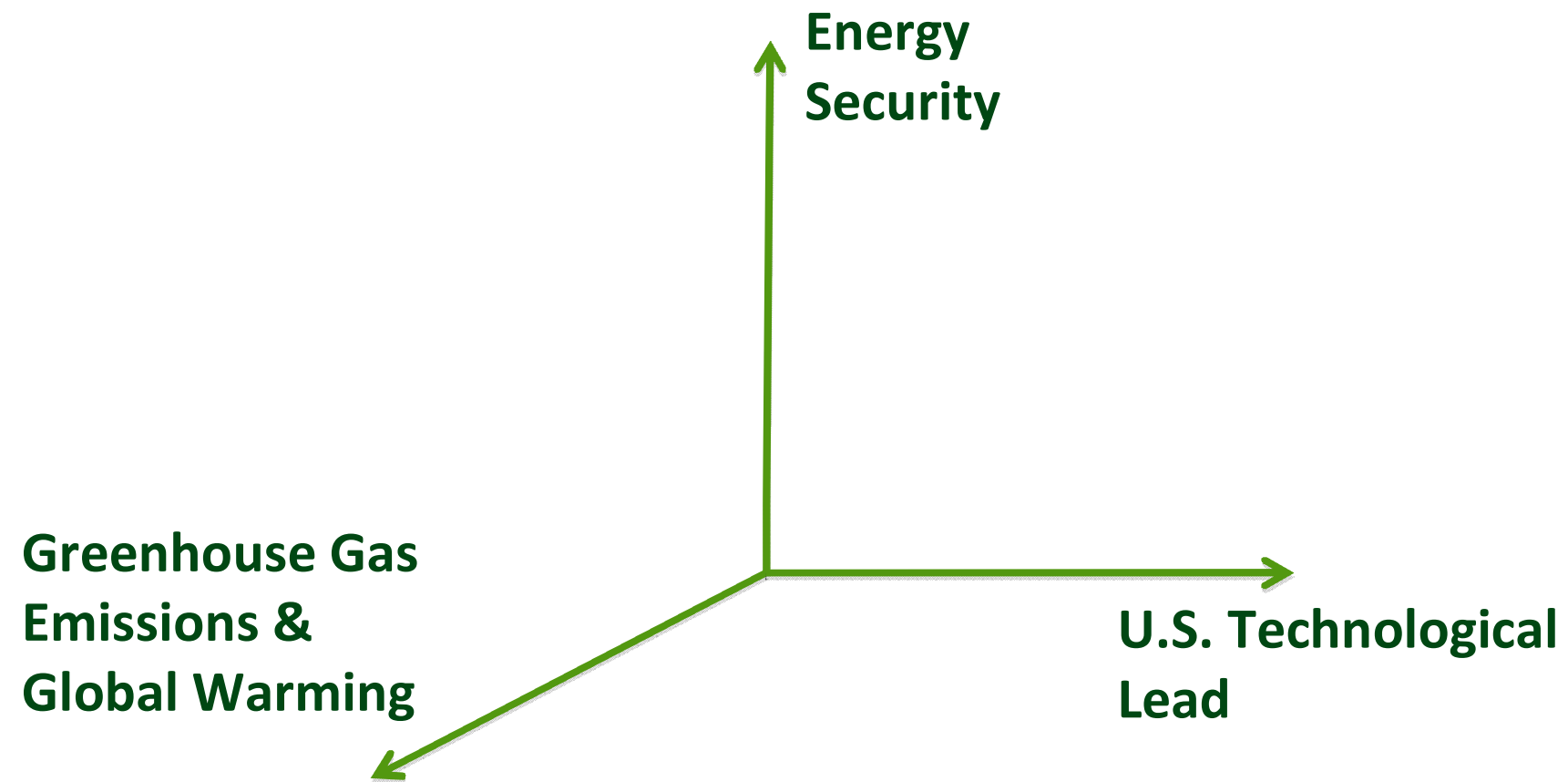


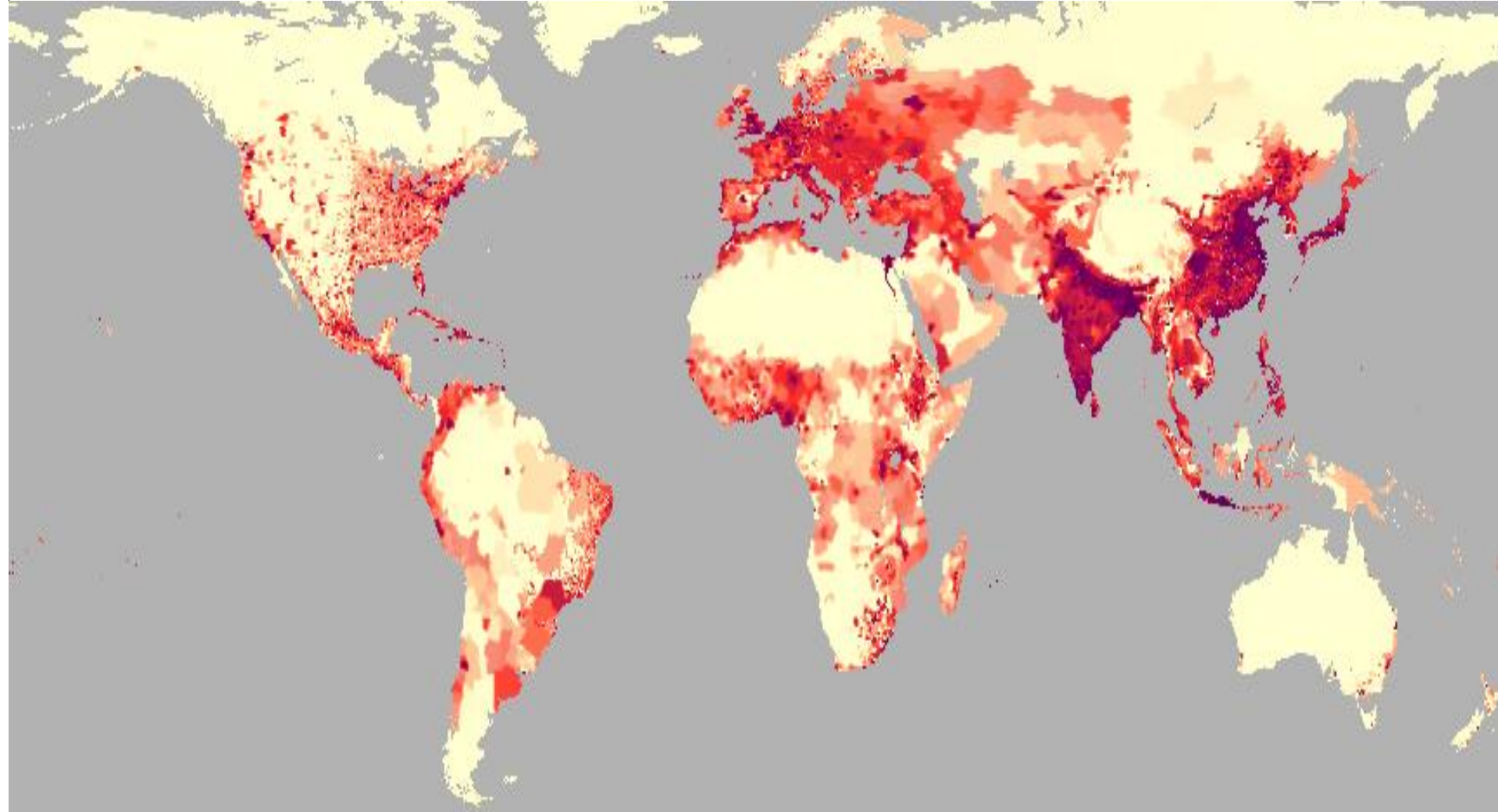
Advanced Research Projects Agency - Energy (ARPA-E)

