Energy Innovation in the 21st Century: Role of ARPA-E

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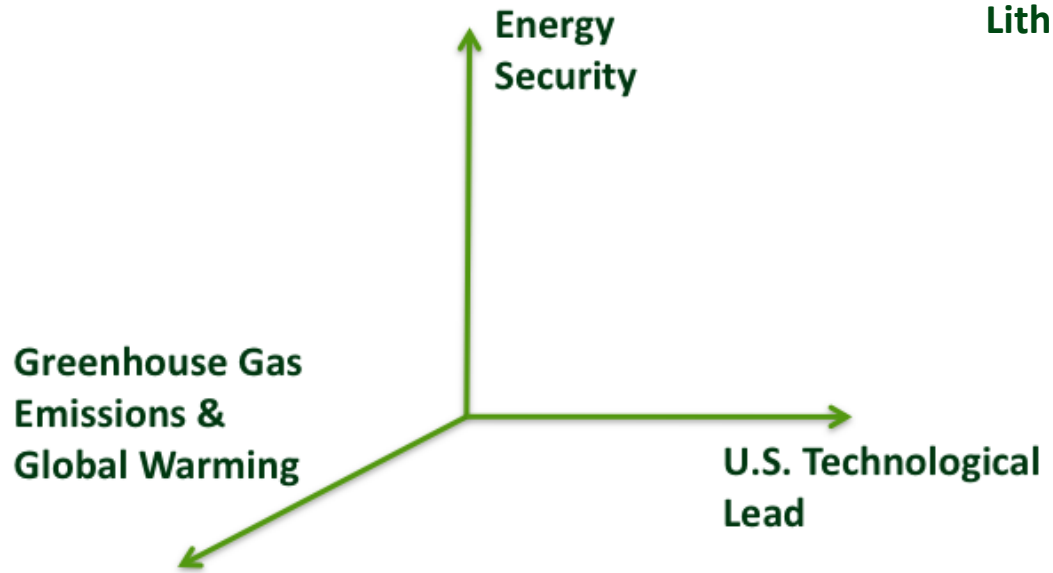
U.S. Department of Energy

