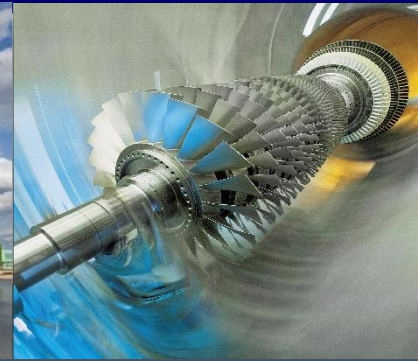
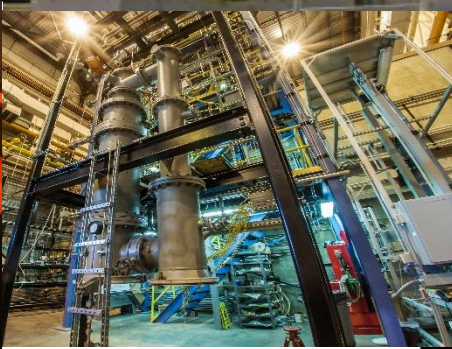
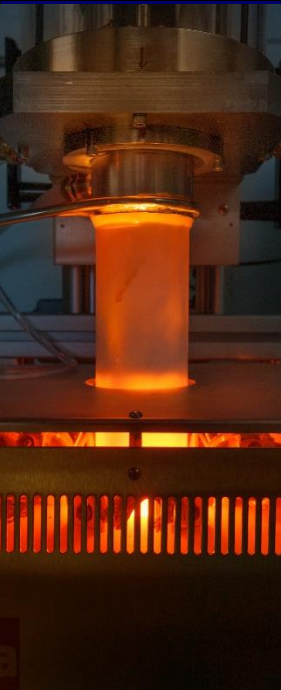




U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Fossil Energy



**AICHE 2016 Natural Gas  
Workshop  
11/2/2016**

***Technology, R&D and Policy In  
A Rapidly Evolving Energy  
Landscape***

**Doug Hollett**

Principal Deputy Assistant  
Secretary

# Fossil Energy Key Goals and Priorities

## Accelerate a Commercial Pathway to CCS

- Advanced Carbon Technologies R&D
- Domestic and international partnerships
- Reduce deployment barriers

## Advance Safe and Environmentally Prudent Oil & Gas Resource Production and Transport

- Low Carbon Pathways
- R&D on water and air quality, induced seismicity
- Emissions mitigation and quantification
- Methane hydrates

## Modernizing the Strategic Petroleum Reserves Program

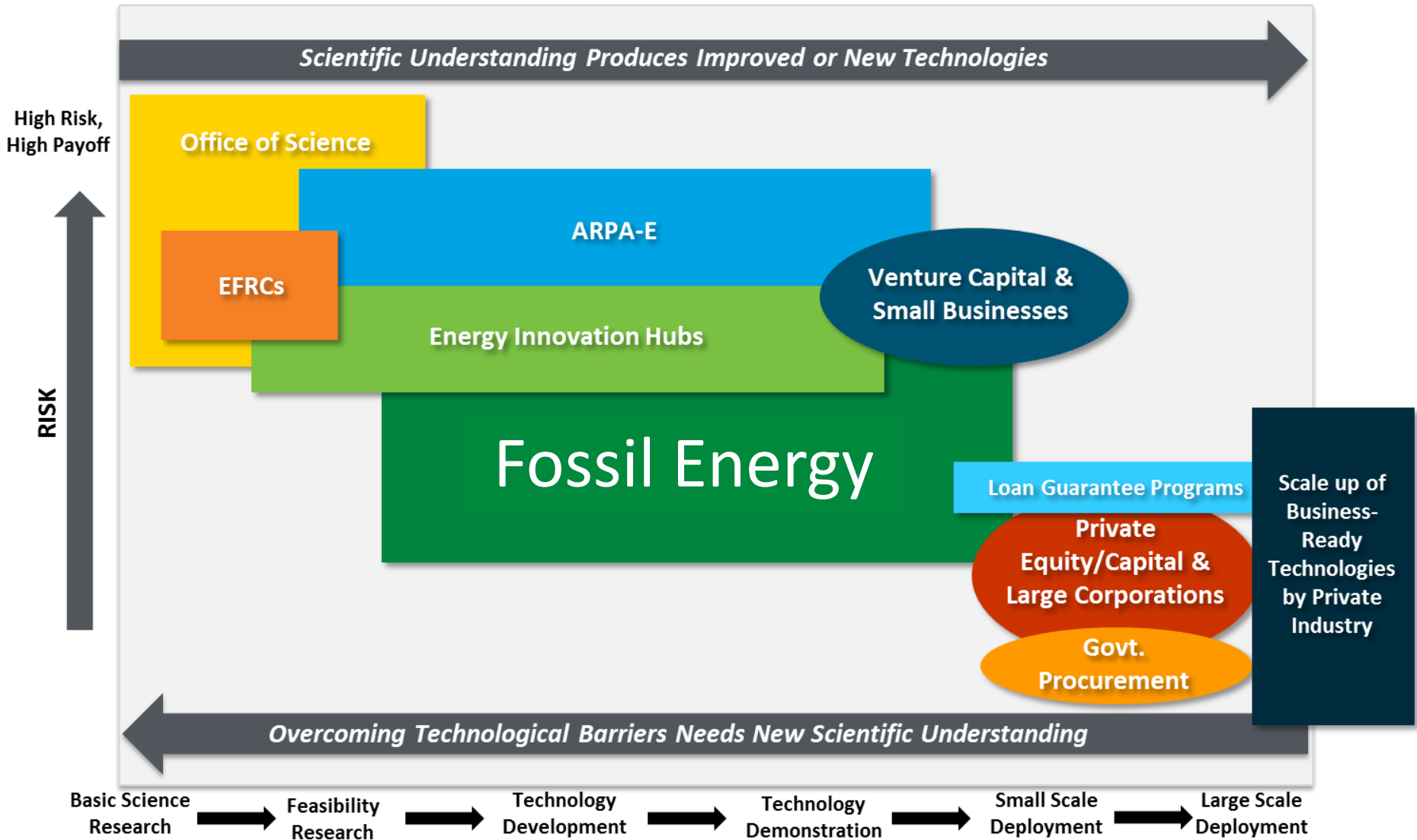
## Natural Gas Trade Regulation

## Department of Energy RD&D Crosscuts

- Intra-agency efforts to address common science and engineering challenges across the energy spectrum
  - Subsurface Technology and Engineering (SubTER)
  - Supercritical CO<sub>2</sub>
  - Energy Water
  - Advanced Materials
  - Grid Modernization