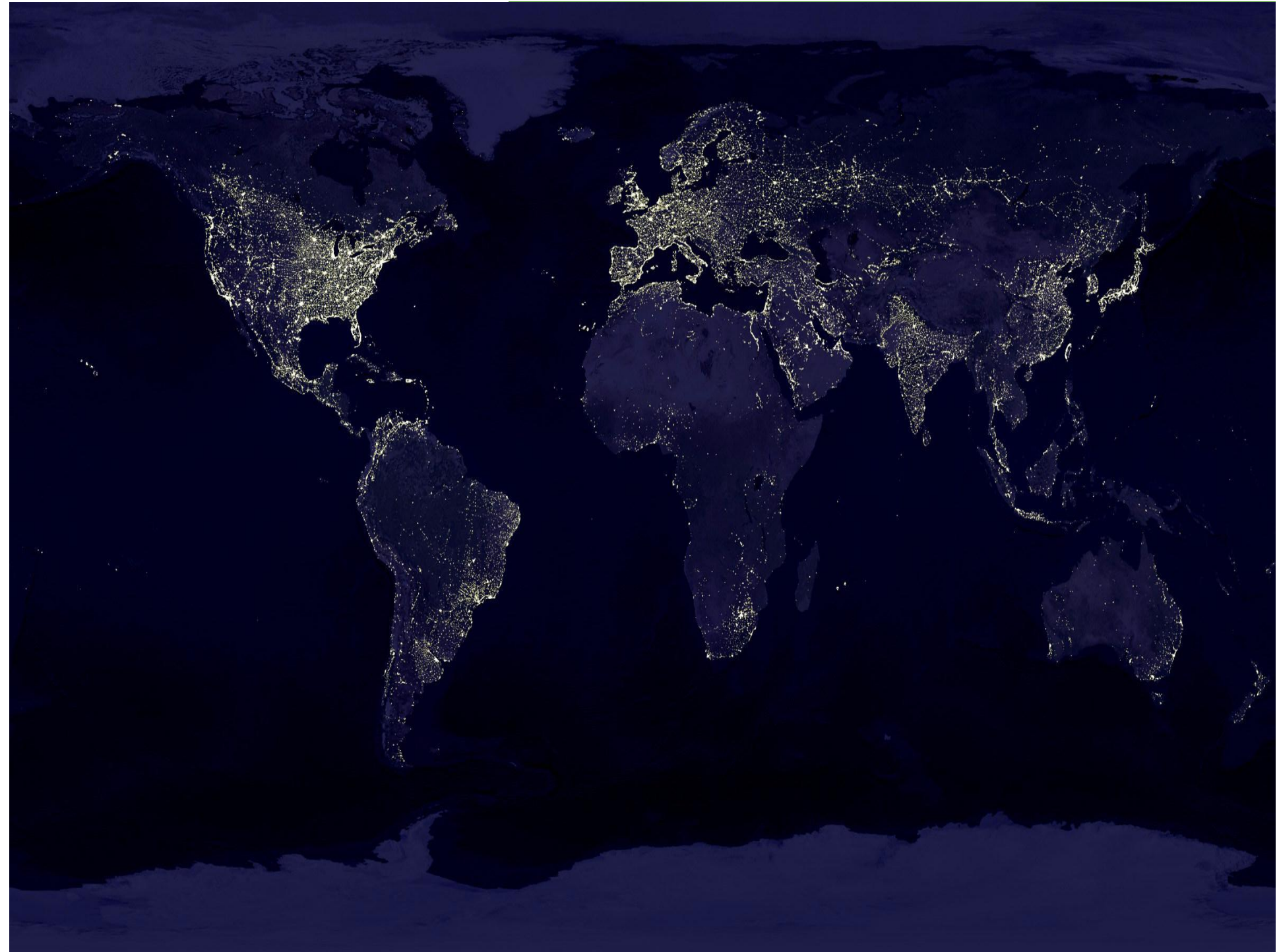
Dr. Arun Majumdar
Director, ARPA-E
U.S. Department of Energy