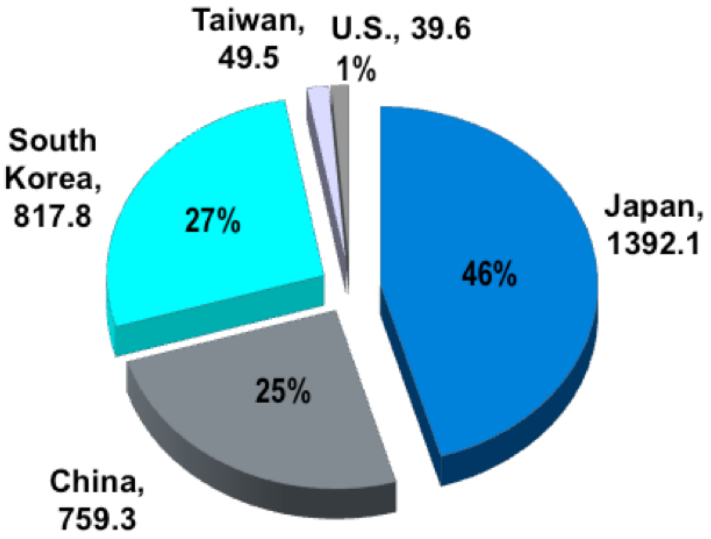
http://arpa-e.energy.gov/

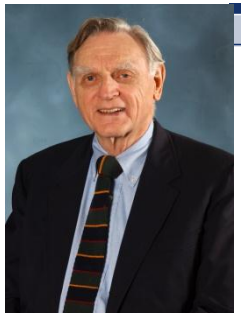
SPUTNIK MOMENT OF OUR GENERATION



EXAMPLE

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





THE ENRICO FERMI AWARD

2009

John Goodenough, U. Texas at Austin

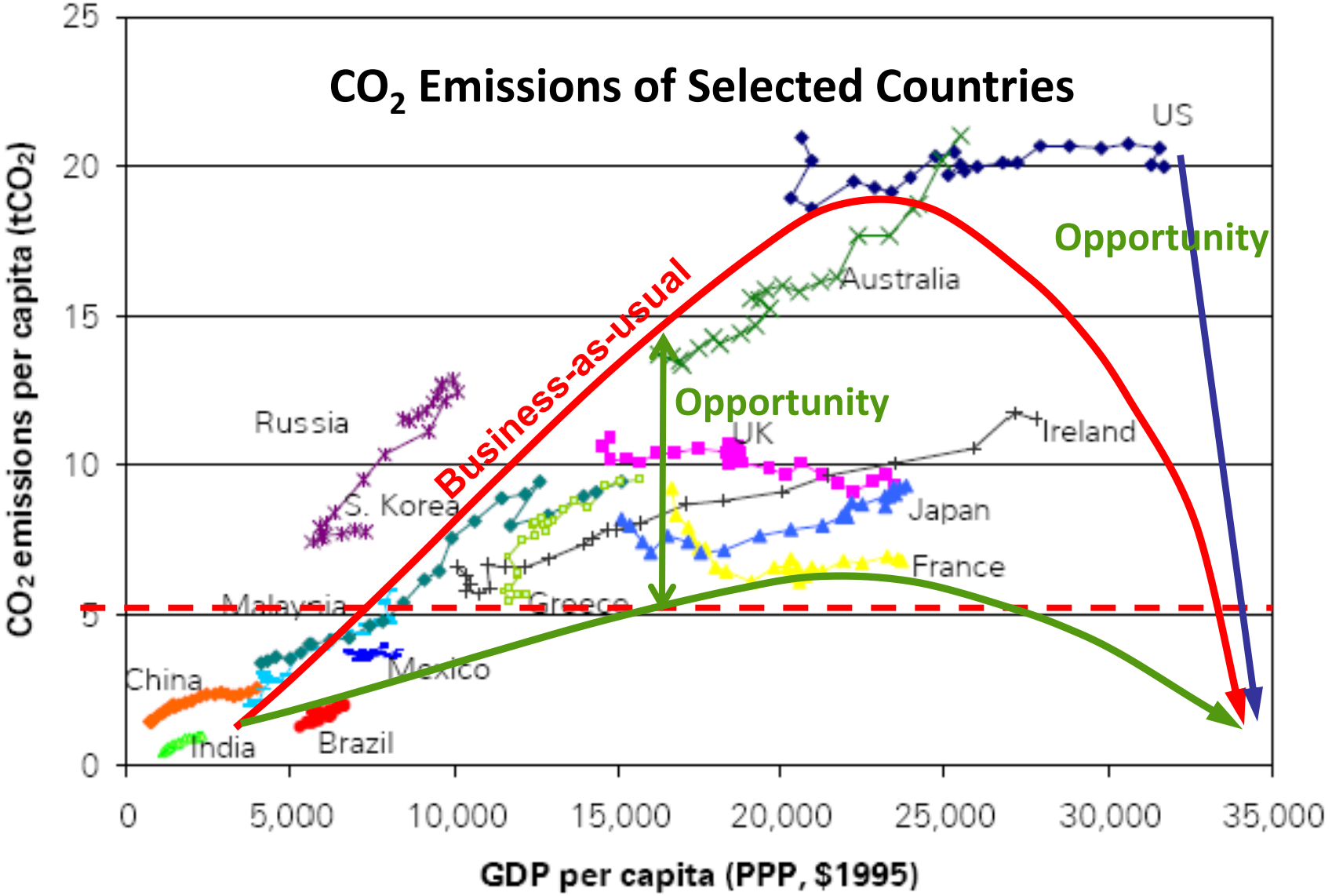
SPUTNIK MOMENT OF OUR GENERATION

We import 60% of our oil. Need to make that 0%!

Energy Innovation is at the core of our

- **National Security**
- **Economic Security**
- **Environmental Security**

WHICH PATH SHOULD WE TAKE?