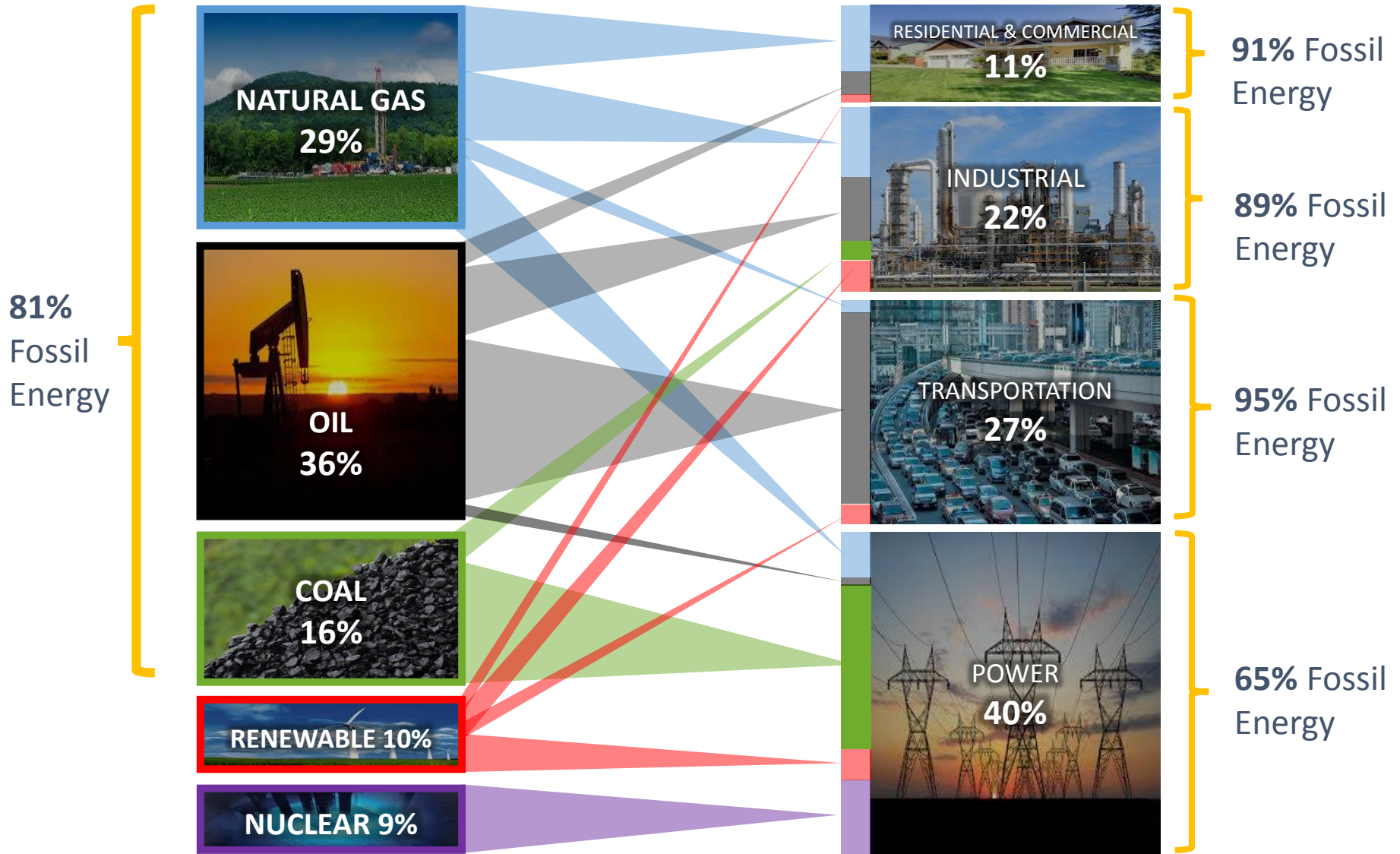


# The Department of Energy R&D Landscape





# Fossil Energy Critical in All U.S. Domestic Sectors

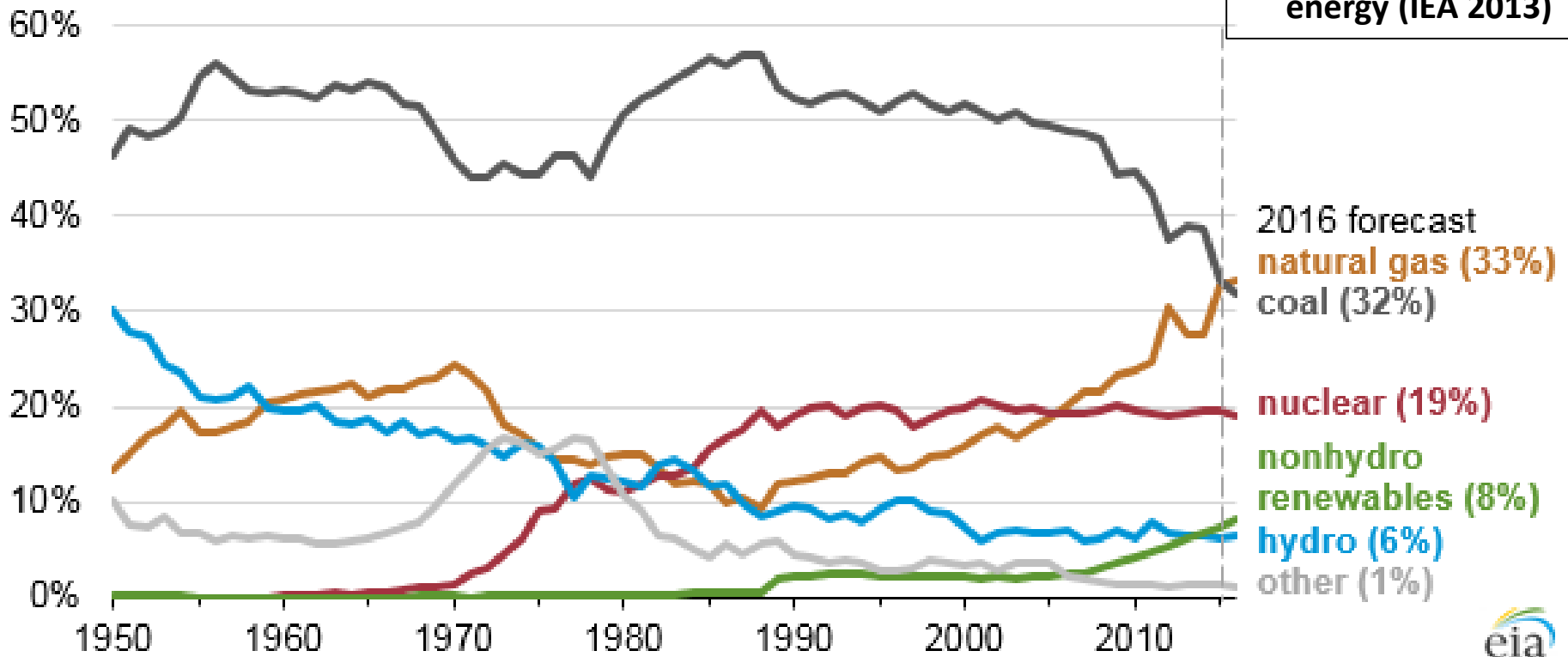


EIA, *Annual Energy Outlook 2015*, Reference Case.

# Natural gas generation exceeds coal generation in 2016

Fossil energy reduces its world share of demand from 82% to 75% by 2035, offset by a surge in renewable energy (IEA 2013)

Annual share of total U.S. electricity generation by source (1950-2016) percent of total



