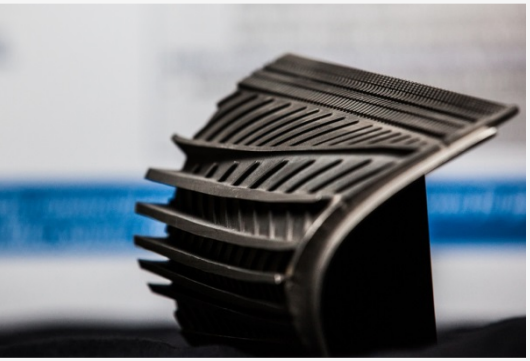
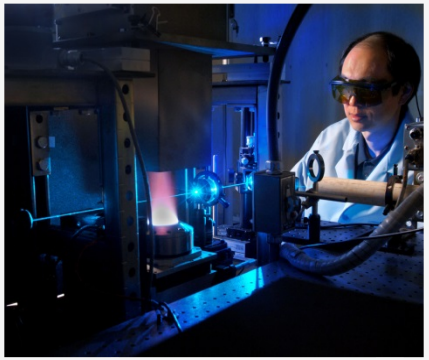
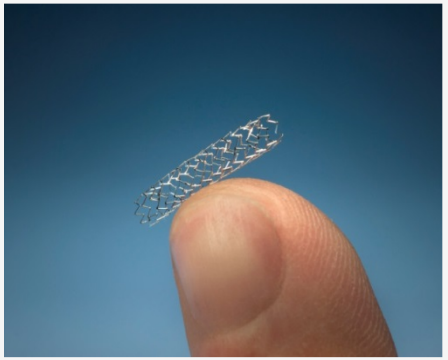
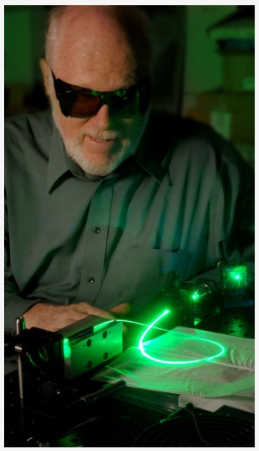
Driving Innovation ♦ Delivering Results