ALIGNED INNOVATIONS

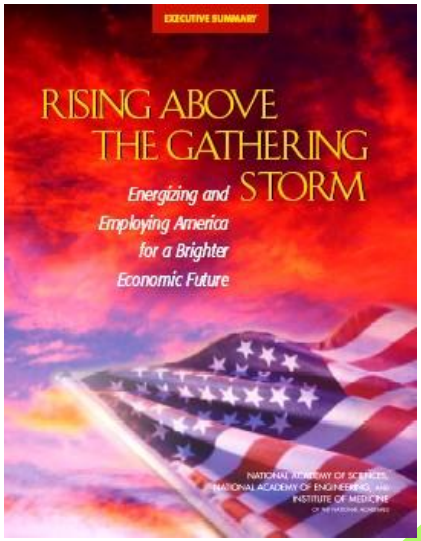
Science and Technology

Finance and Markets

Policy

Education and Society

CREATION OF ARPA-E



2006
Rising Above the Gathering Storm
(National Academies)

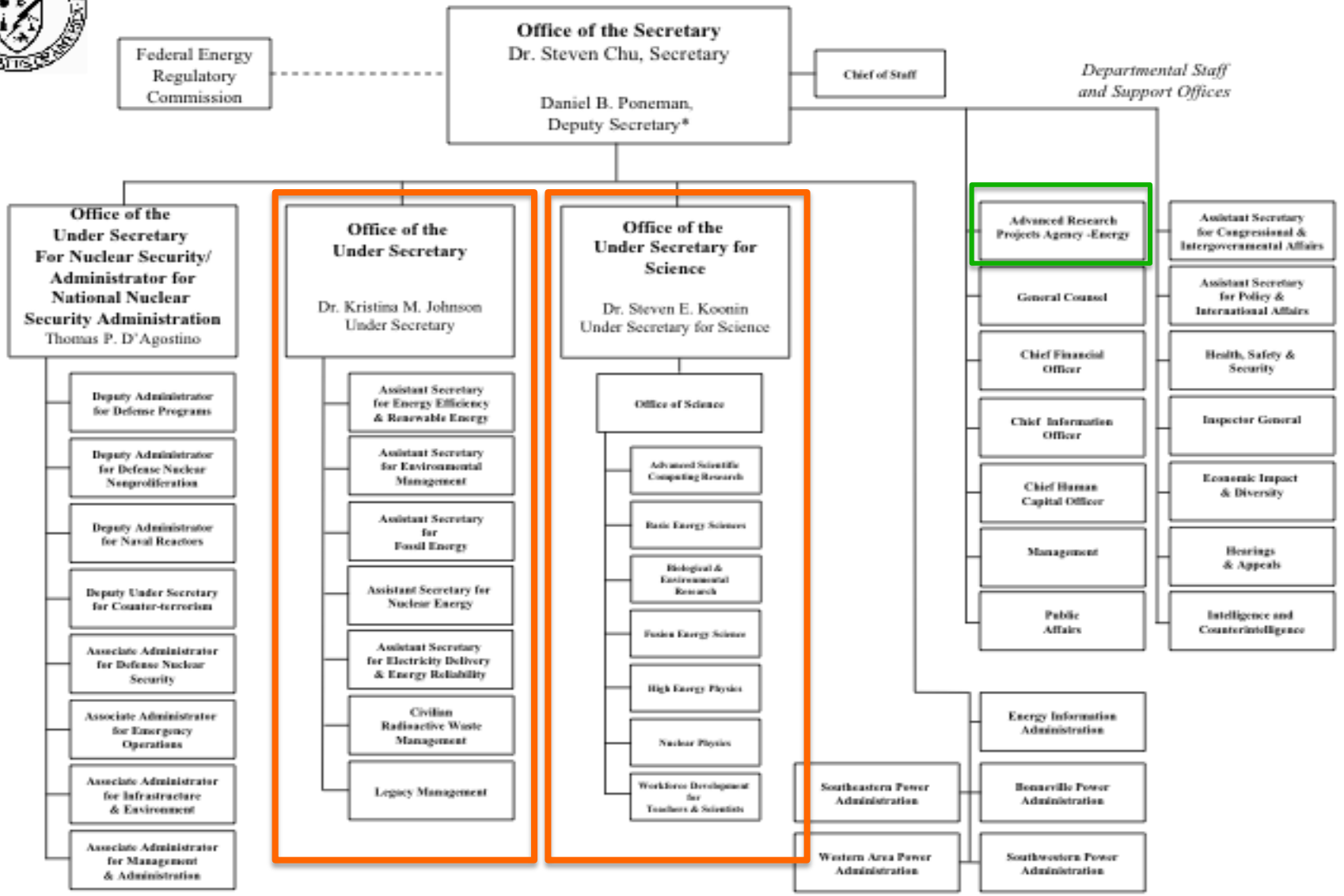
2007
America COMPETES Act

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

DEPARTMENT OF ENERGY



* The Deputy Secretary also serves as the Chief Operating Officer

26 May 09

ARPA-E TEAM

Program Team

Eric Toone

Dave Danielson

Mark Hartney

Rajeev Ram

Mark Johnson

Ravi Prasher

Karma Sawyer

Shannon Yee

Commercialization Team

Sanjay Wagle

Srini Mirmira

Leshika Samarasinghe

Strategic Outreach

Peder Maarbjerg

Shannon Barrett

Operations Team

Shane Kosinski

Tony DiGiovanni

Matt Dunne

Erin Alexander

WHAT IS AN ARPA-E PROJECT?