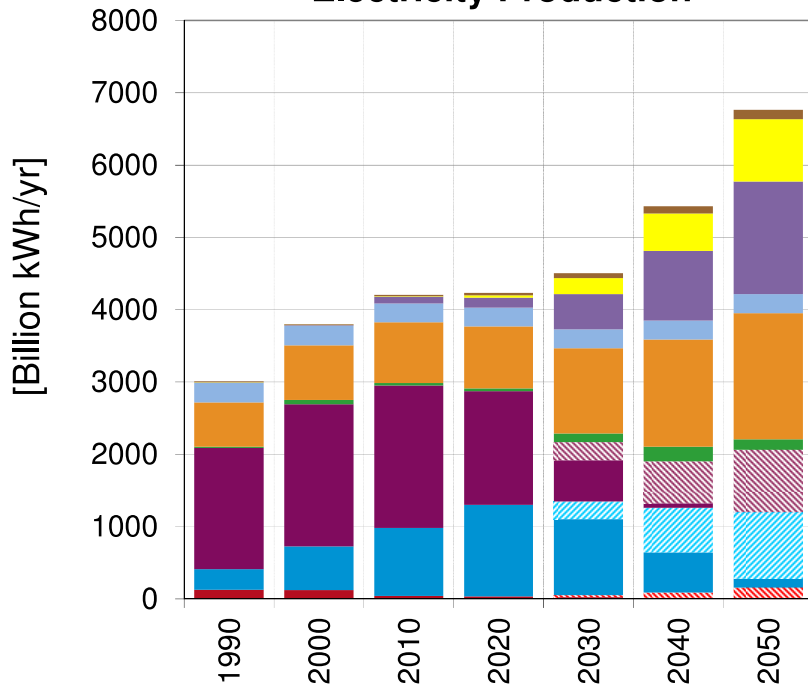
Source: U.S. Energy Information Administration, Monthly Energy Review, and Short-Term Energy Outlook (March 2016)



# CCS for coal and gas will be needed even with substantial efficiency

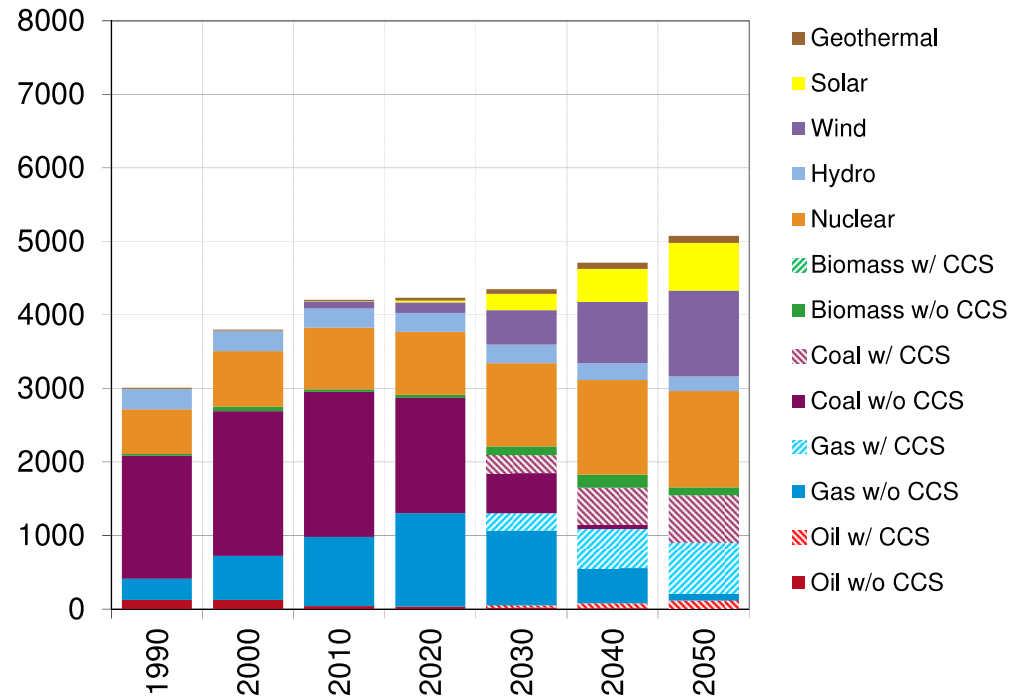
US Power Gen: Mixed Scenario

Electricity Production



US Power Gen: Low-Demand Scenario

Electricity Production



Financing / business case (cost recovery) is the main issue for widespread CCS deployment

