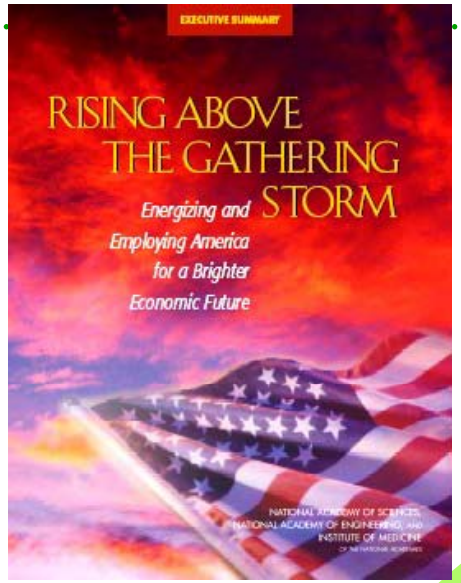
Catalyzing Energy Breakthroughs for a Secure American Future

Arun Majumdar

ARPA-E Director

Senior Advisor to the Secretary of Energy

Creation & Launching of ARPA-E



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

2007
America COMPETES Act

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

2006
Rising Above the Gathering Storm
(National Academies)

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

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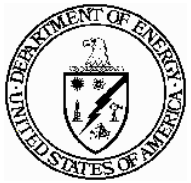
DOE ORGANIZATIONAL CHART

Breakthroughs in Technology



Advanced Research Projects Agency - Energy

Loan Programs Office

American Recovery & Reinvention Act Office

Office of the Secretary
Dr. Steven Chu, Secretary

Daniel B. Poneman,
Deputy Secretary*

Federal Energy Regulatory Commission

Inspector General

Chief of Staff

Office of the Under Secretary For Nuclear Security/ Administrator for National Nuclear Security Administration
Thomas P. D'Agostino

- Deputy Administrator for Defense Nuclear Nonproliferation
- Deputy Administrator for Naval Reactors
- Associate Administrator for Defense Nuclear Security
- Associate Administrator for Infrastructure & Environment
- Deputy Administrator for Defense Programs
- Deputy Under Secretary for Counter-terrorism
- Associate Administrator for Emergency Operations
- Associate Administrator for Management & Administration

Office of the Under Secretary for Science

Dr. Steven E. Koonin
Under Secretary for Science

Office of Science

- Advanced Scientific Computing Research
- Basic Energy Sciences
- Biological & Environmental Research
- Fusion Energy Science
- High Energy Physics
- Nuclear Physics
- Workforce Development for Teachers & Scientists

Breakthroughs in Science

Office of the Under Secretary

Arun Majumdar
Senior Advisor to Secretary Chu

- Assistant Secretary For Energy Efficiency And Renewable Energy
- Assistant Secretary Electricity Delivery Energy Reliability
- Assistant Secretary for Nuclear Energy
- Assistant Secretary For Environmental Management
- Assistant Secretary for Fossil Energy
- Legacy Management
- Civilian Radioactive Waste Management

Breakthroughs in Scaling

- Energy Information Administration
- Bonneville Power Administration
- Southwestern Power Administration
- Southeastern Power Administration
- Western Area Power Administration

- Management
- Health Safety & Security
- Hearings & Appeals

- Assistant Secretary for Policy & International Affairs
- Assistant Secretary for Congressional & Intergov. Affairs
- General Counsel
- Chief Financial Officer
- Chief Human Capital Officer
- Chief Information Officer
- Intelligence & Counterintelligence
- Public Affairs
- Economic Impact & Diversity