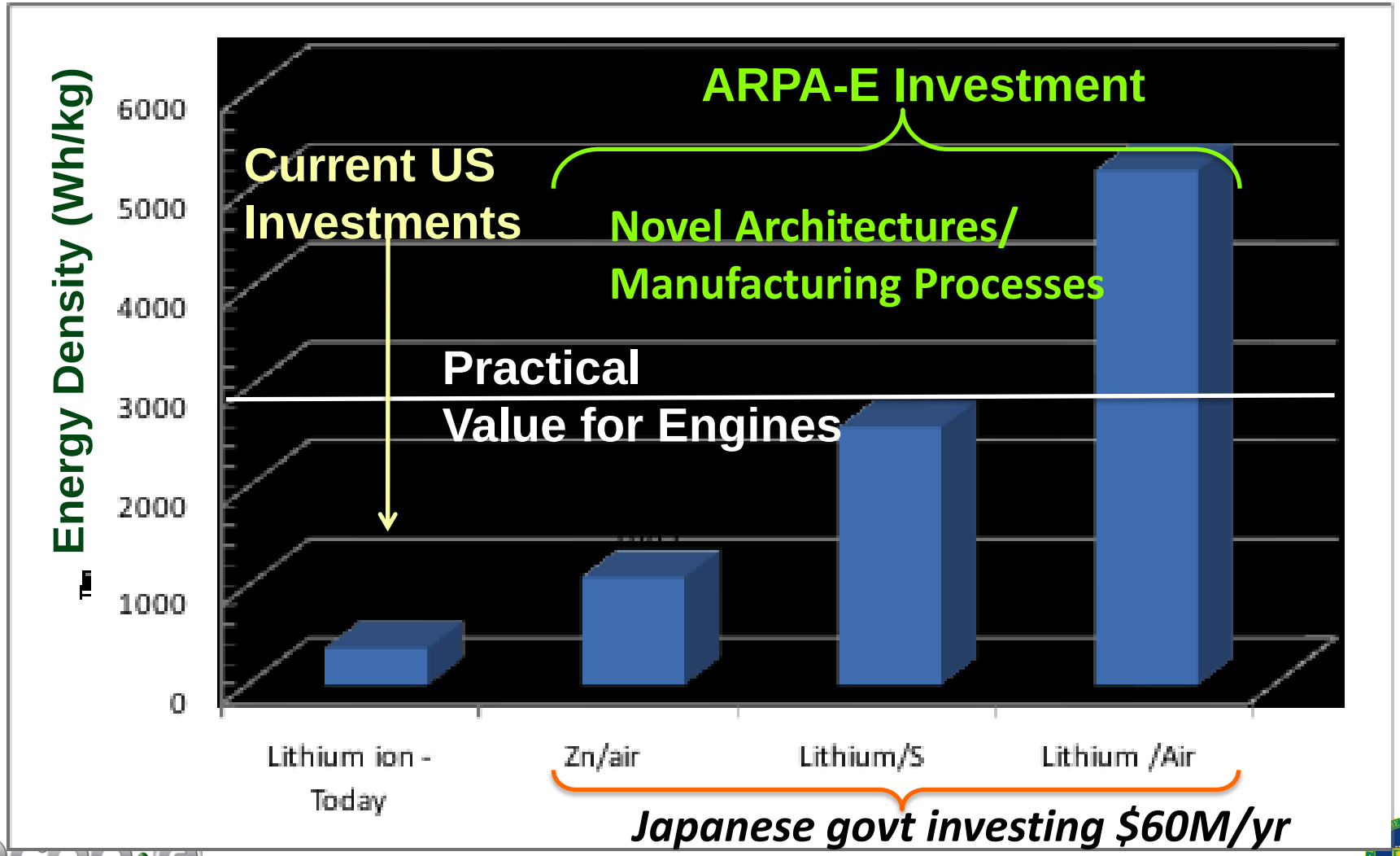
High Impact on ARPA-E Mission

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)



BATTERIES FOR ELECTRICAL ENERGY STORAGE FOR TRANSPORTATION (BEEST)

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

Recapping Stanford (Capacitive)

Ultra-High Energy

Upside

Sion Power (Li-S)

PolyPlus (Li-Air)

Missouri Inst of Sci/Tech

ReVolt (Zn-Air Flow)

MIT (Flow Batt)

Mfg Innovations

Pellion (Mg-Ion)

AMAT/A123/ LBNL (Li Ion Mfg)

Planar Energy Devices (Solid State Li-Ion)

Infrastructure Compatible High Energy Materials

Time to Market

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LOW-COST CARBON CAPTURE

Today: CO_2 +

Today's CO_2 Binding Chemicals

Bind, Isolate & Release →

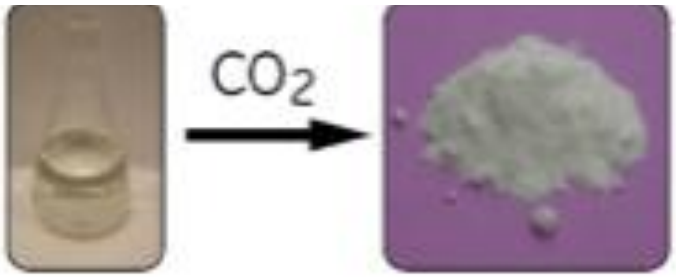
Cost: $70-100/t$CO_2$
Cost Above Price = Loss!