# Technological Carbon Management Options

## *Pathways to reduce CO<sub>2</sub> Emissions*

### Reduce Carbon Intensity

- Renewables
- Nuclear
- Fuel Switching

### Improve Efficiency

- Demand Side
- Supply Side

### Sequester Carbon

- Enhance Natural Sinks
- Capture, Store, Use

All options needed to:

- Provide energy security
- Affordably meet energy demand
- Address environmental objectives





# Carbon capture, utilization and storage (CCUS): limit global warming to “well below 2°C”

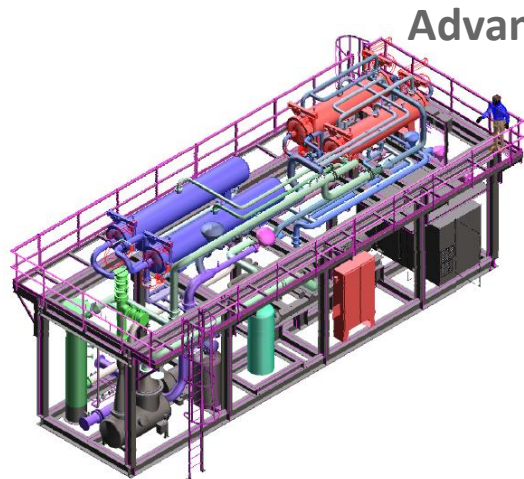
*Advanced CO<sub>2</sub> capture technologies: many pathways to success*