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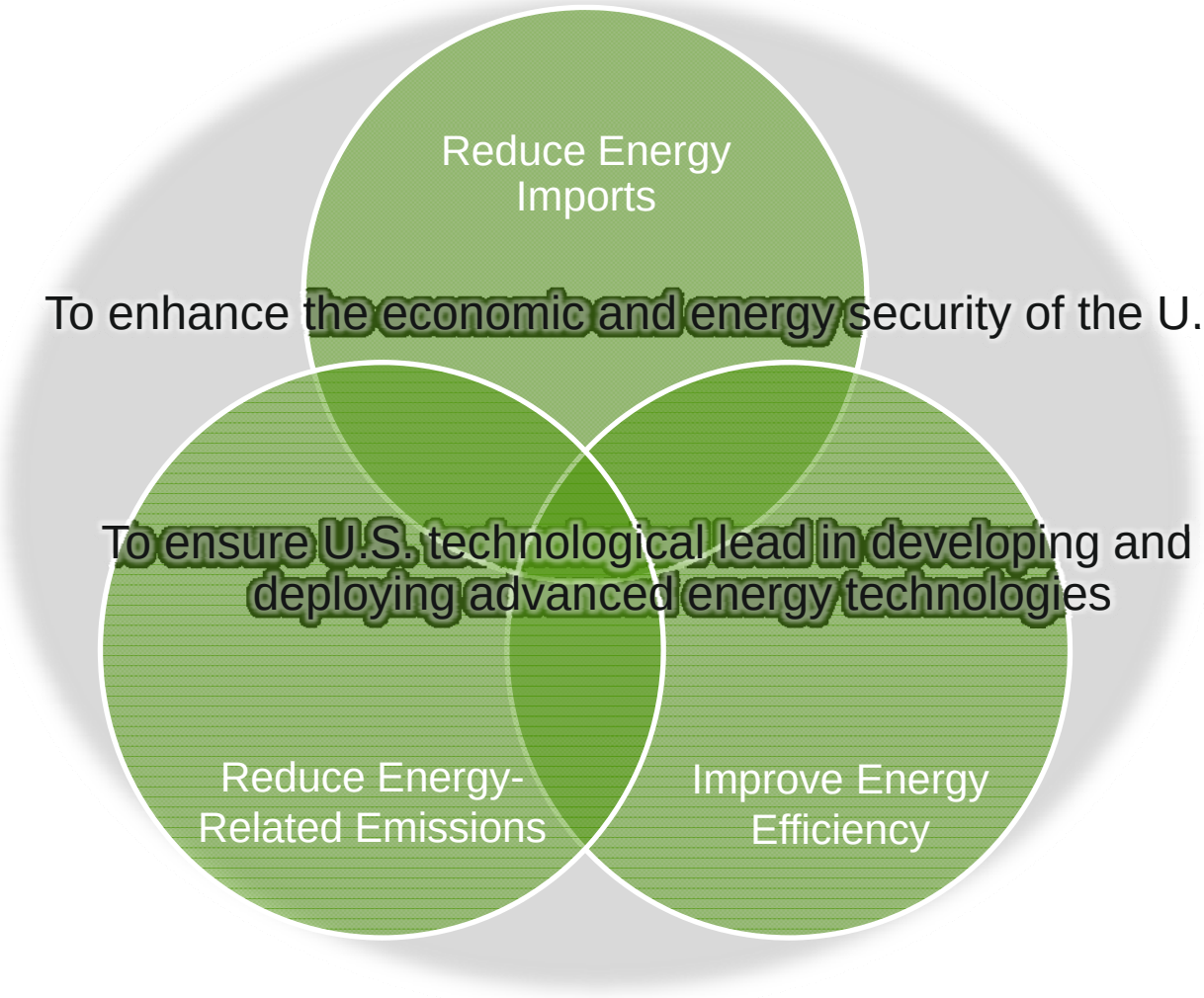
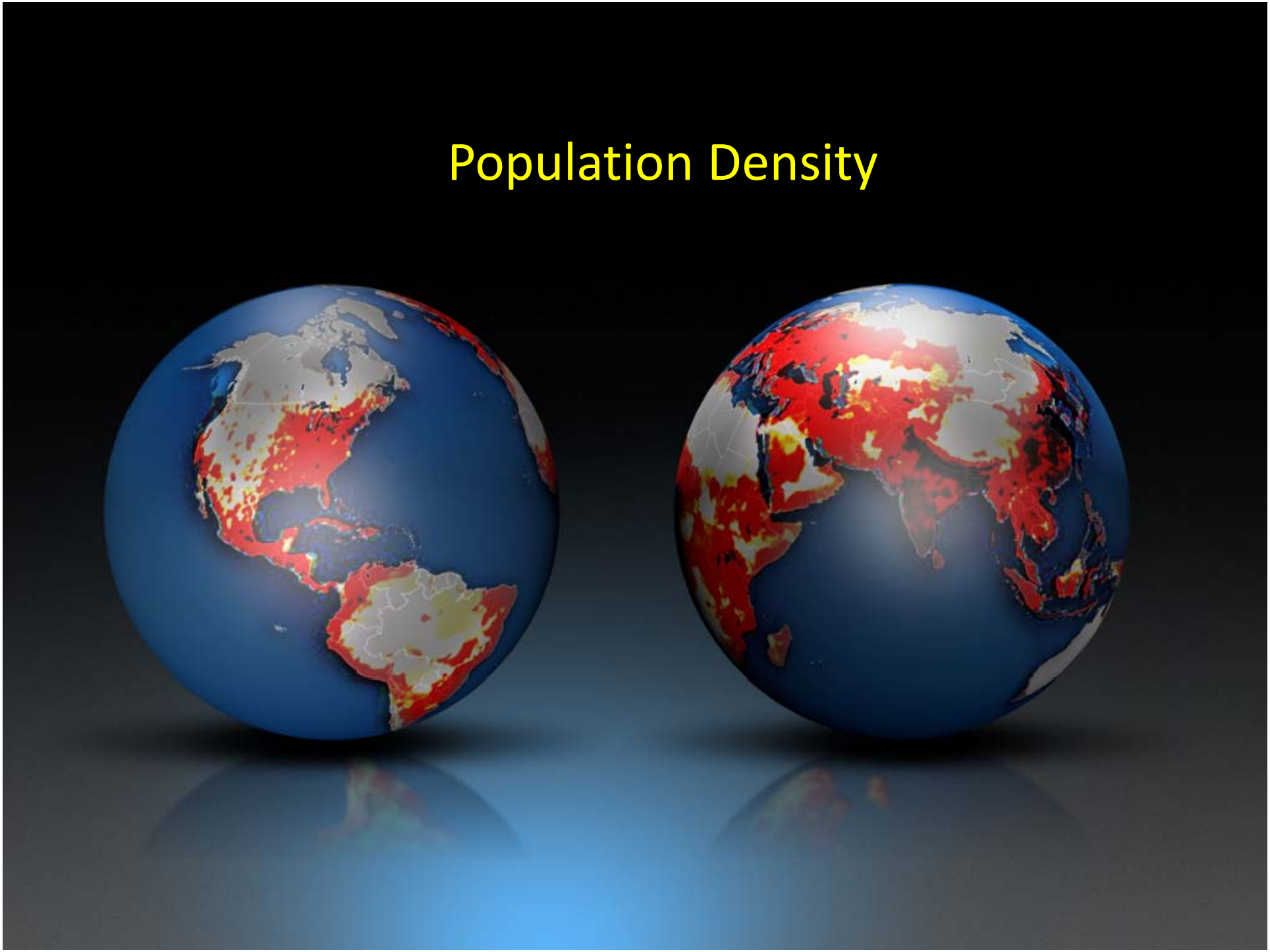
* The Deputy Secretary also serves as the Chief Operating Officer