↑ High-Temperature Heat

Market Price of CO_2: ≈ $30/t$CO_2$

Carbon Capture in Solid Form

Potential Cost = $25-30/t$CO_2$



The ARPA-E Projects are Distinct from Existing DOE Programs

Concept (TRL 1-2)

Lab Testing (TRL 3-4)

Bench-scale (TRL 5-6)

Pilot/Demonstration (TRL 7-8)

EFRC for Gas Separations
UC Berkeley

Stimuli Responsive MOFs

Cryogenic Capture

NETL FOA Bench-Scale

NETL FOA Slipstream

EFRC for Geologic Storage
LBNL

Biological Catalysts

Solvent-Membrane Hybrid

ARPA-E FOA 1

IMPACCT

ELECTROFUELS: SOLVING 4 PROBLEMS WITH 1 NOVEL SOLUTION

Photosynthesis: Less than 1% efficient
Electrofuels: Up to 90% efficient

CO_2

3. Greenhouse gas emissions

Non-Photosynthetic/
Modular/Mix-and-Match

Gasoline

4. 60% imported

Hydrogen

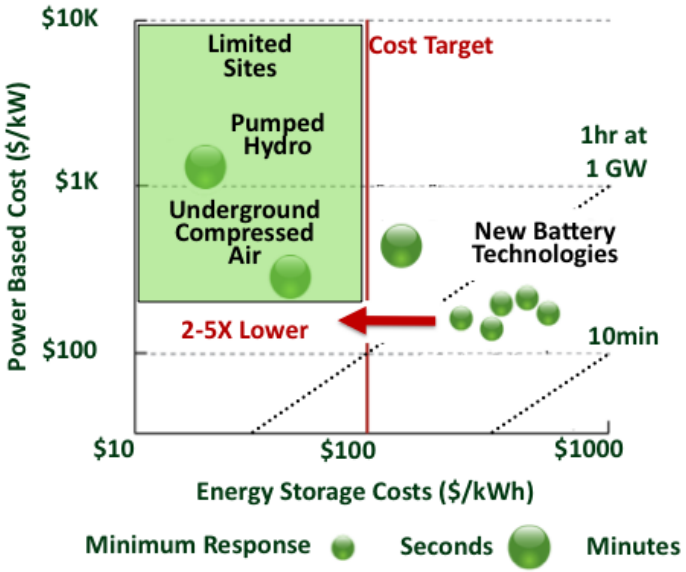
2. Difficult to store

Electricity

1. Difficult to store

NEW PROGRAMS

Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS)



Building Energy Efficiency Through Innovative Thermo-devices (BEETIT)