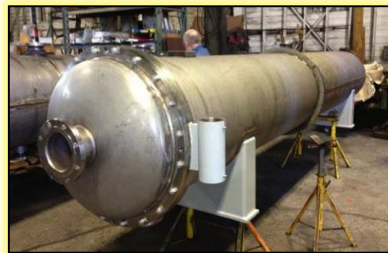
**Novel solvents**



**Transformational concepts and  
advanced compression**



**Advanced membranes**

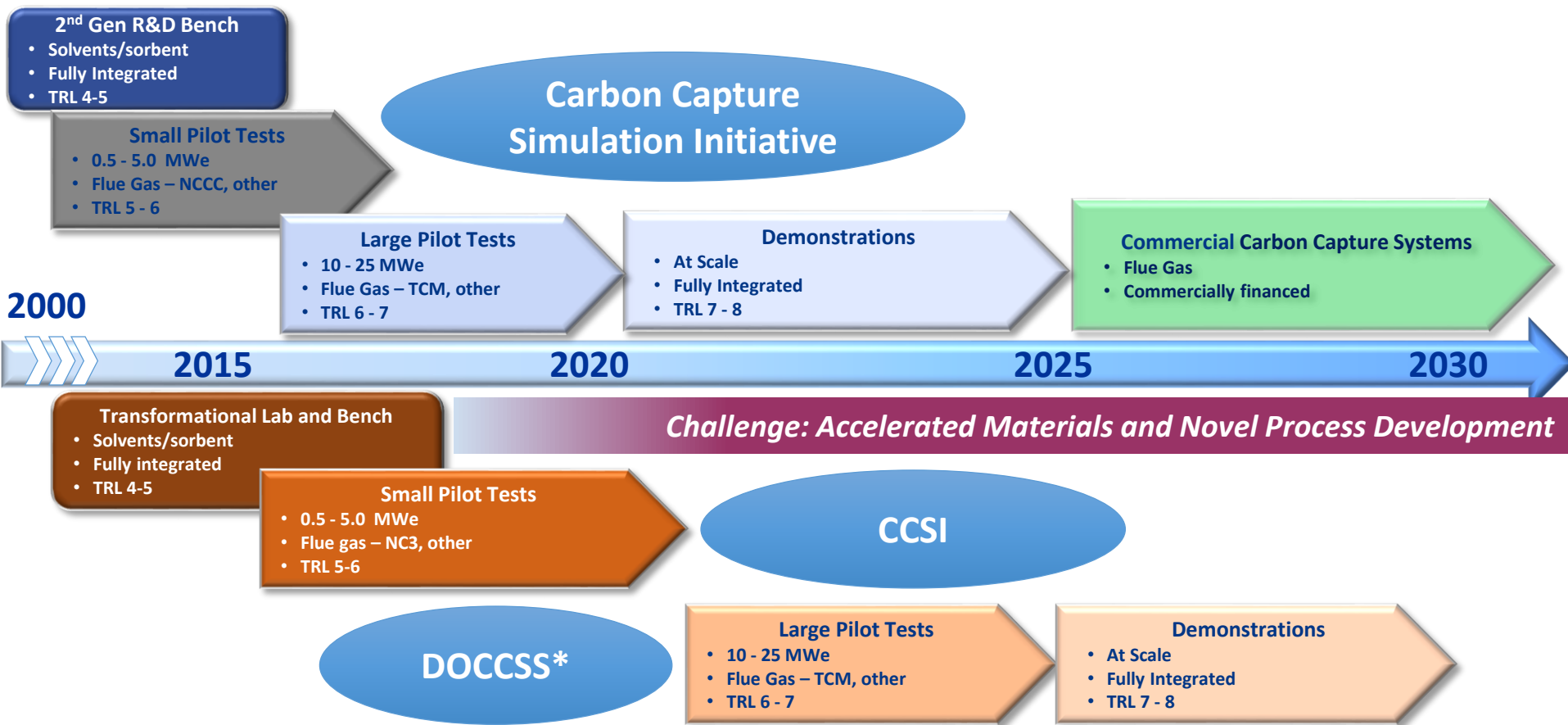


**Solid sorbents**



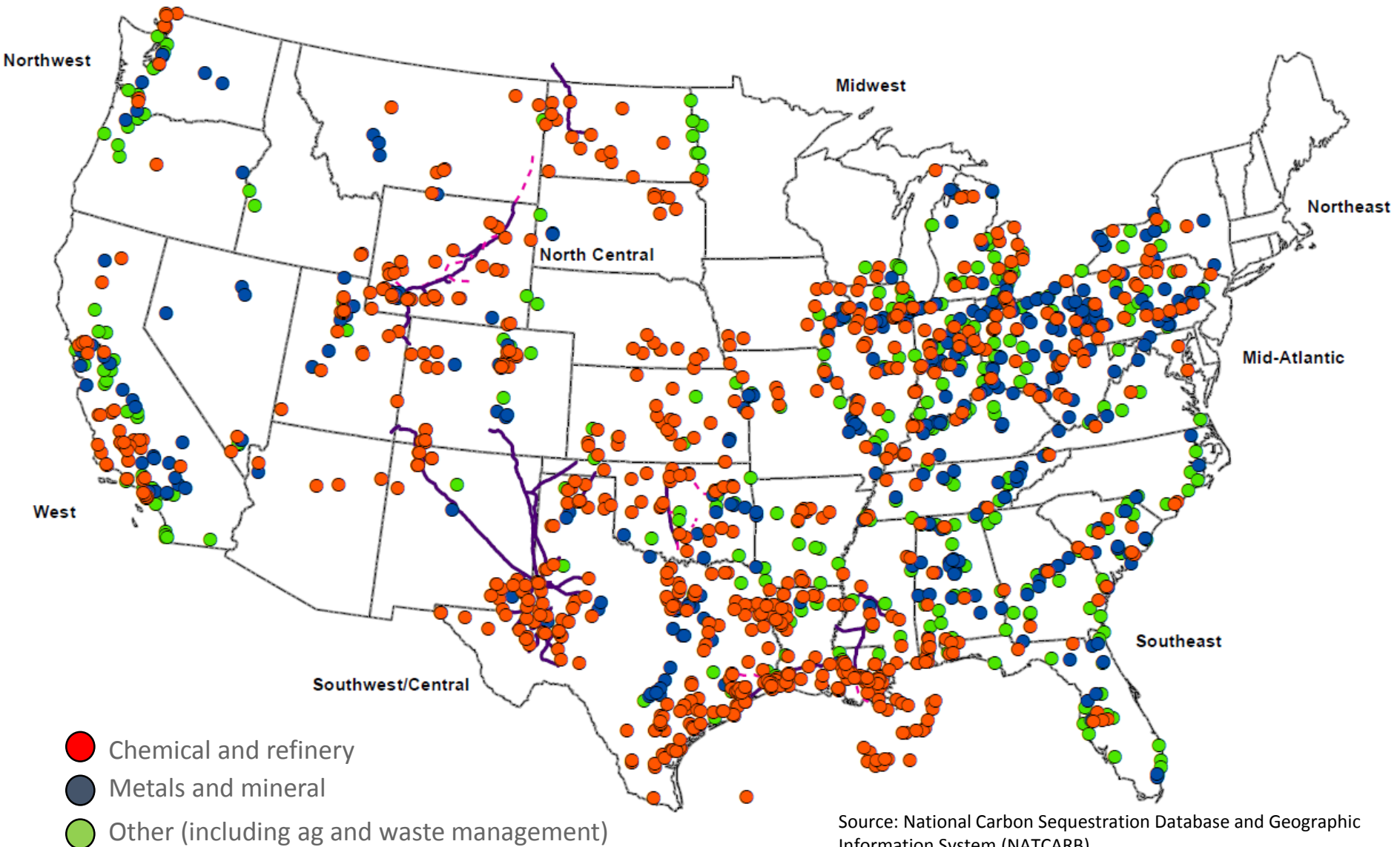


# DOE Technology Development Schedule



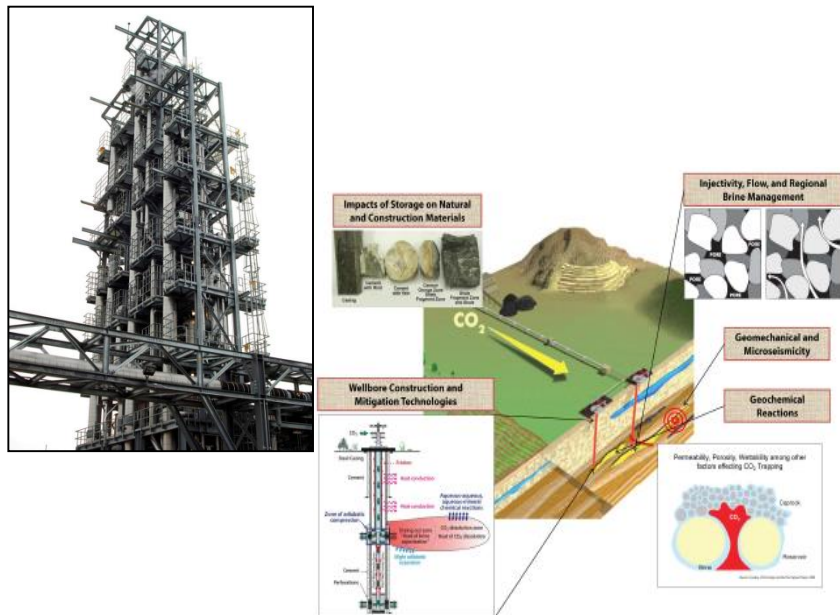
\*Discovery of Carbon Capture Substances and Systems