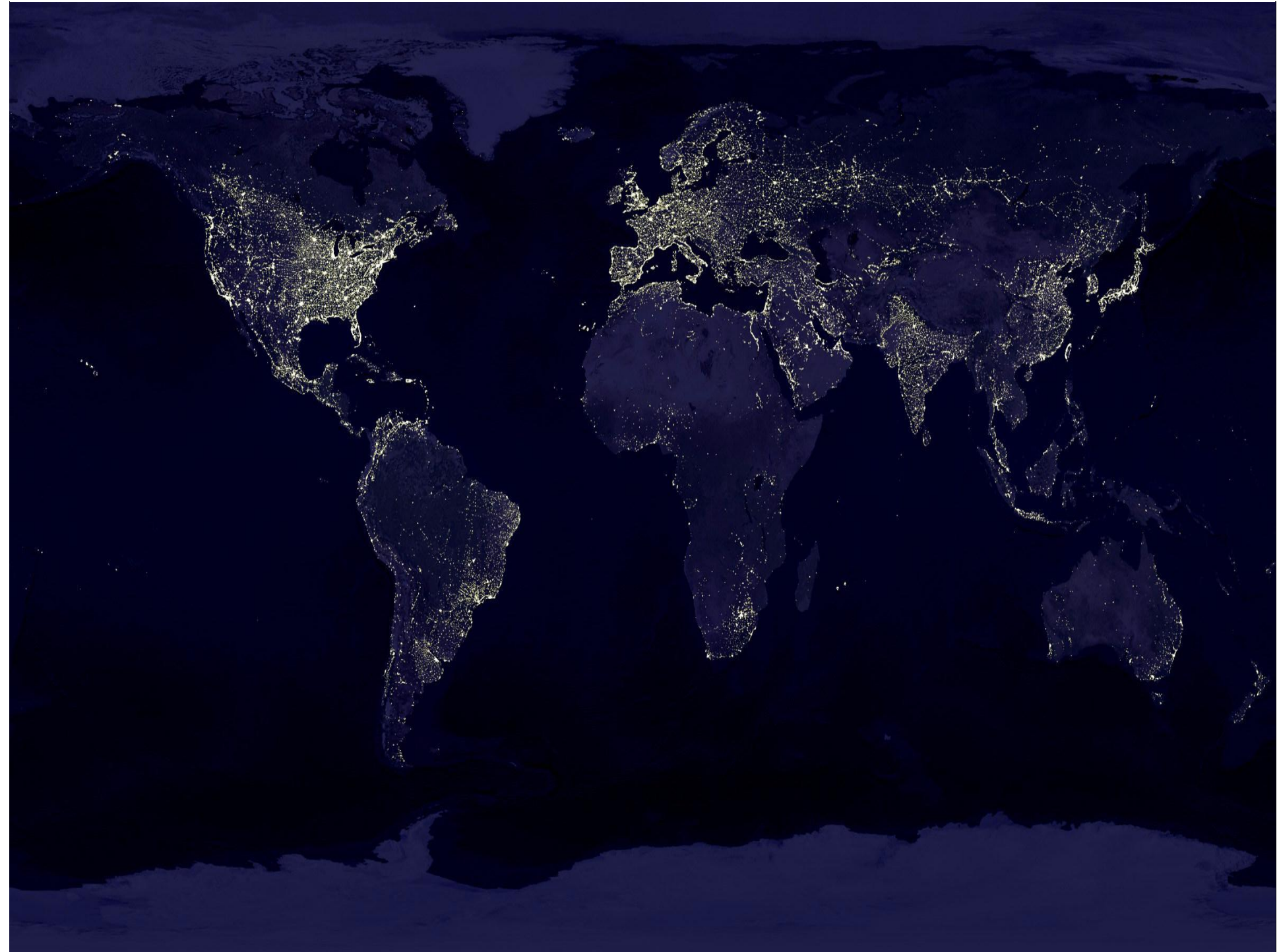
<http://arpa-e.energy.gov/>

SPUTNIK MOMENT OF OUR GENERATION

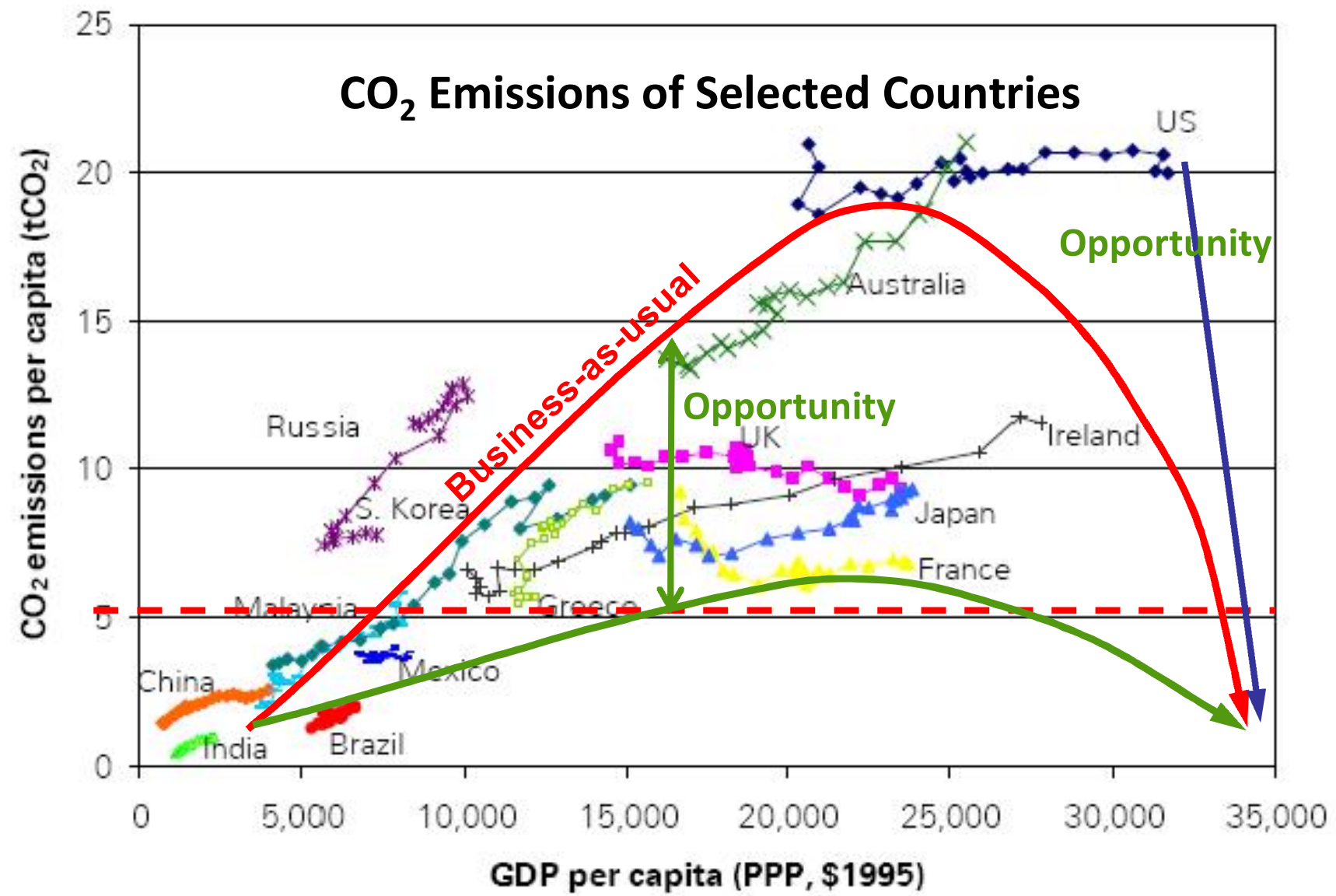








WHICH PATH SHOULD WE TAKE?



PACE AND SCALE OF INNOVATIONS NEEDED IN ENERGY TECHNOLOGIES



Game Changers from 20th Century

100 years

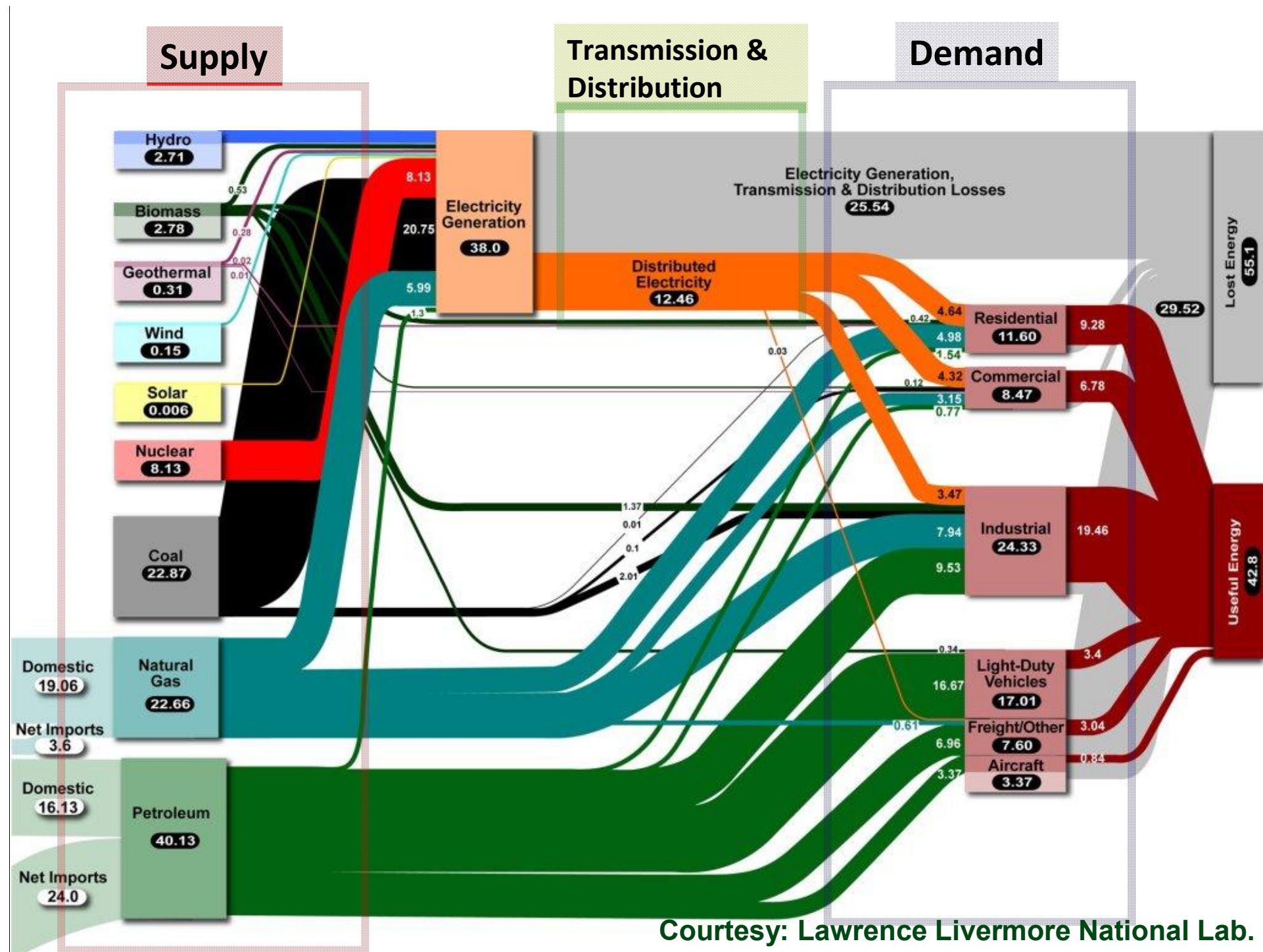
Artificial Fertilizers
Green Revolution
Polio Vaccination
Antibiotics
Airplanes
Electrification
Nuclear Energy
Transistor
Integrated Circuits
Fiber Optic Communication
Wireless Communication
Internet