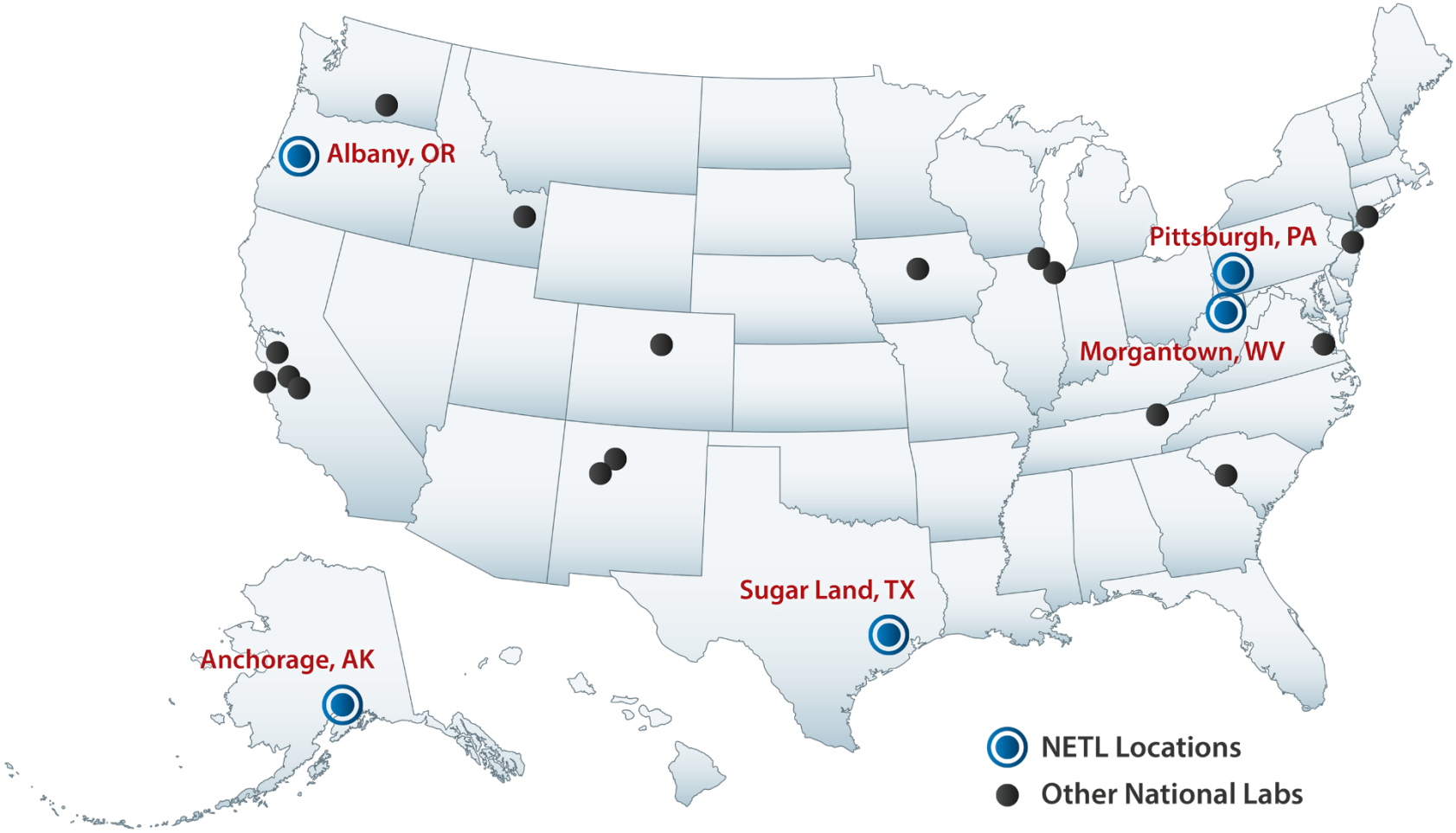

DOE Office of Fossil Energy
Advanced Combustion Systems Program

John Rockey

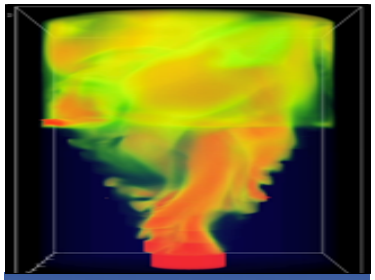
Technology Manager

September 20, 2016

NETL: THE Fossil Energy Laboratory

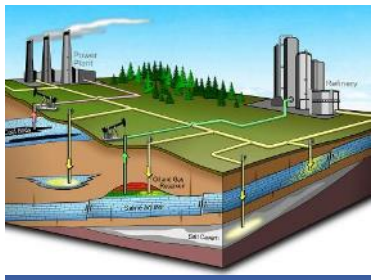


Technology Thrusts



Computational Engineering

Materials Engineering & Manufacturing



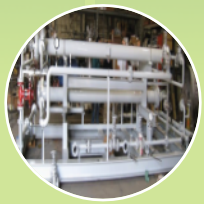
Geological & Environmental Systems

Energy Conversion Engineering

Systems Analysis & Engineering

Carbon Storage

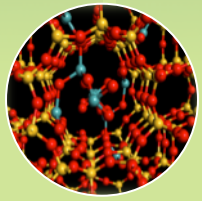
Carbon Capture



Sensors

Advanced Materials

Advanced Computing



Advanced Energy Systems

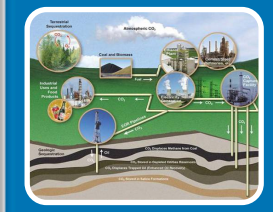
Enhanced Resource Production

Environmentally Prudent Development