# Industrial sources could become early movers for CCUS



# CCUS Technology Development and Market Mechanisms

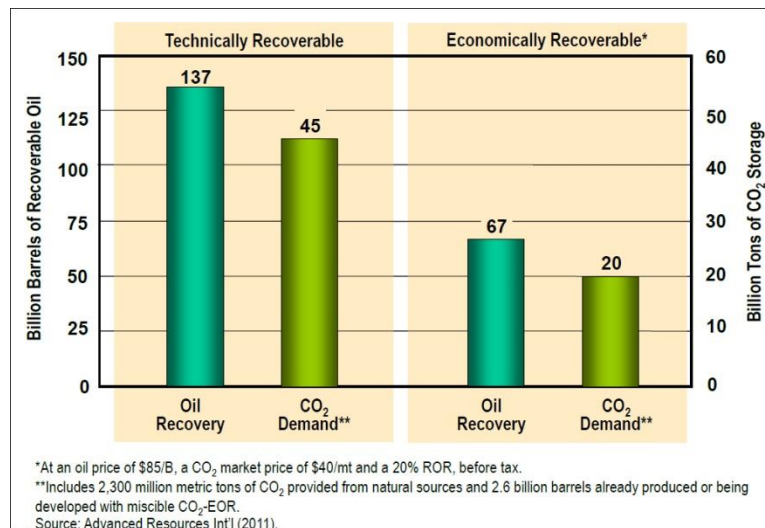
## TECHNOLOGY PUSH



- Research and Development
- Pilots, Demos (integration and learning)

## MARKET PULL

Domestic Oil Supplies and CO<sub>2</sub> Demand (Storage) Volumes from “Next Generation” CO<sub>2</sub>-EOR Technology\*\*



- **Existing Market Mechanisms: Enhanced Oil Recovery (EOR)**
  - 65 million tons/yr of CO<sub>2</sub> to produce nearly 300,000 barrels of oil/day
- **Regulatory Framework (Evolving)**
- **Financing (Tax Credits and Loan Guarantees)**

# Gas Utilization Pathways: Critical Connections

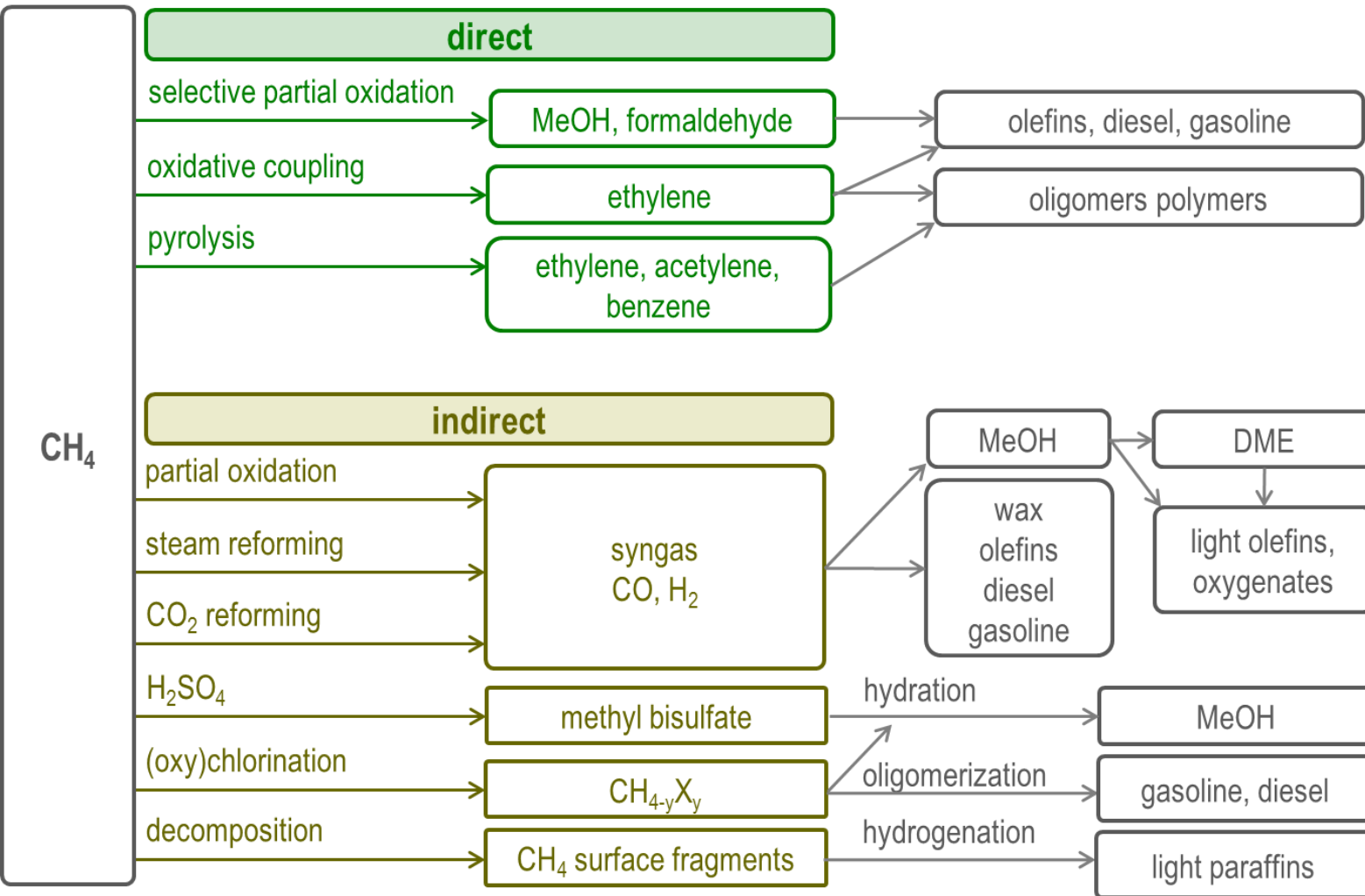
- **Clean Energy Perspective, integration with renewables/rest of energy system**
- **Integration with CCS vital**
- **Modularization and remote/stranded applications**
- **Methane emissions**
- **Importance of infrastructure**
- **Global implications for 5 Tcf of gas flared annually**