ARPA-E's Mission

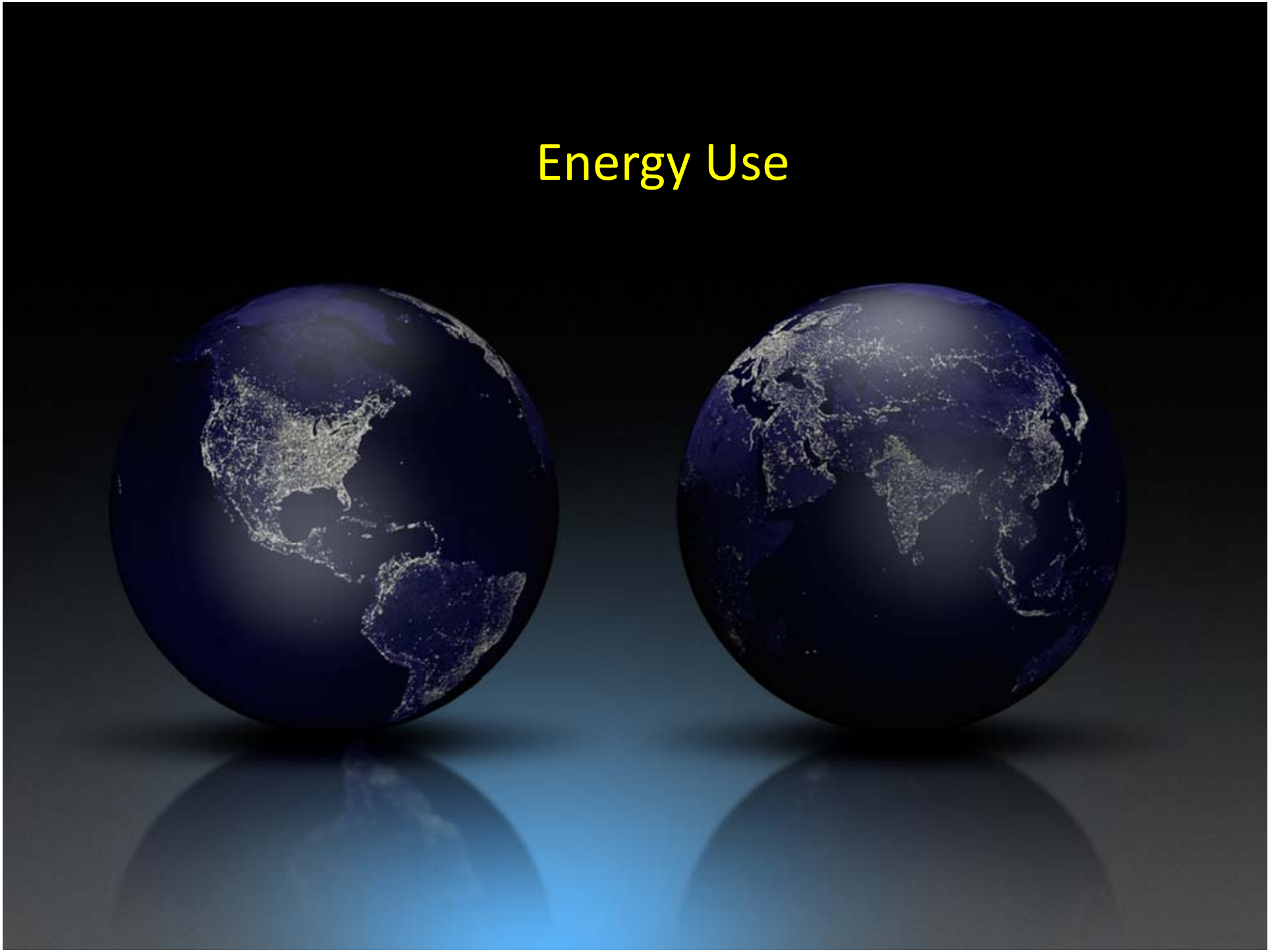


US Oil Imports

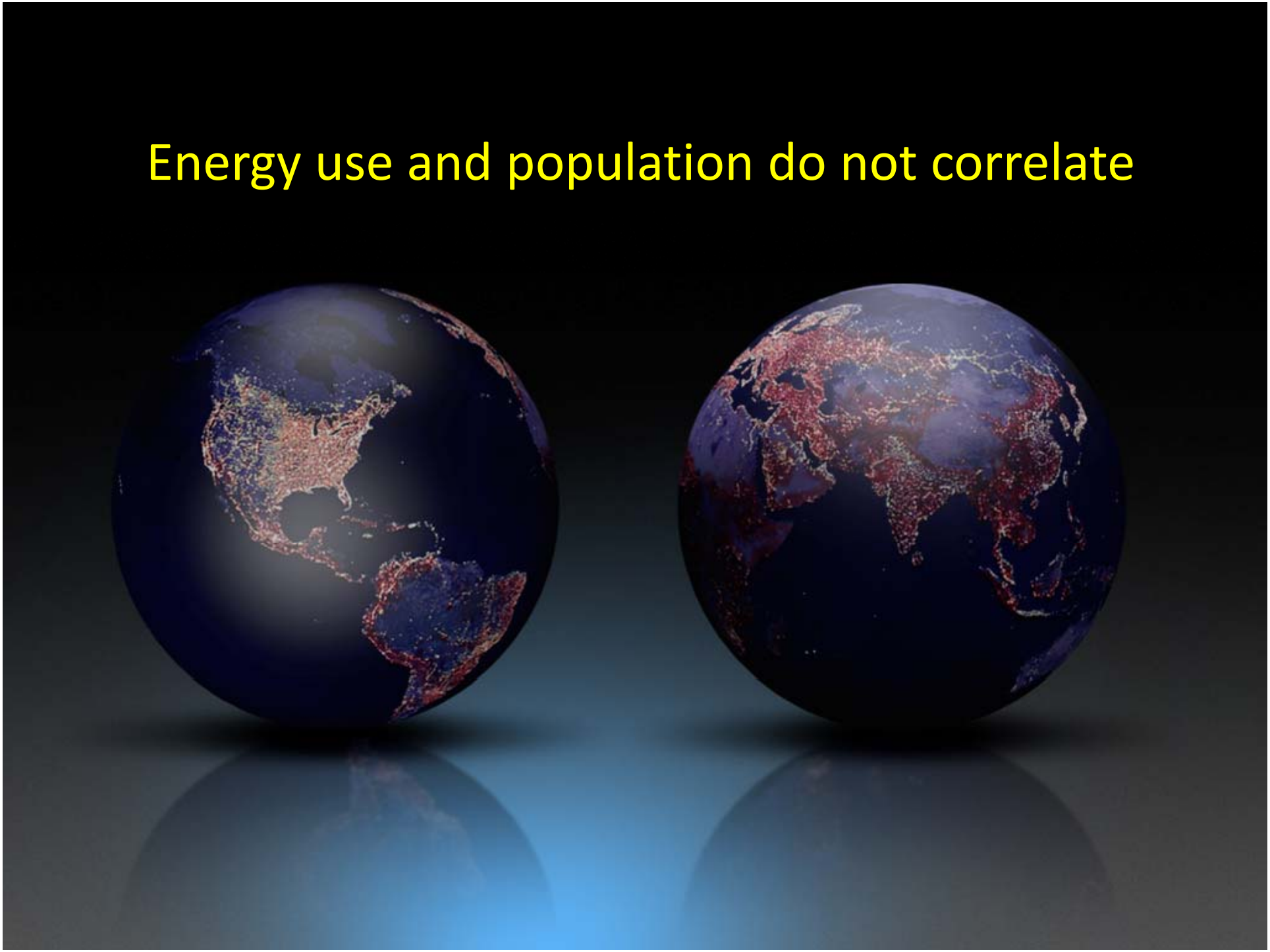
Population Density

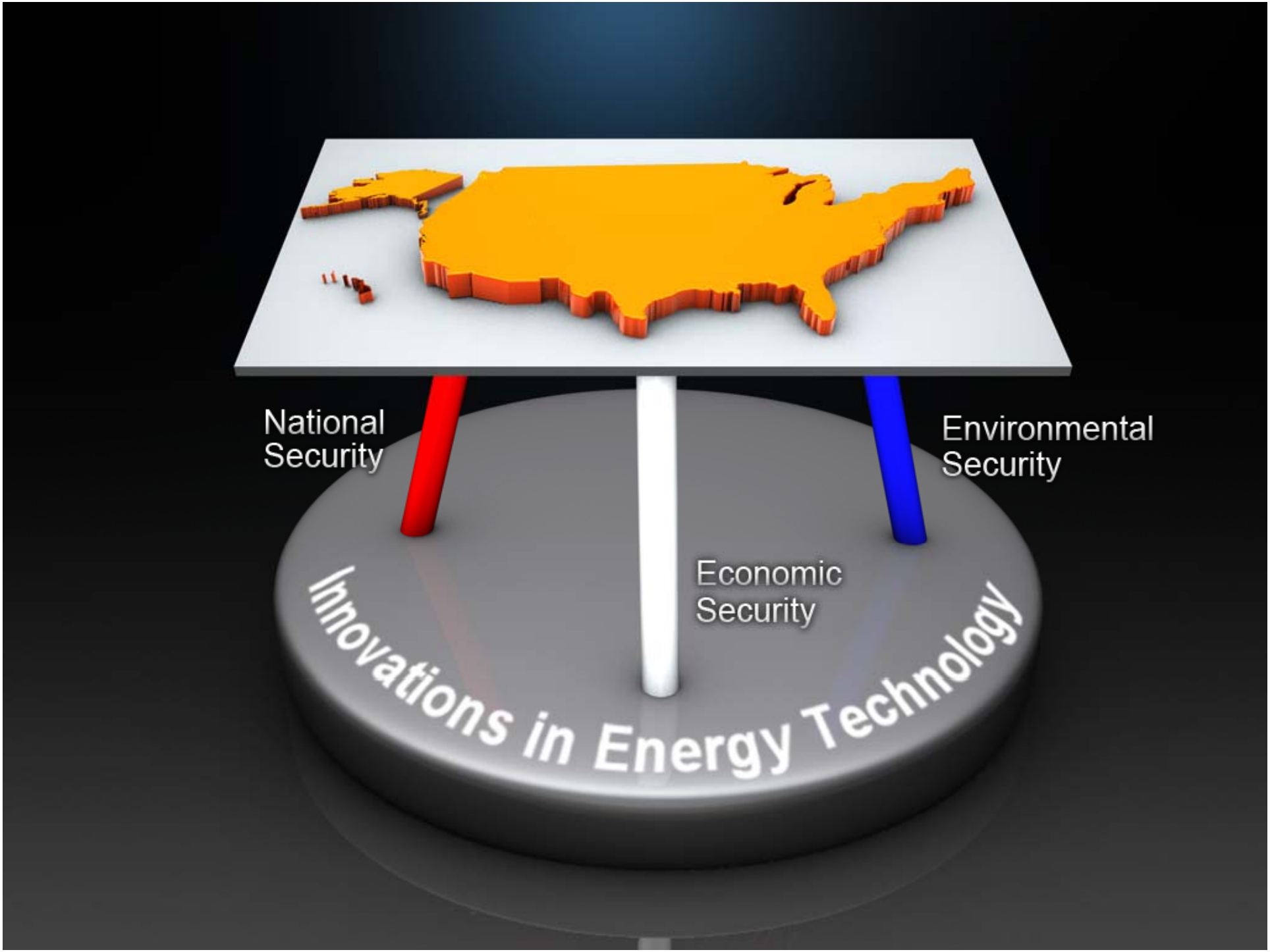