Transmission & Delivery

Methane Hydrates

The Big Technology Issues for Coal



Manage CO_2 Emissions

Reduce Criteria Pollutants

Minimize Water Use

Control Costs

Full RD&D Life Cycle

EXTRAMURAL

INTRAMURAL & EXTRAMURAL

Technology Demonstration

TRL 8-9

Process Engineering & Integration

TRL 5–7

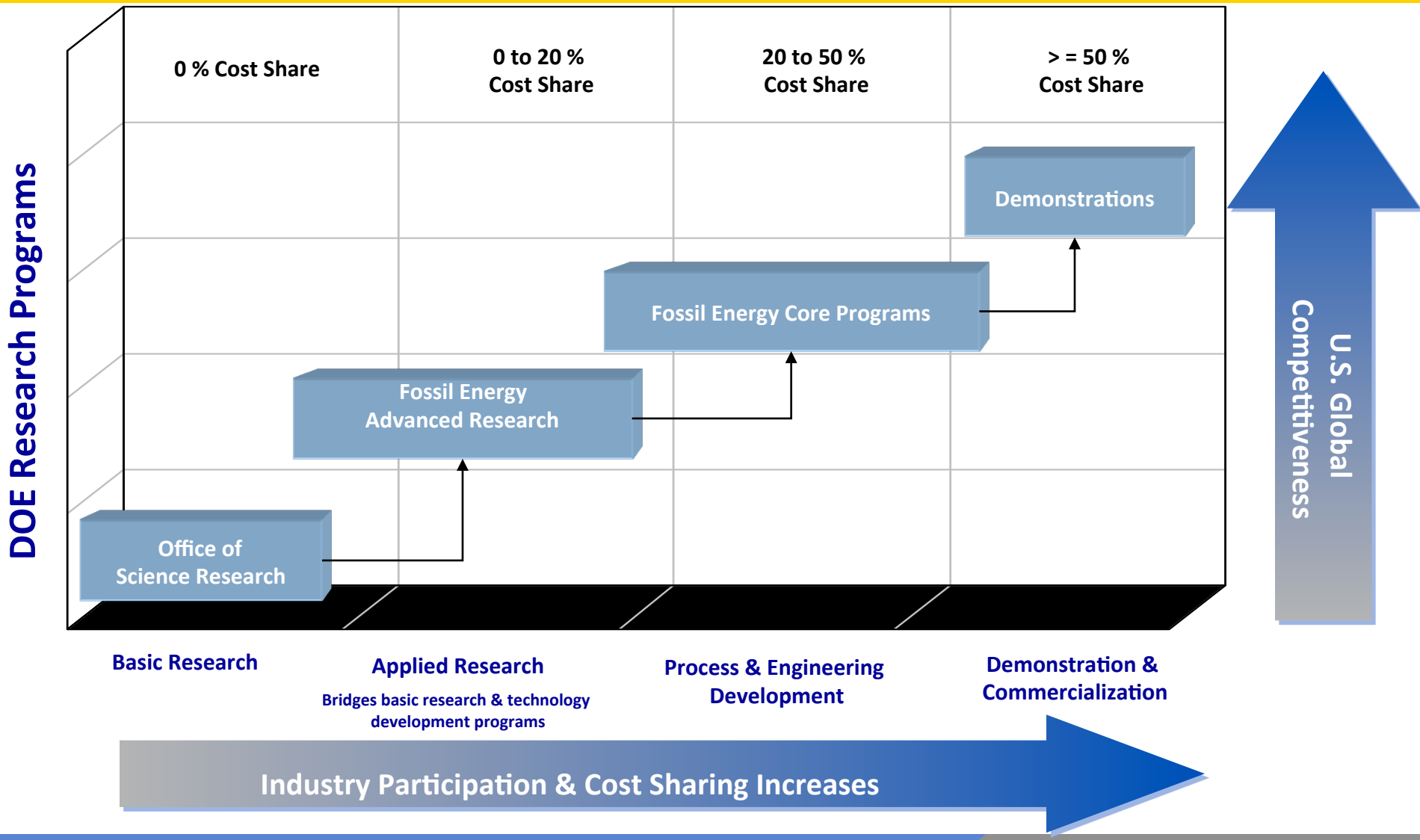
Applied Research

TRL 2-4

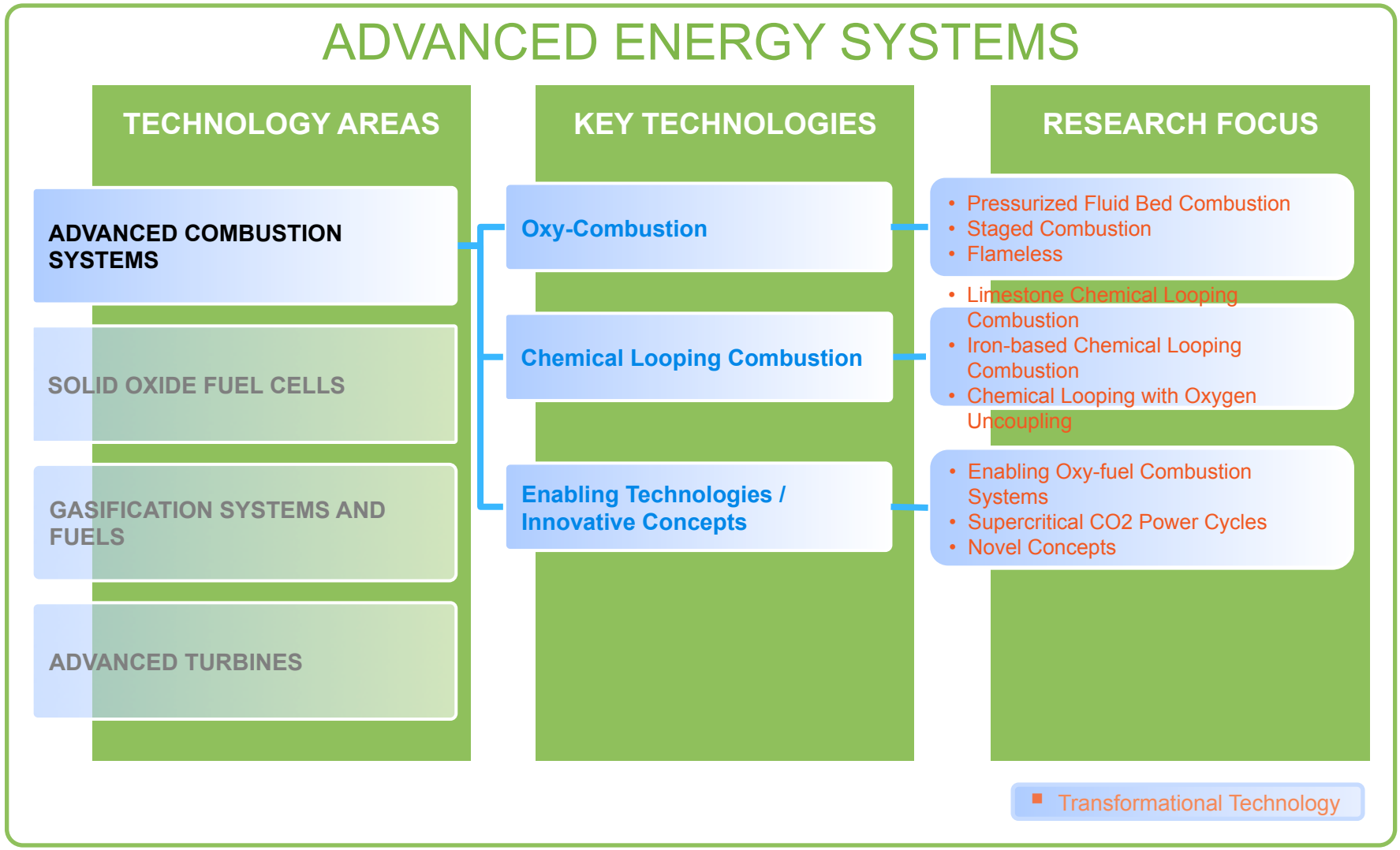
Energy Solutions for Today

Energy Options for Tomorrow

Cost Share Ensures Commercial Relevance

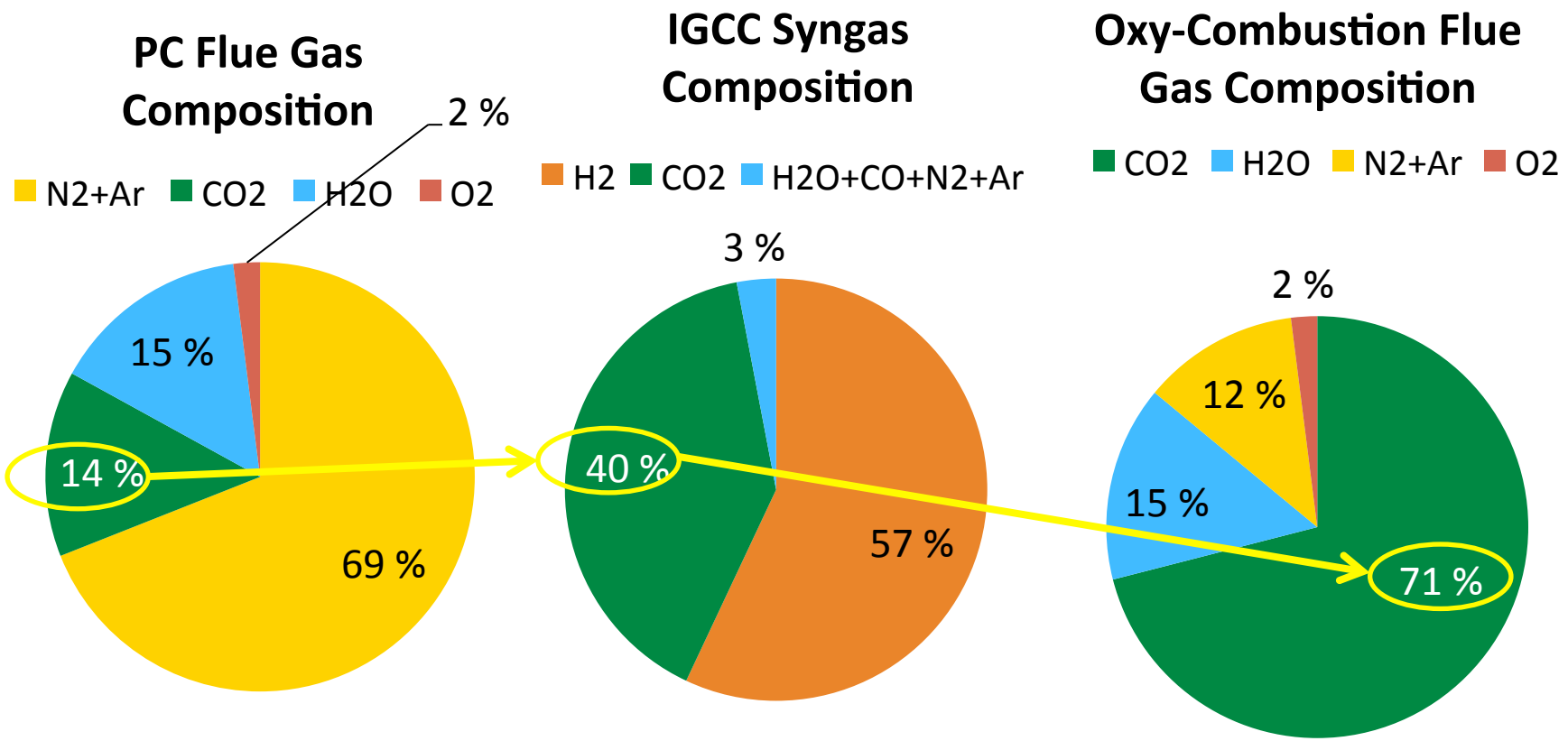


Advanced Combustion Systems Program



Carbon Capture Advantage of Advanced Combustion Systems

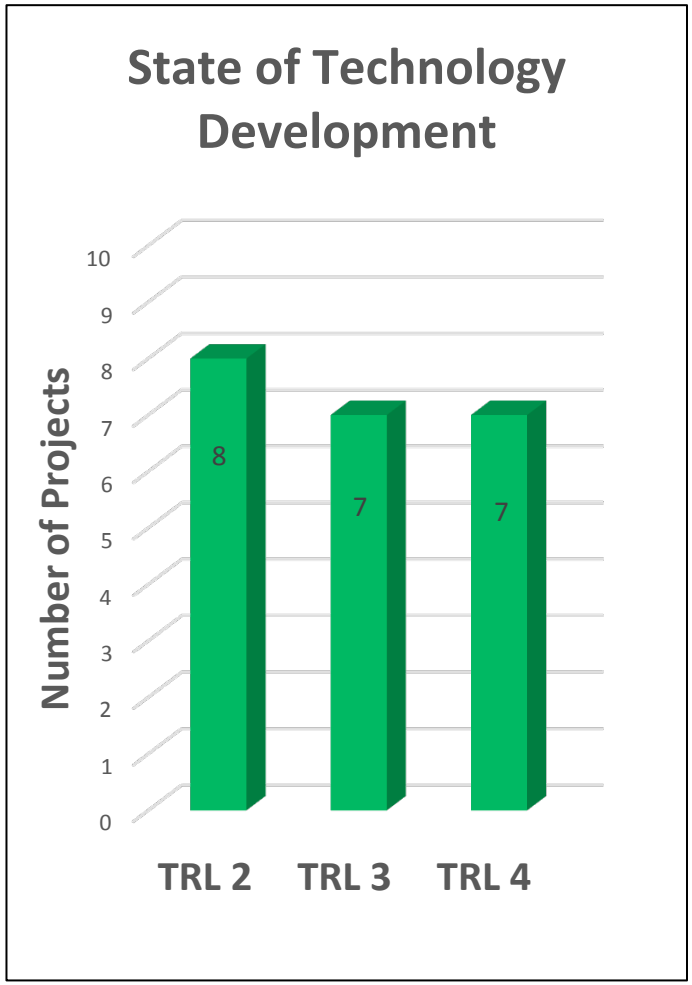
INCREASING CO_2 CONCENTRATION -> REDUCED CAPTURE SYSTEM COST AND ENERGY