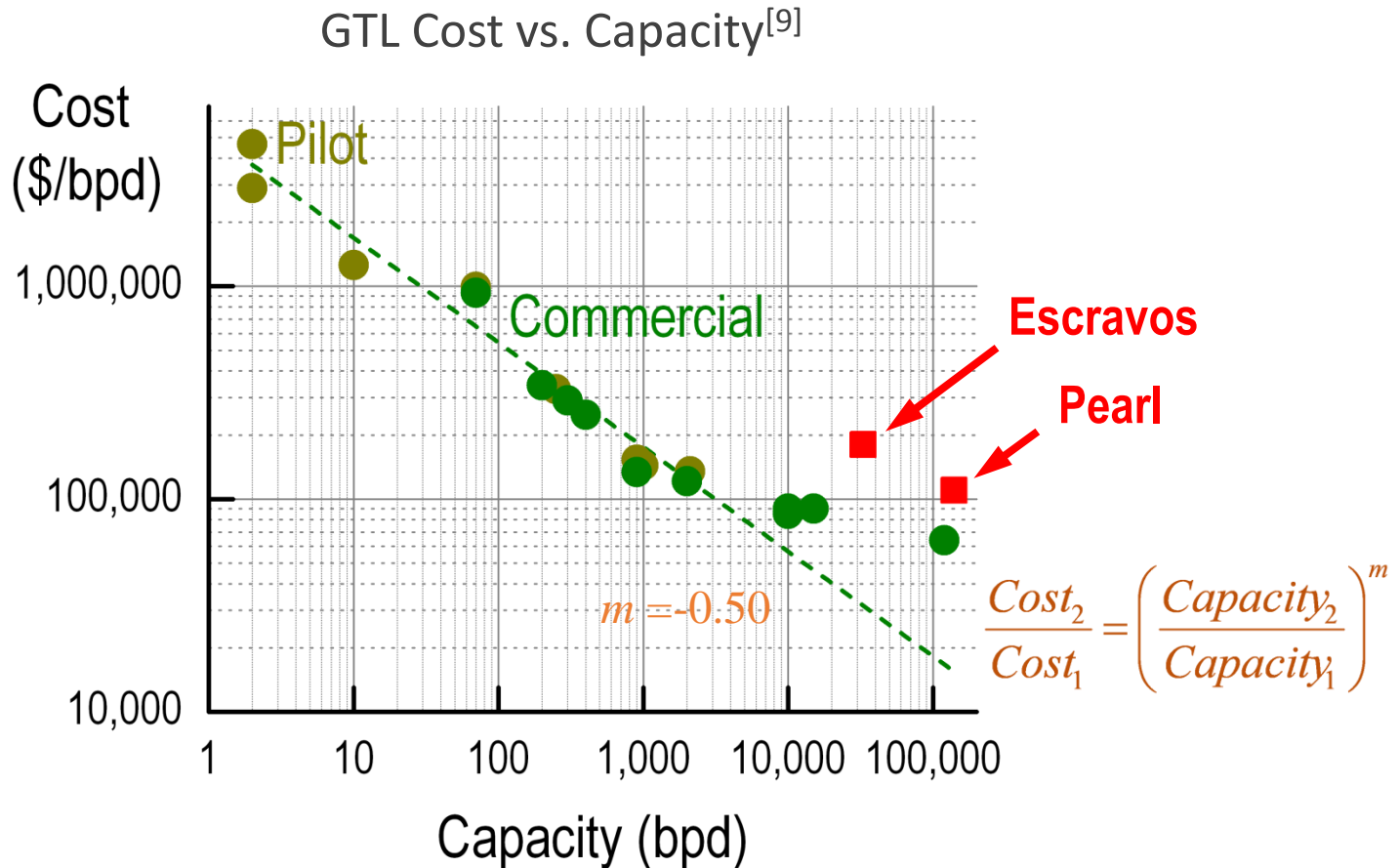
# Government Role?

- **Consistency with top-line strategy and objectives**
- **Proper government role, national interest**
- **Not compete with industry and avoid overlaps**
- **Think long term ... but consider short term impacts (wins)**
- **Big enough challenge; impact; inclusive approach; “hard”**