20 years

Imagine all of this happening in the next 20 years...

- Solar electricity generation at a cost lower than that from fossil fuels
- Carbon capture and utilization at net cost lower than its market price
- Car batteries with 3X energy density and 4X lower cost
- Transportation fuels from sunlight and/or agricultural waste at cost lower than petroleum
- 50-80% reduction in energy consumption in homes and buildings
- Optimized and secure grid with storage
- Cement, steel, glass ... production at 5X lower carbon emissions
-



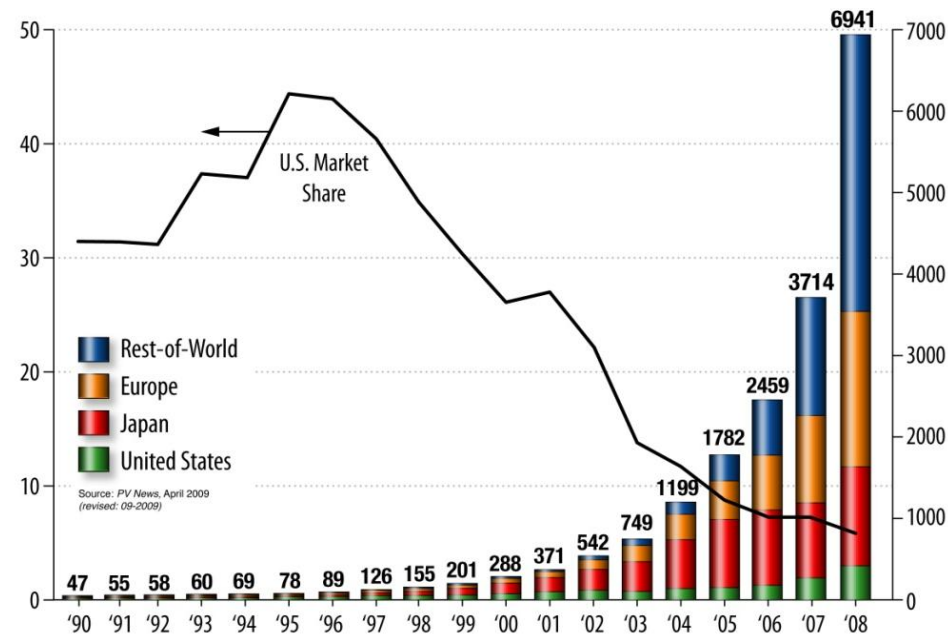


Courtesy: Lawrence Livermore National Lab.

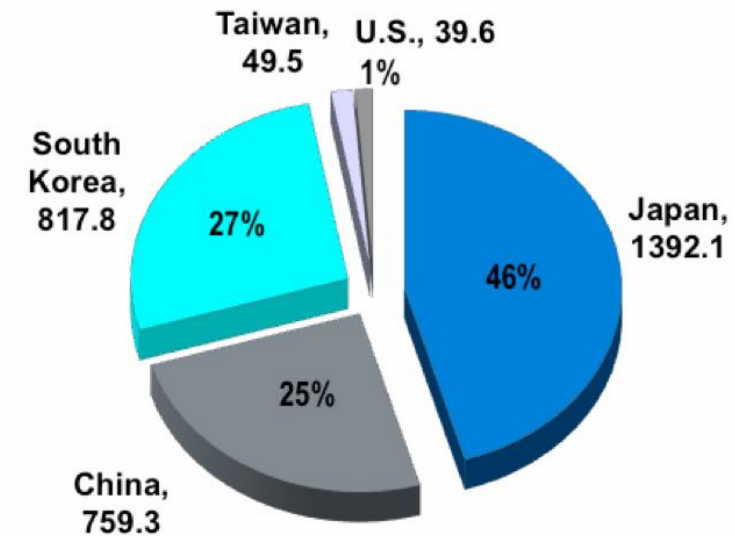
THE U.S. IS FALLING BEHIND IN THE CLEAN ENERGY RACE



Worldwide shipments of Solar Cells in 2008 (Megawatts)



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



THE ENRICO FERMI AWARD

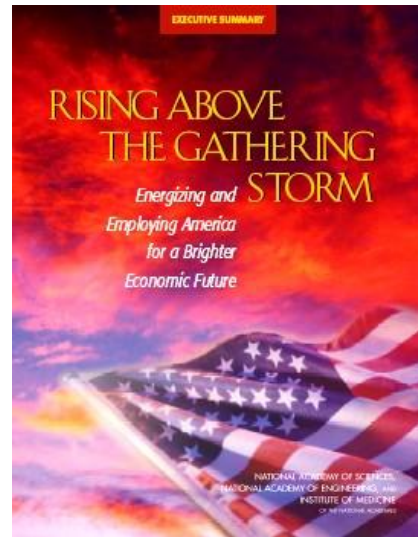
2009



John Goodenough, U. Texas at Austin



CREATION OF ARPA-E



American Recovery and Reinvestment Act of 2009 (Recovery Act)