Energy Use



Energy use and population do not correlate




National Security
Environmental Security
Economic Security
Innovations in Energy Technology

Sustainable Growth

Wastefree Energy

Affordable Around the World

Growth

Constraints

Global

Population

Economy

Constraints

Energy & Material Resources

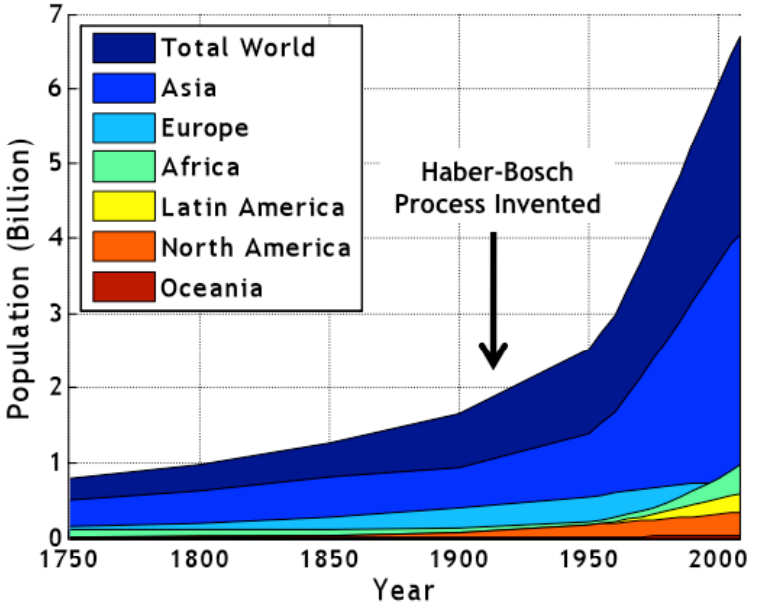
Emissions & Waste

?