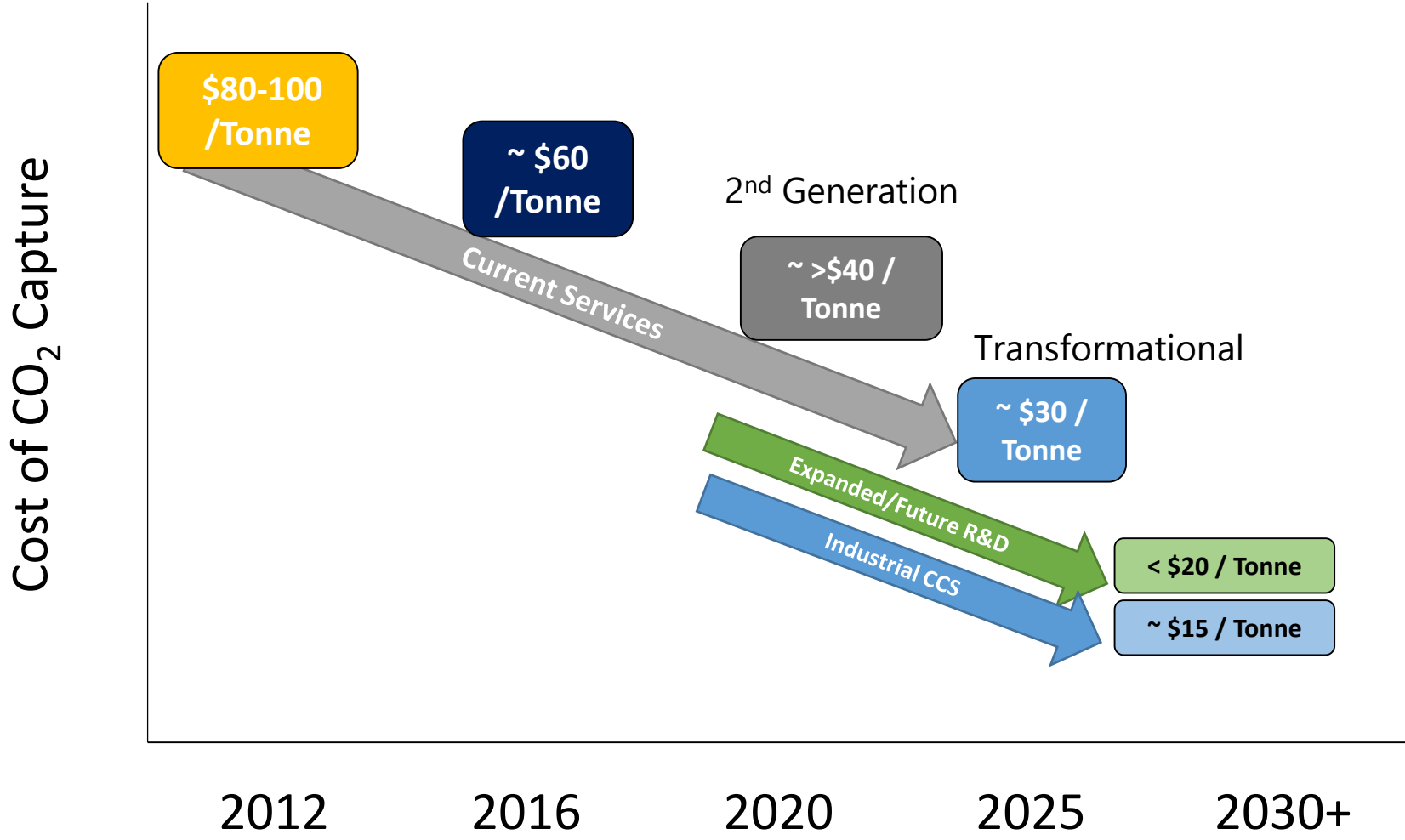
# Methane Routes to fuels and chemicals



# Economies Of Scale: Is Bigger Always Better?

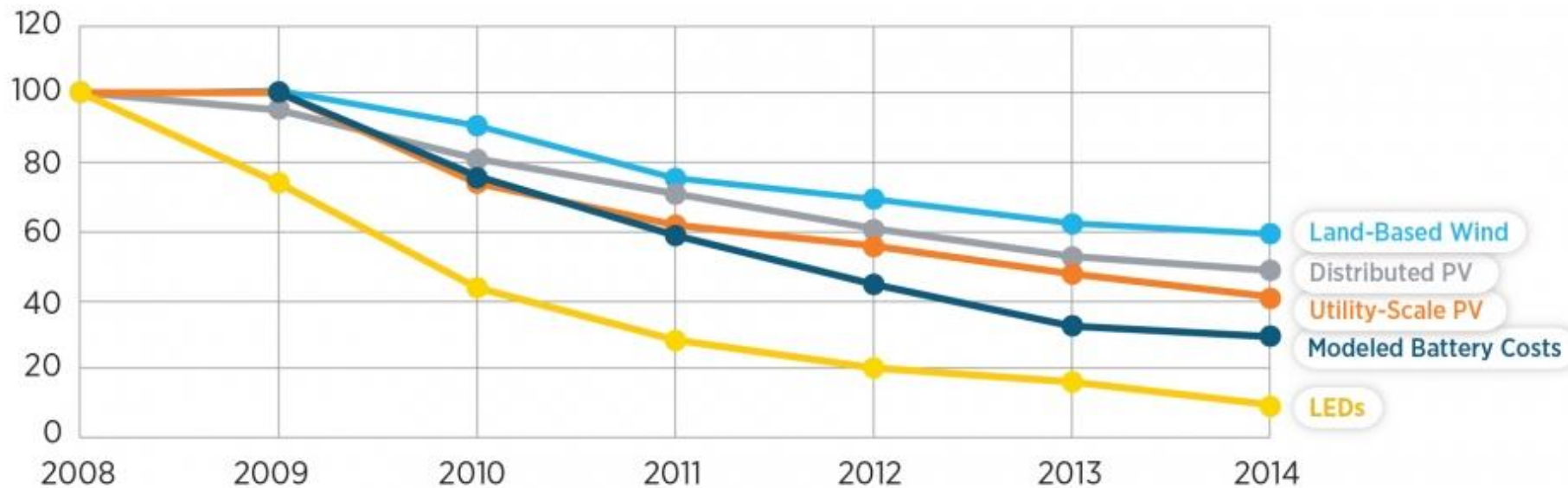


# DOE RDD&D: CCUS Program Goals





# Falling Costs for Other Clean Energy Technologies



*Each of these technologies has dropped 40-90% in cost since 2008  
Indicates the opportunity pathway for advanced fossil technologies*

*Indexed Cost reductions since 2008*

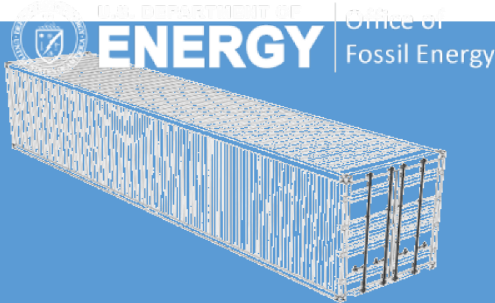
# Fossil Energy Benefits

## Program

## Cross-Cutting Areas for Modular Process Solutions

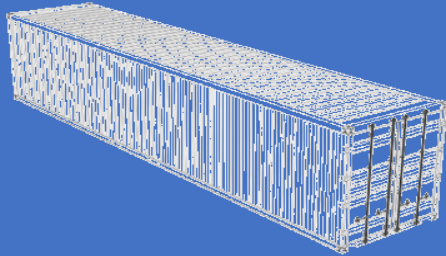
Advanced Energy Systems

- Air separation units
- Gasification modules
- Syngas conversion
- Power gensets



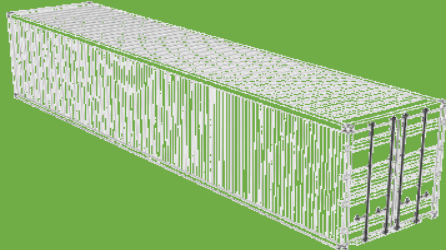
Carbon Capture & Storage

- Air separation units
- Post-combustion carbon capture
- Compressor modules



Oil & Gas

- Compressor modules
- Produced water clean-up
- Syngas conversion
- Stranded gas/methane conversion



# What Might It Take?

- **Workshops to ID R&D gaps. More Modular, deployable, plug-and-play solutions**
- **Open collaboration, standardization, more aggressive dashboarding and multi-year planning. More players = faster innovation.**
- **Intensification, additive manufacturing, automation, at the same time lower complexity and focus on integration**
- **New business models, niche applications, combined with proper policy tools**
- **Climate/environment context**



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