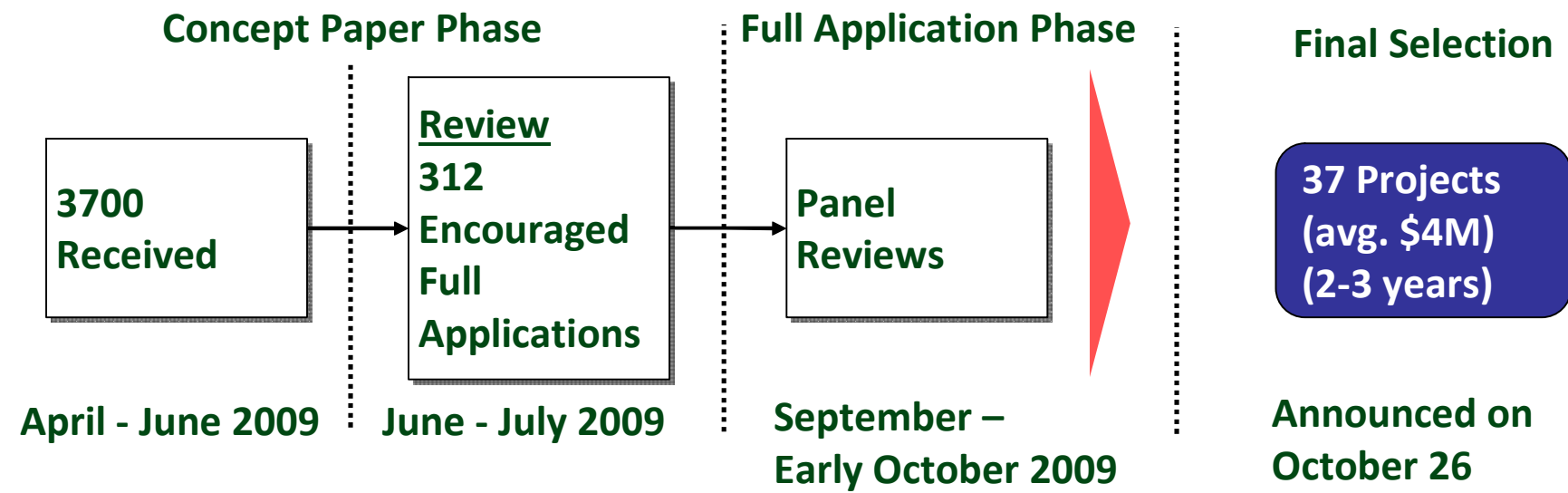
2007
America COMPETES Act

\$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)



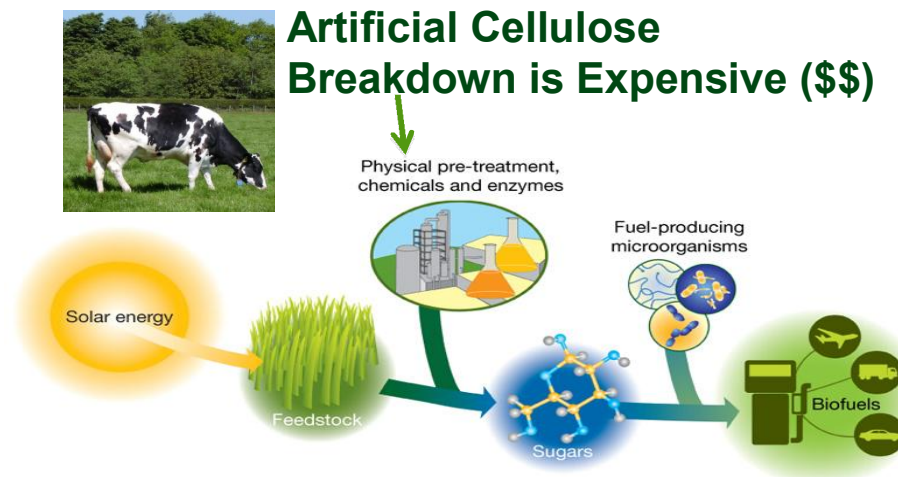
FIRST ROUND OF FUNDING



EXAMPLES FROM FIRST ROUND OF FUNDING



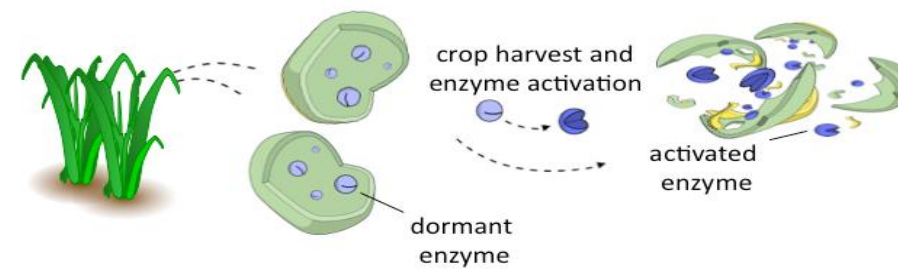
Cellulosic Biofuels



Agrivida

GreenGenes™ Technology

Putting the cow inside the plant!



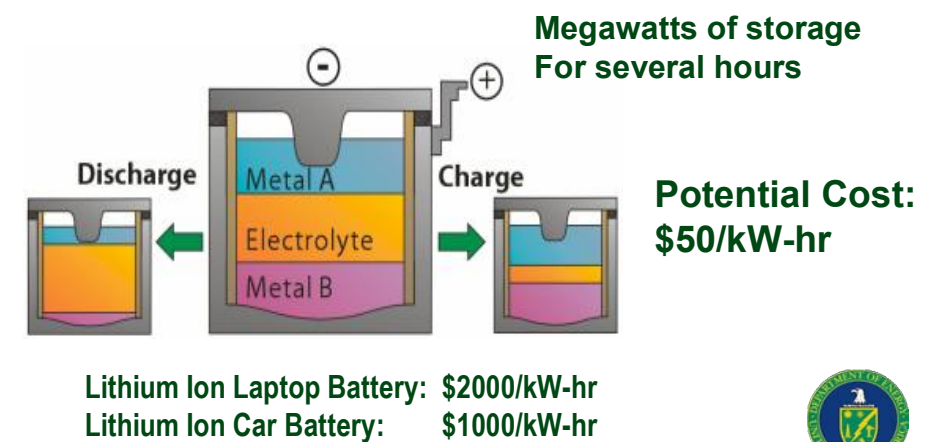
Plant produces all the enzymes & chews itself from the inside!!

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





Sampling of New Programs

Wayne Gretzky

"I skate where the puck is going to be, not where it has been"

"You miss 100% of the shots you don't take"



BATTERIES FOR ELECTRICAL ENERGY STORAGE FOR TRANSPORTATION (BEEST)



Where We Are Now



- Expensive cars
- Powered by Li-ion batteries
- Battery Cost: approx. \$15,000
- Limited range: 40 miles
- Cell-level energy density: 150 W-hr/kg
- Cost: approx. \$1000/kW-hr