Today:
≈ 100-120 kJ/kg

ARPA-E Target

Theoretical Limit:
≈ 10-12 kJ/kg

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

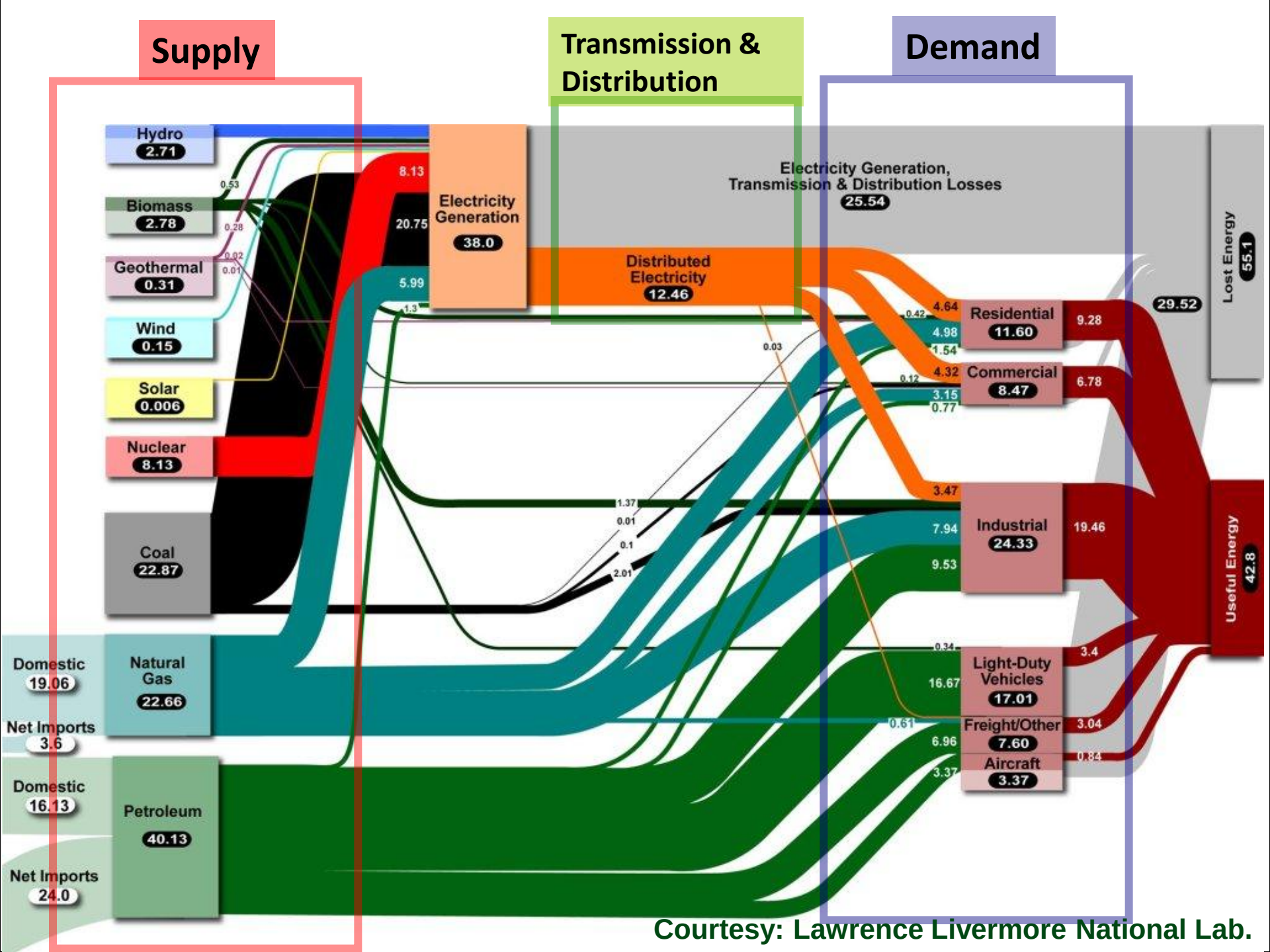

Motors

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


Solid-state electrical substations


Wind turbines

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



Courtesy: Lawrence Livermore National Lab.

Where are we going next?
Workshops Planned or Held

- $1/W fully installed solar
- Natural gas generation and cost-effective and usable storage
- Grid security, reliability, capacity, control, optimization…
- Integrated energy systems for distributed generation/use
- Long-term thermal storage at low-medium-high temperatures
- Education via energy clubs…
- …

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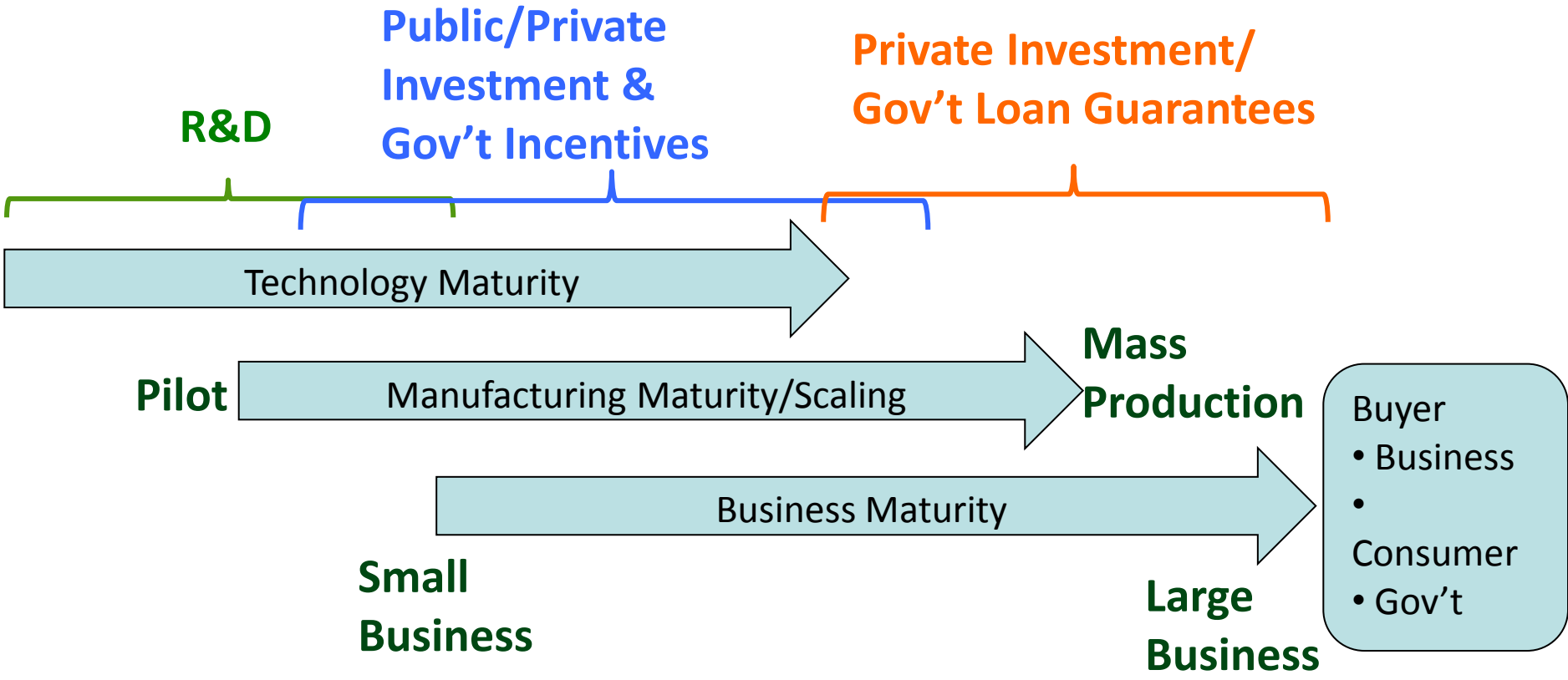
Innovation Ecosystem – How to scale?