Advanced Combustion Systems Program

KEY TECHNOLOGIES	RESEARCH FOCUS
Oxy-Combustion	• Pressurized Fluid Bed Combustion • Staged Combustion • Flameless
Chemical Looping Combustion	• Limestone-based CLC • Iron-based CLC • Pressurized CLC • Chemical Looping with Oxygen Uncoupling
Enabling Technologies / Innovative Concepts	• Enabling Oxy-fuel Combustion Systems • Supercritical CO2 Power Cycles • Novel Concepts

■ Transformational Technology



Advanced Combustion Systems
Research Objectives and Approach

RESEARCH OBJECTIVES

- Complete pre-feed design and techno-economic analysis of chemical looping combustion and oxy-combustion pilot facilities by 2018
- Initiate construction of two 10+ MW integrated large pilots by 2020
- Ready for demonstration by 2025

APPROACH

- *Early Applied (TRL 2-4):* RIC conducts fundamental research focused on addressing technical gaps regarding advanced combustion technologies. NETL's internal R&D focus is on applied research with results made broadly available to interested parties via regularly scheduled semi-annual meetings.
- *Development (TRL 5-7):* The program is focused on developing fully integrated power systems. Multiple Teams provide technology diversification and reduce program dependency on a single developer.

NETL'S PARTNERS & ROLES

- Technology Developers: Alstom, B&W, GTI, Univ. of Kentucky, Univ. of Utah, Washington Univ. at St. Louis
  - ✓ Development of multiple, proprietary technology pathways
  - ✓ Provides the vehicle for commercialization