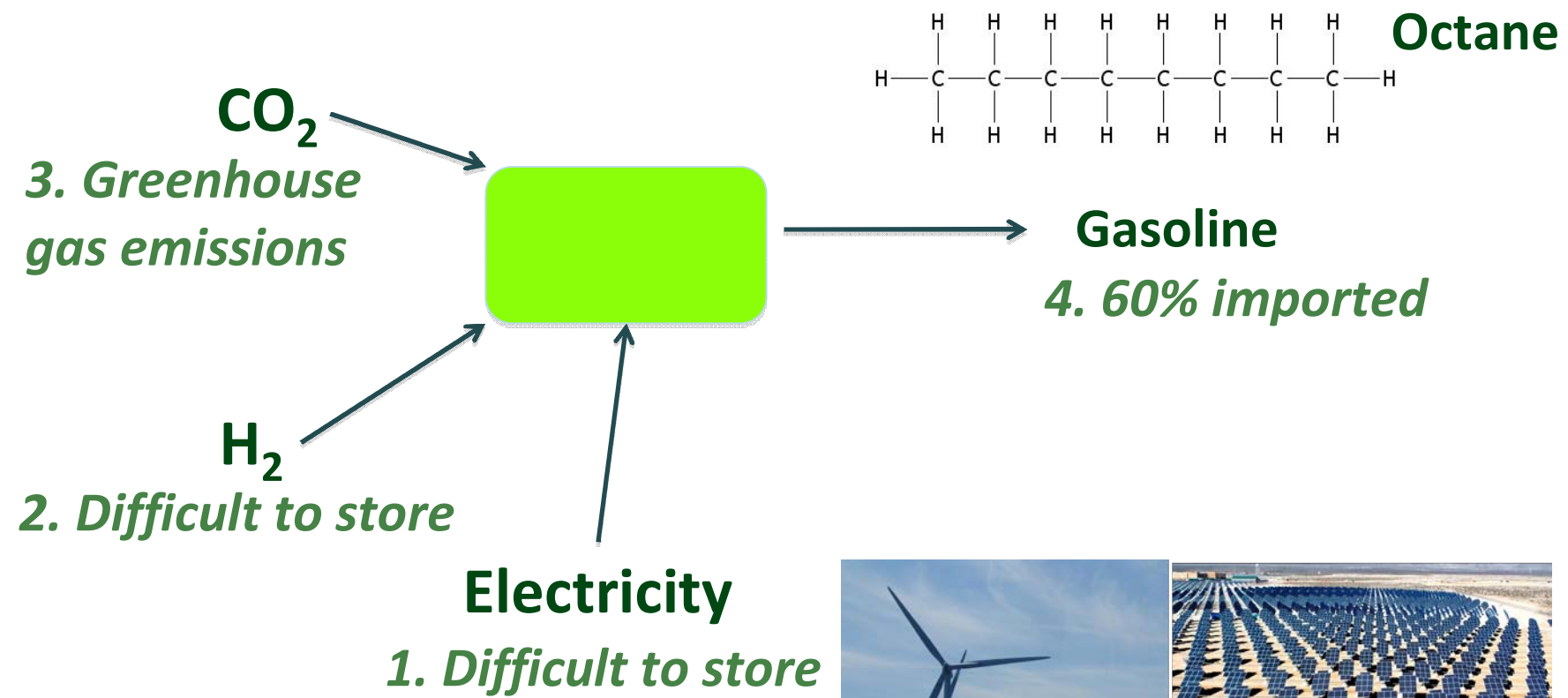
Majority of Current Investments :
Improvement in Today's Lithium Ion Batteries

Where We Need to Go

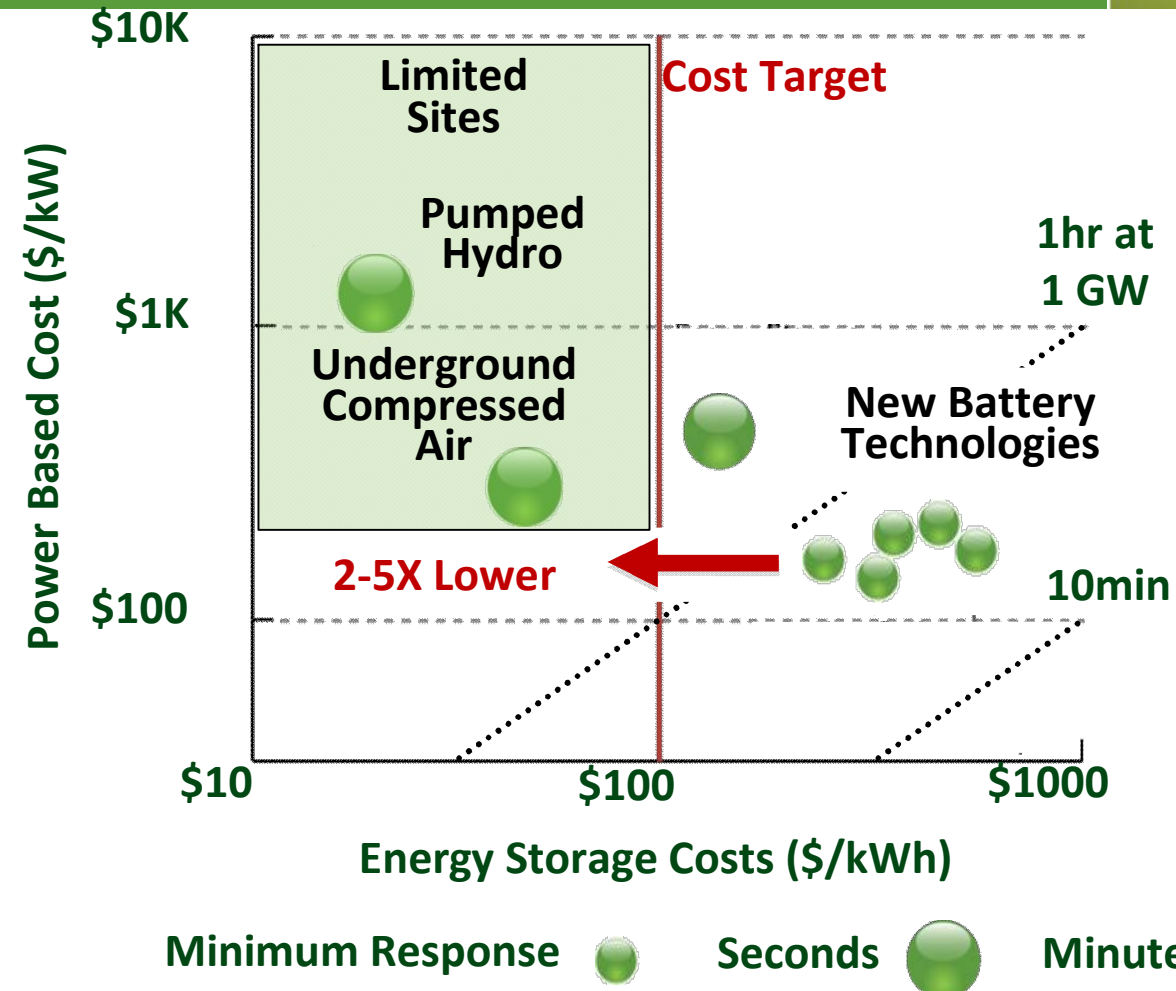
- Broad range of vehicle types
- Battery Cost < \$10,000
- Range of 300+ miles
- Targets:
 - Cell-level energy density: 400 W-hr/kg
 - Cost: \$250/kW-hr
 - New architectures & manufacturing processes
 - Examples
 - Metal-air batteries
 - Li-S batteries

Japanese gov't investing \$60M/yr

ELECTROFUELS



Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)



ARPA-E Focus:
 Transformational approaches to energy storage that enable grid-scale deployment at very low cost (~\$100/kWh)

Need: Innovative Technologies for Cost-Effective Energy Storage



FOA 3: Building Energy Efficiency Through Innovative Thermo-devices (BEETIT) – Building Cooling

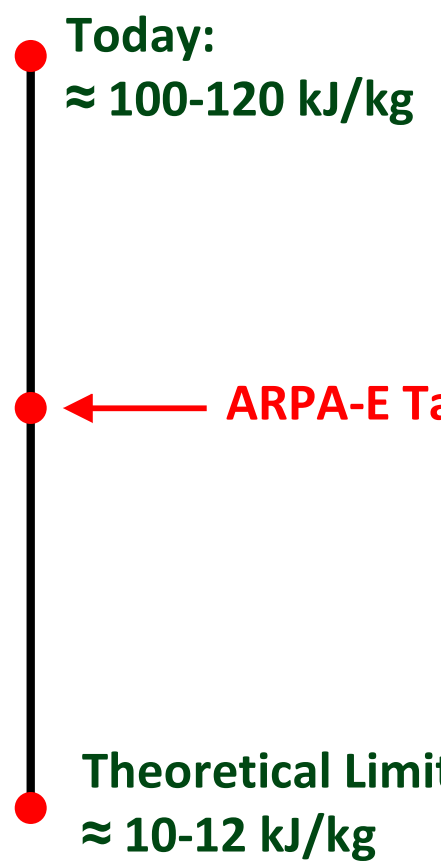


Primary Energy Use for Cooling (kJ of energy used to cool 1 kg of air.)