Industry Structural Transformation

Verticals

Cray

DEC

Constrained Competition

Horizontals

Design, Sales and Marketing

Integrators

Chip & Component Makers

Software

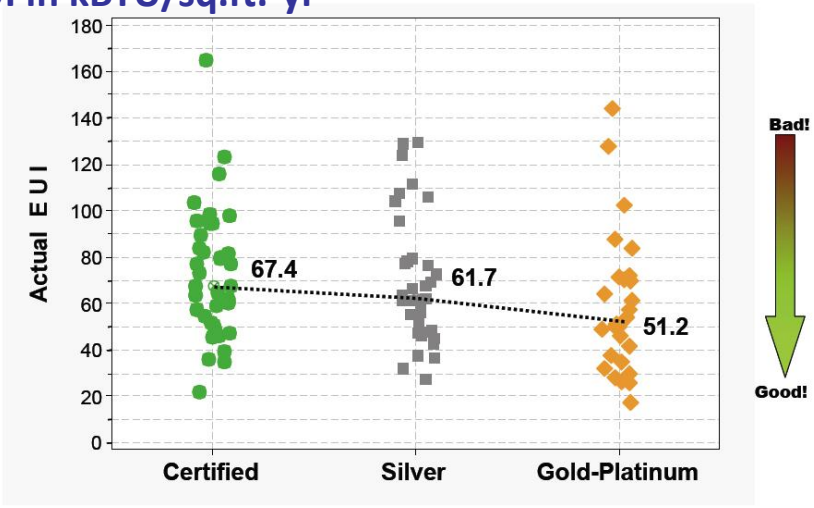
- Standards
- Plug-and-play or Mix-and-match
- Open competition

Reality of LEED Rated Buildings

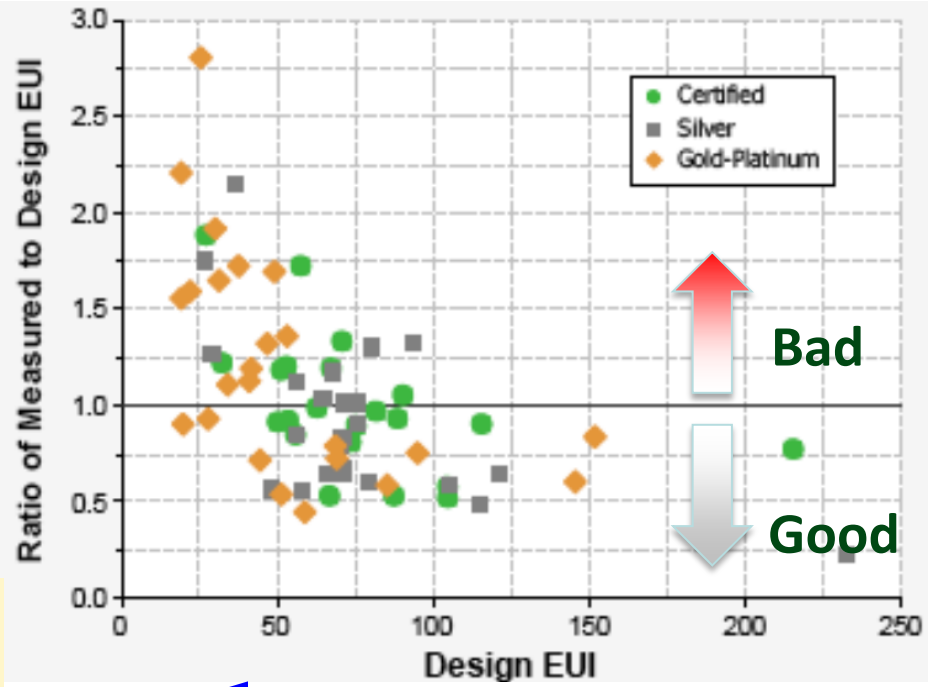
Building codes/ratings are for Design Performance, NOT based on Measured Performance.