WHAT IS A GAME CHANGER?

1898: "**Calling upon Science to save the world from impending starvation**," Sir William Crookes, President, British Assoc. for the Advancement of Science.

- *Lack of nitrogen in the European & American soil*
- *Nitrates found in South American Guano islands and Chilean Saltpeter*
- *Wars between Chile-Bolivia/Peru, conflicts between England, French, Spain, Germany*
- *US Guano Island Act of 1856 – food & gunpowder*

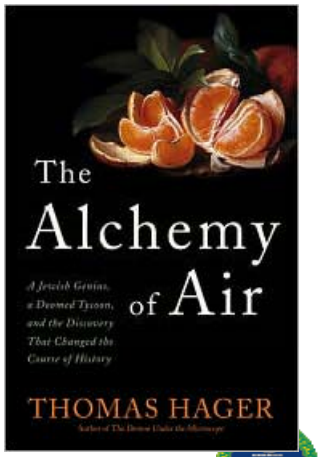


1908: Fritz Haber (Chemist) discovered a catalyst that would combine atmospheric nitrogen with hydrogen to form ammonia. Catalyst - Uranium!!

1913: Carl Bosch (BASF) developed process to mass produce ammonia and made fertilizers.

Haber

Bosch



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Pace and Scale of Innovation: 1900-2000

Artificial Fertilizers & Green Revolution

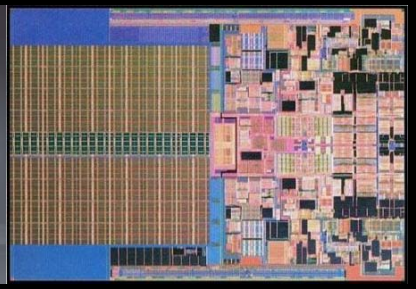
Airplanes

Polio Vaccination

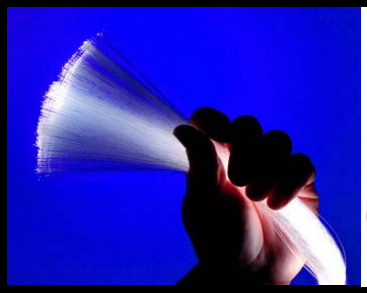
Electrification

Nuclear Energy

Space



Transistor & Integrated Circuits



Fiber Optic & Wireless Communication

Internet

Linear vs Interactive

Basic Science → Applied Science → Engineering → Technology Innovations

Science

Engineering

Technology

Conditions for Game-Changing Innovations

1. Great national, societal or business urgency and need that can be addressed by science and technology
2. Acknowledgment that business-as-usual will be insufficient to address the problem
3. Clearly defined and challenging goals
4. Thriving Ecosystem: Collaboration & Competition between teams to reach same goals
5. Teams containing scientists & engineers with no artificial demarcation between basic and applied. Low/No barriers.
6. Ability to attract talent and leverage progress from other fields
7. Reward and recognition for solving the problem
8. Adequate funding

Photosynthetic Biofuels

Sugarcane

Corn

Algae

Cellulose

Less than
1% efficient

Electrofuels

Sour Crude

H_2S

H_2

Electricity

Non-photosynthetic Microbes

>10X more efficient

Batteries for Electrical Energy Storage for Transportation (BEEST)