In this example, we assume:

**$T_{amb} = 90^\circ \text{ F}$,
Rel. Hum. = 0.9)**

**$T_{supply} = 55^\circ \text{ F}$,
Rel. Hum. = 0.5**



ARPA-E Focus: Cut cooling energy consumption and GHG emissions by 25 – 40%

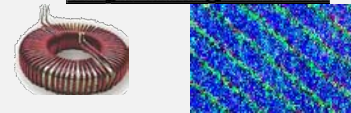


AGILE DELIVERY OF ELECTRICAL POWER TECHNOLOGY (ADEPT)

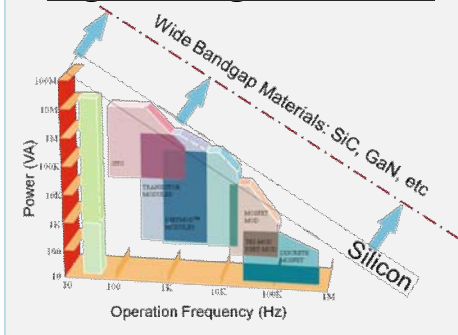


Advancements in power electronics materials...

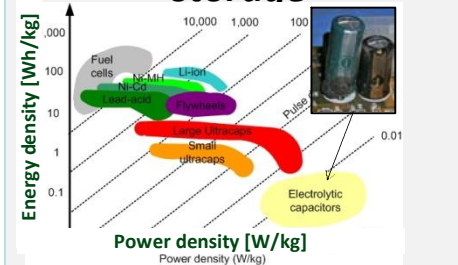
Soft magnetics



High voltage switches

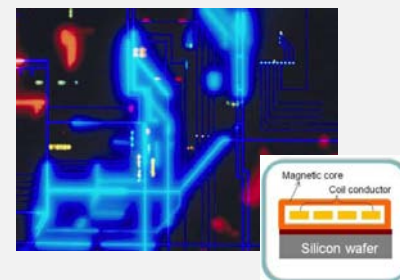


High-density charge storage



...coupled with advanced circuit architectures and scalable manufacturing processes...

Advanced circuit architectures



Scalable manufacturing processes



...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

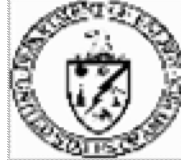
Lightweight, solid state, medium voltage energy conversion (1MW, 13kV)