The Spread

EUI in kBTU/sq.ft.-yr



Measured to Design Ratio



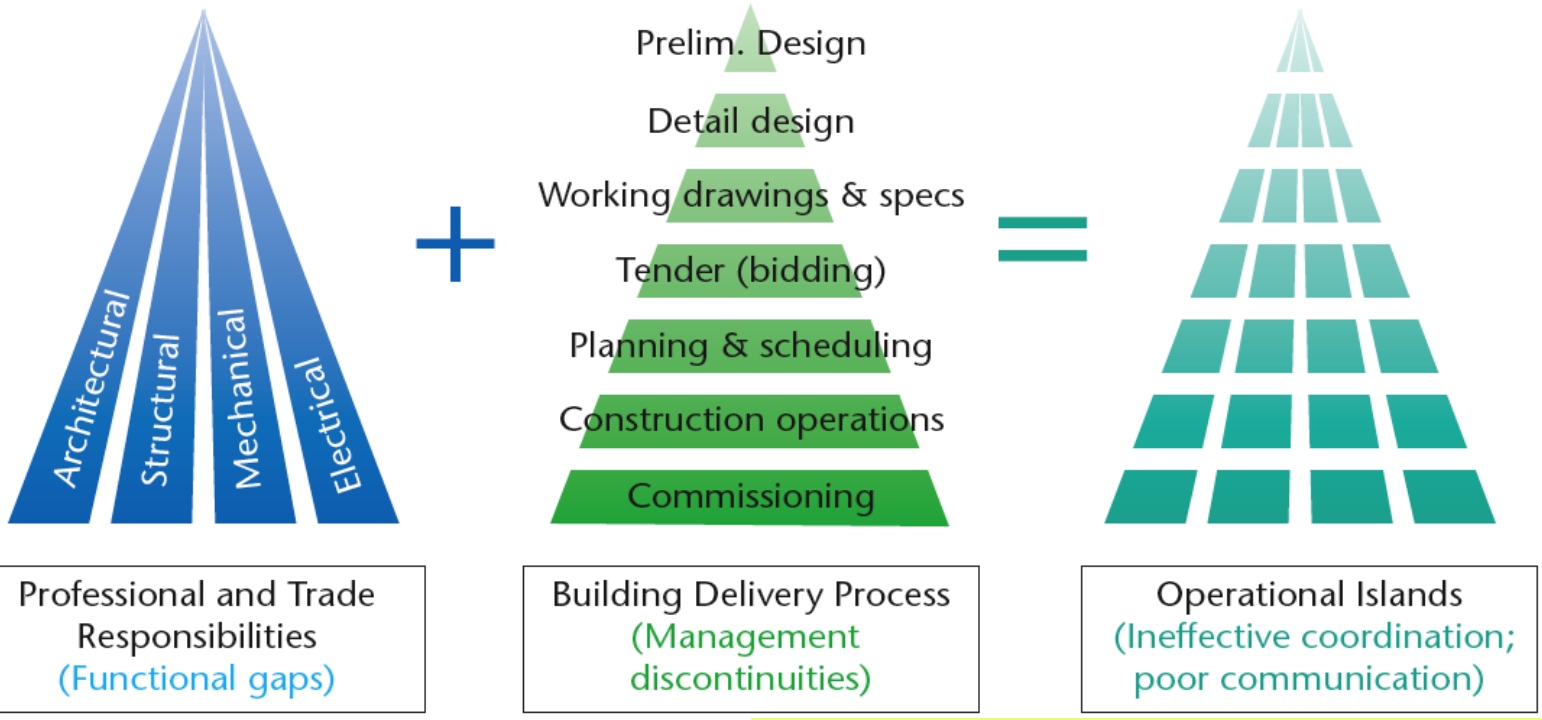
Gap

- **Lack of Measurements & Policies Requiring it**

Towards Zero-Net Energy

M. Frankel, "The Energy Performance of LEED Buildings," presented at the *Summer Study on Energy Efficient Buildings, American Council of Energy Efficiency Economy*, Asilomar Conference Center, Pacific Grove, CA, August 17-22, 2008.

Fragmentation of Industry and Building Design, Construction & Delivery Process



Professional and Trade Responsibilities (Functional gaps)	Building Delivery Process (Management discontinuities)	Operational Islands (Ineffective coordination; poor communication)

Need to:

- **Integrate process & communities**
- **Integrate building system**
- **Align incentives**

Policy Innovation:

National Standards Based on Measured Energy and Indoor Environmental Quality Performance

Courtesy: World Business Council for Sustainable Development (WBCSD) Report on Energy Efficiency in Buildings, July 2008

Testimony Regarding

Reducing Energy Consumption in Buildings

Statement of

Arun Majumdar

Director, Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

Professor, Departments of Mechanical Engineering &
Materials Science and Engineering
University of California, Berkeley

Before the

United States Senate Committee on Energy and Natural Resources

February 26, 2009

ARPA-E ENERGY INNOVATION SUMMIT

ARPA-E ENERGY INNOVATION SUMMIT

MARCH 1ST – 3RD, 2010
GAYLORD CONVENTION CENTER
WASHINGTON, DC

- 2 months preparation
- 1700 attendees
- Integrating relevant communities
- Favorite aspects
  - *Technology showcase*
  - *Summit acting as a "catalyst"*
  - *Interacting with ARPA-E Program Directors*

"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*

"The ARPA-E showcase was the best venue to meet potential funding sources, collaborators, customers, partners, and vendors with an excellent opportunity to talk to the best and brightest experts in the field. This will become a must do event." - *Technology company executive, Showcase exhibitor*

"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*