Electric cars with longer range and lower life-cycle cost than gasoline cars

BEEST Targets

2X increase in energy density

+

3X reduction in cost

BEEST Competition

All Electron Battery

Lithium-Oxygen

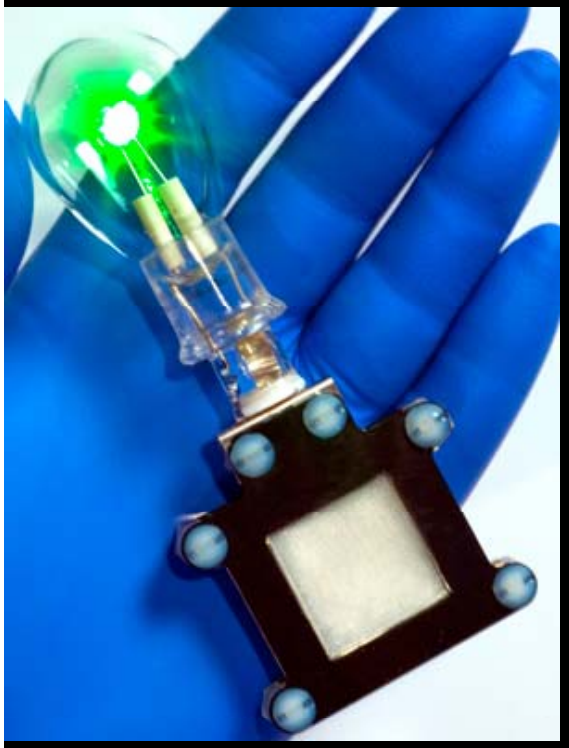
Lithium-Ion, Flow Battery

Lithium-Sulfur

Metal-Air

Magnesium-Ion

Lithium-Oxygen Battery from PolyPlus



Steve Visco

Grid-Level Power Conversion & Storage

Today

10,000 lbs

$100/kWh

Future

100 lbs

And
Smart!

Cree Inc, North Carolina

$100/kWh

Use anywhere in the world

City University, New York

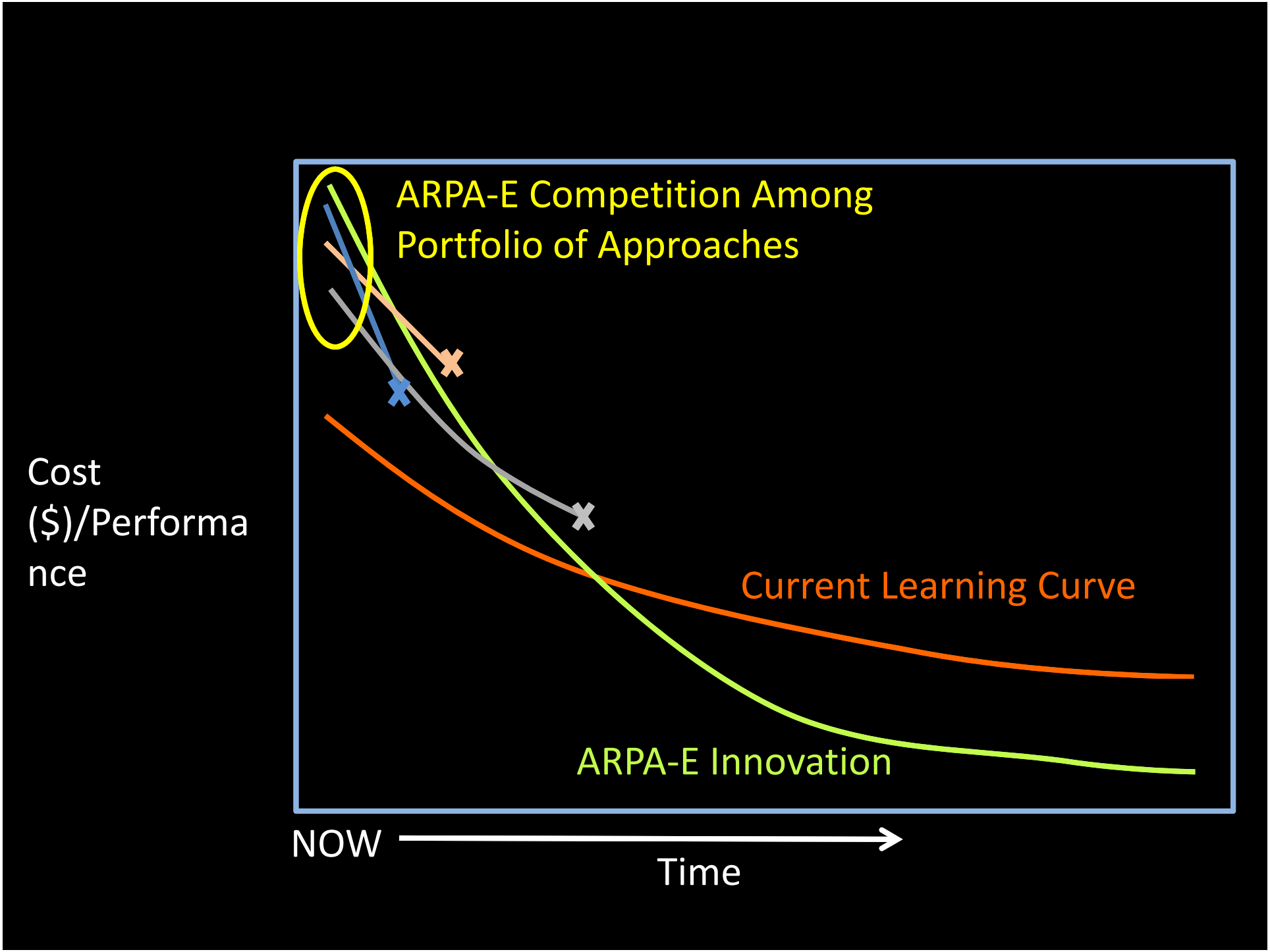
Technology Push – Market Pull

Applied Science and Technology

ARPA-E Programs
- $30-40M
- 3 years
- 10-20 projects (large, seedlings)

Integrated Energy Systems

Market


ARPA-E Competition Among
Portfolio of Approaches
Cost
($)/Performa
nce
Current Learning Curve
ARPA-E Innovation
NOW
Time

Geographical Distribution of Projects

Fierce Urgency of Now

Speed and Efficiency

Envision	Engage	Evaluate	Establish	Execute
Internal Research & Program Idea	Scientific Workshop & Internal Debate	Thorough Technical Review	Award Selection & Contracting	Hands-on Active Project Management

How do we measure success?