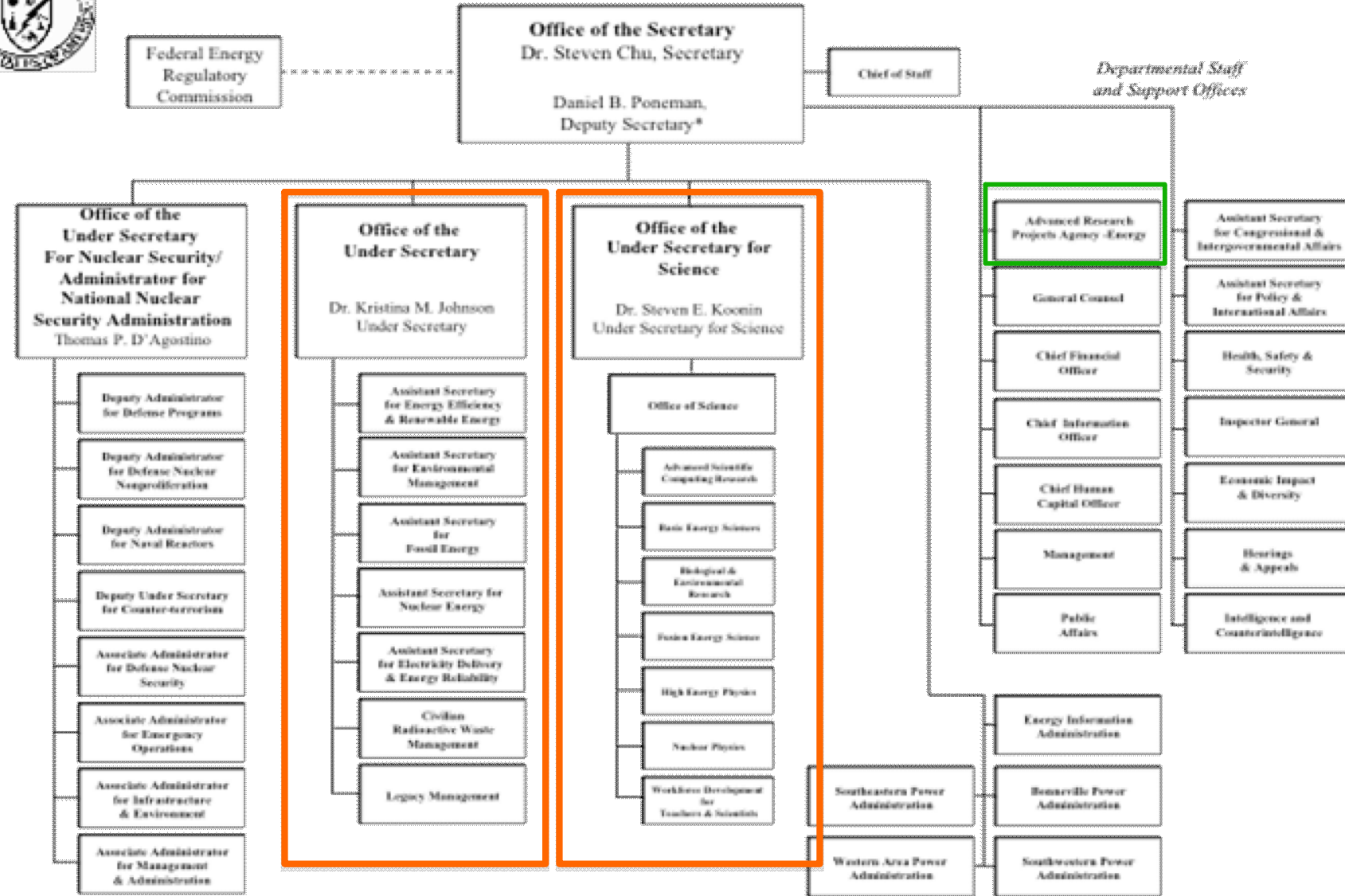
Solid-state electrical substations



Wind turbines



DEPARTMENT OF ENERGY



* The Deputy Secretary also serves as the Chief Operating Officer

ARPA-E ORGANIZATION

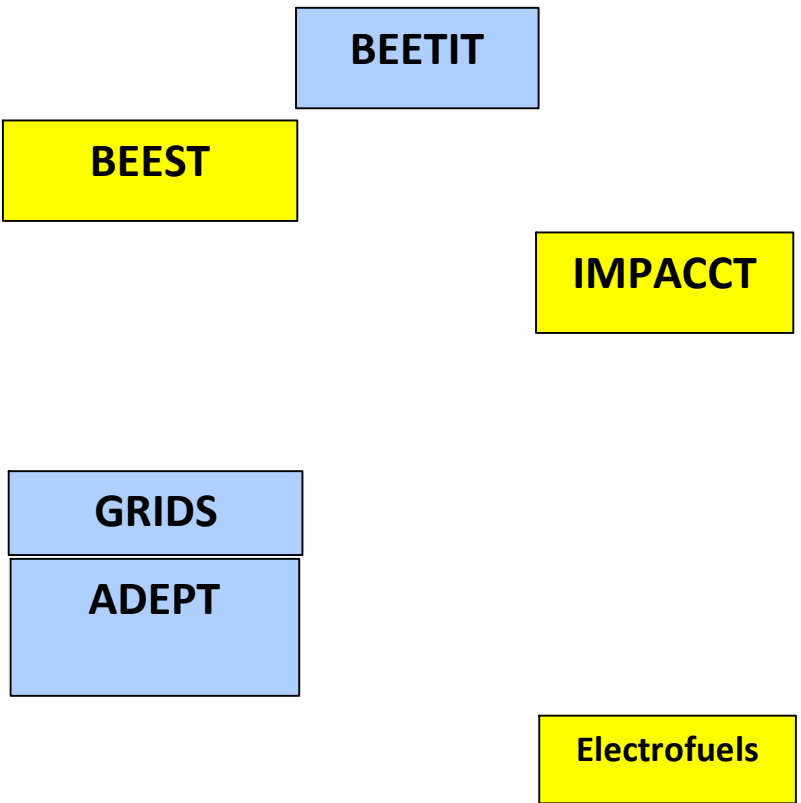
Lean, Nimble, Collaborative, Flat



Coordinates with Office of Science
Technology Push Office

All-Star Program
Directors
(4 yrs max)

- Break down stovepipes
- Encourage debate and partnership between technology pushers and pullers
- Provide thought leadership to create new programs



Technology Pull Office
Coordinates with Applied Energy Offices



BUILDING ON OUR STRENGTHS



- Best R&D infrastructure in the world
- Best innovation ecosystem in business and entrepreneurship
- Highly energized youth, ready to deeply engage
 - ARPA-E Fellows Program (Launched Dec 8th at MIT Energy Club): bring best and brightest scientist, engineers, and technical entrepreneurs in to ARPA-E and create a think tank



MANAGING EXPECTATIONS



NOW

3 - 5 YRS

10+ YRS

- 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 (#)
- Help identify mechanisms for scaling innovations

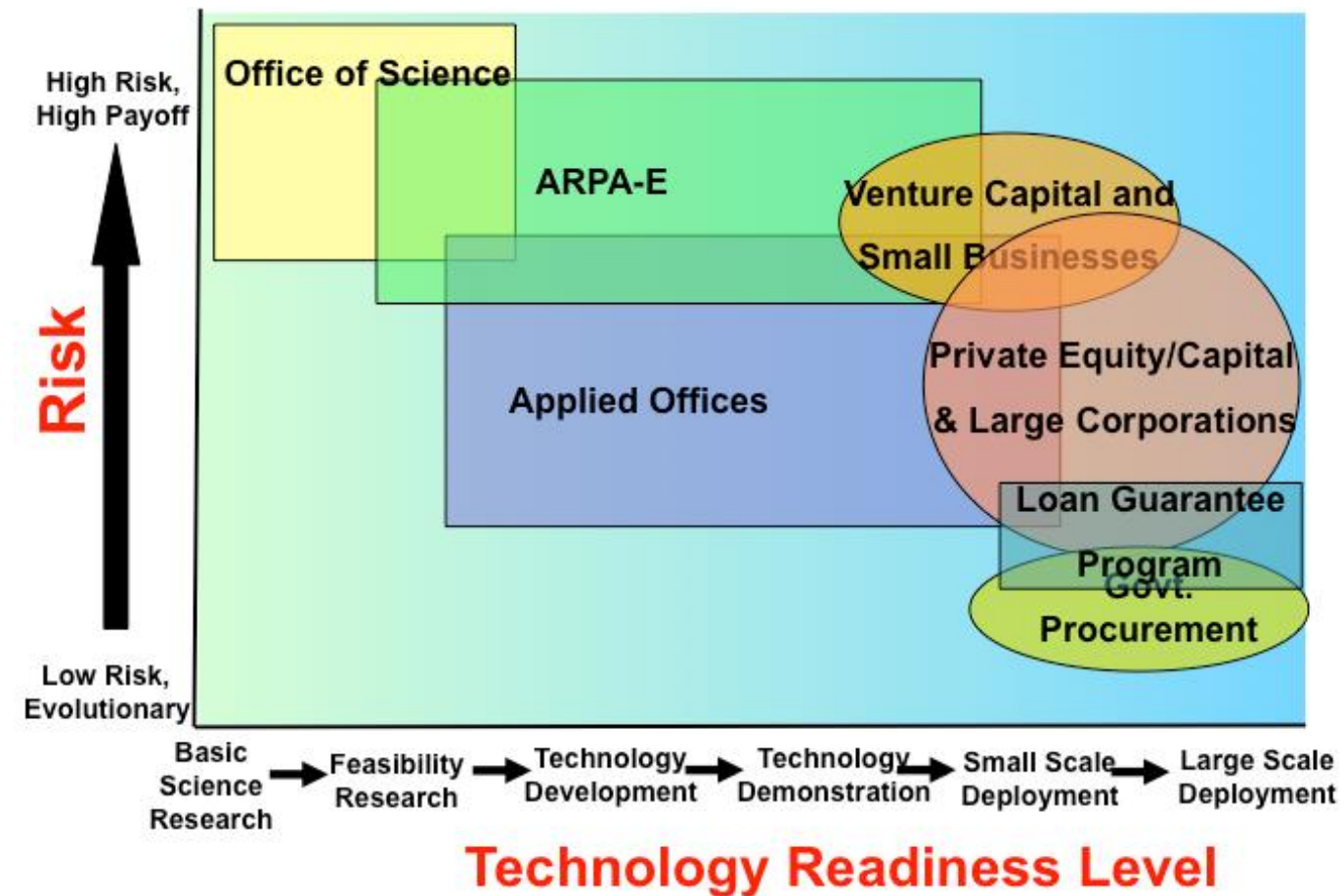
Home Runs

- Domestic and global sales, US market share (\$)
- Avoided greenhouse gas emissions (tCO₂ 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 PIPELINE



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





- 1700 people on 2 months notice
- Technology showcase

**Scientist/Engineer (Academia, National Labs, Industry); Investors;
Small/Large Industry Senior Management; Policy Groups; Congress; White**

Plus Topics

- How do we foster and identify game-changers? Is it random or is there a system?
- How do we go from lab to market with disruptive energy technologies that challenge business-as-usual?
- How do we scale innovations in the US? How do we accelerate the pace?
- How do we balance global competitiveness and partnerships?
- How do we ensure national security through energy technologies?
- How do we build and engage regional innovation clusters through private-public partnerships?
- How can DOE play a role in energy innovation?

Martin Luther King (1967) :

“...We are now faced with the fact, my friends, that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history, there is such a thing as being too late.”