2010

2013-15

Beyond 2020

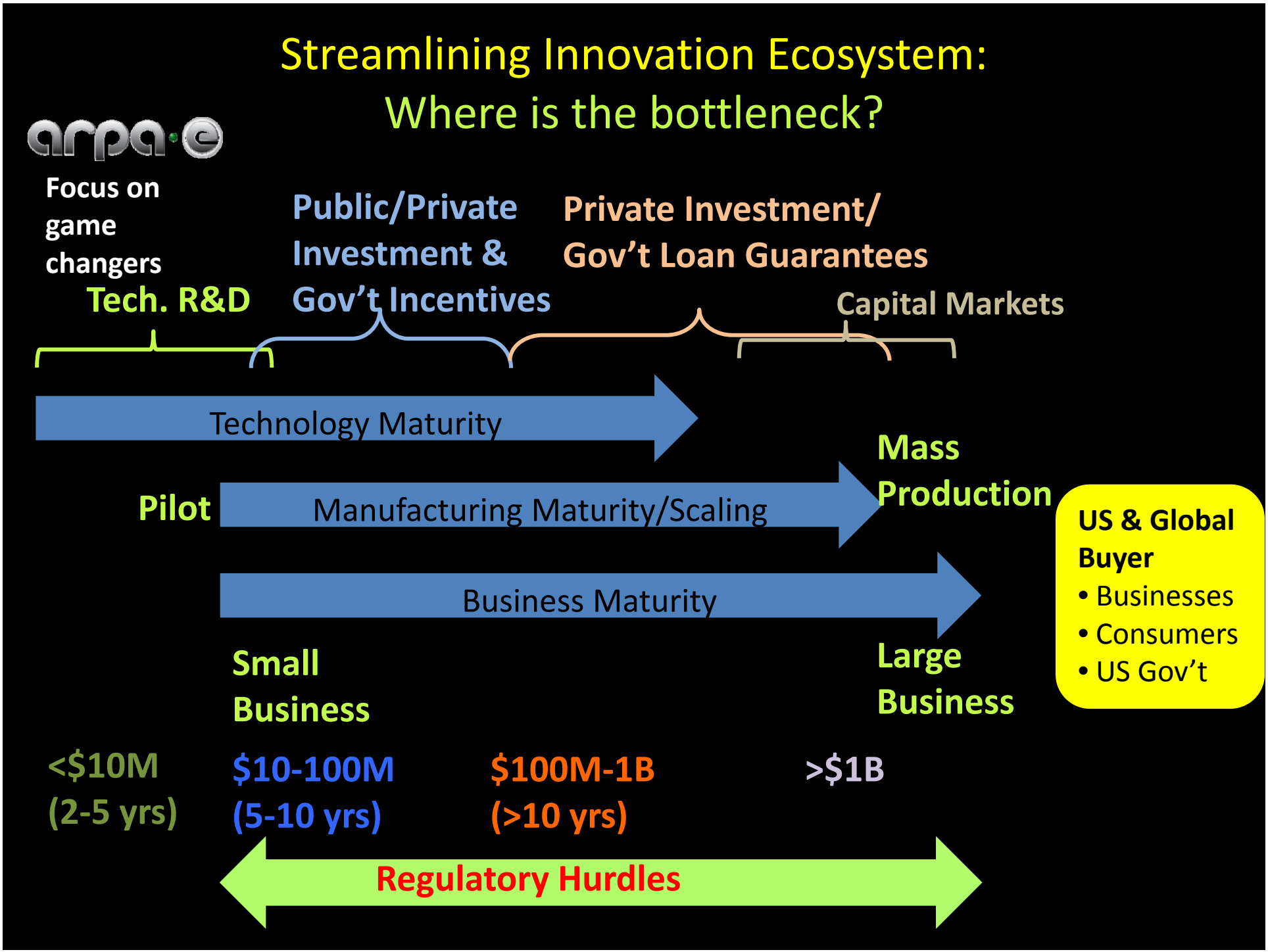
Private Sector

6 technologies $24M from ARPA-E

R&D to overcome technology barriers

$100M from private sector within 1 year

Streamlining Innovation Ecosystem: Where is the bottleneck?



Aligned Innovations