- NETL RIC addresses chemical looping technical gaps
- Universities & small businesses advance concepts and components to identify next generation systems, improve system benefits, and address scale-up challenges

KEY MILESTONES

FY16: Demonstrate multiple (3-4) small pilot (0.1-1MWe) systems

FY18: Design 2 integrated 10-25 MWe large pilot systems

FY20: Operate 2 integrated 10-25 MWe large pilot systems

FY25: Demonstrate ~70 MWe FOAK Advanced Combustion Coal Power Plant (AUSC or SCO2 power cycle, Advanced O_2 integration, Advanced flue gas purification)

Pressurized Oxy-Combustion

Avoid back end separation while taking advantage of pressurization

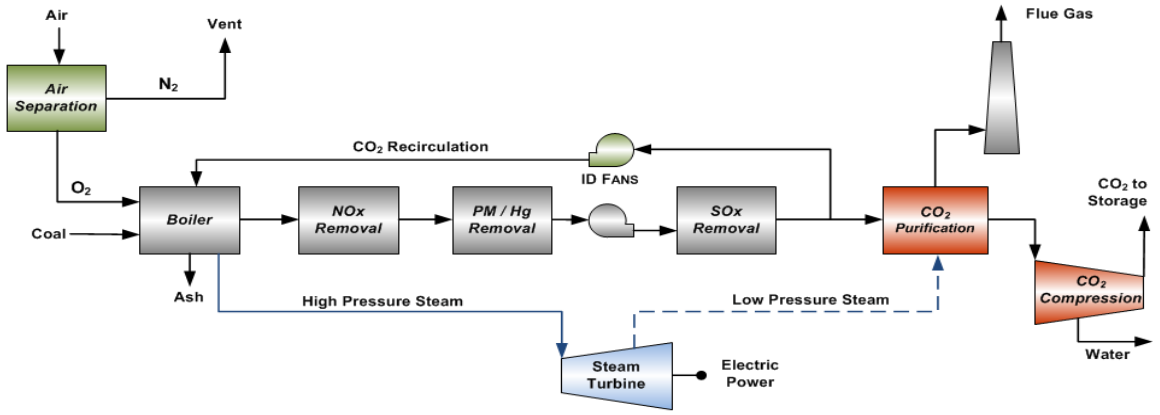
Advantages of Pressurized Oxy-combustion:

In pressurized oxy-combustion, the mass and volume of flue gas are reduced relative to atm. combustion in air:

- Latent heat recoverable and heat transfer rates increased… *increases efficiency*
- Reduces equipment size…*decreases capital costs*
- No air in-leakage… *increases CO_2 purity*
- Developer's projected CO_2 capture costs exceed program goals

R&D Challenges

- Pressurized Combustor Design
- Fuel Feeding
- Emissions Control
- Heat Recovery & Integration



Generalized Oxy-combustion Block Flow Diagram

Pressurized Oxy-Combustion

STATUS

- Pressurized Oxy: TRL 3/4
- Testing at bench scale, complimented by cold flow testing, and modeling
- 1 MWe small pilot under construction at Canmet, operation starts in FY16

PROJECTS

1. **Aerojet Rocketdyne**

   Oxy-Pressurized Fluidized Bed Combustion (Oxy-PFBC)

2. **Washington Univ. in St. Louis**

   Staged Oxy-Combustion

3. **SWRI**

   Flameless Combustion

BENEFITS

- Increased efficiency
- Less fuel use, water use, solid waste
- High CO_2 concentration exhaust
- High heat transfer rates
- Recoverable latent heat
- Decreased mass flow rates, smaller capital equipment

TECHNOLOGY GAPS

- Cost and complexity of pressure
- Combustion
- Materials
- Heat transfer
- Oxygen demand
- CO_2 purification & compression

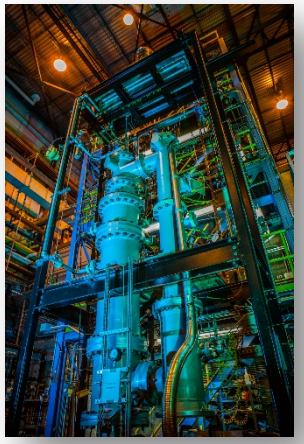
Chemical Looping

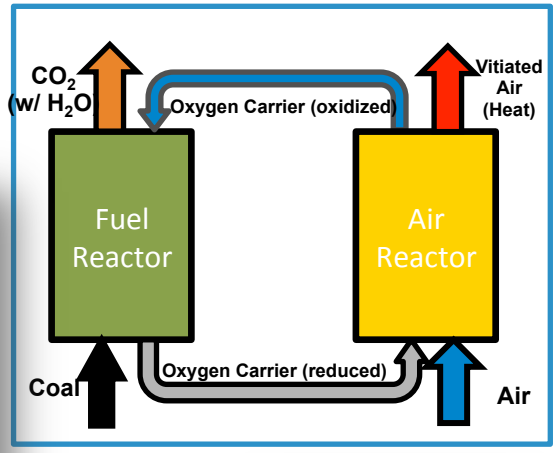
Benefits

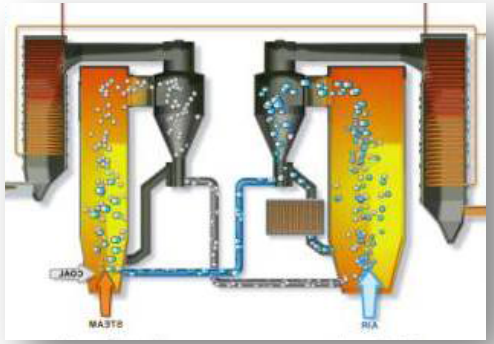
- Transformational cost reduction potential
- No need for O_2 production
- High CO_2 concentration exhaust
- Uses conventional materials and fabrication techniques
- Leverages large-scale CFB experience, especially with limestone carriers

R&D Activities

- Limestone-based chemical looping combustion
- Iron-based chemical looping combustion
- Chemical looping combustion with oxygen uncoupling
- Pressurized chemical looping
- H_2 production from syngas
- Chemical looping coal gasification
- Chemical looping oxygen carrier development







Chemical Looping Combustion

STATUS

- TRL 3-5
  - Testing with coal in continuous autothermal mode (10s of hours at a time)
  - Alstom has largest system (1MWe) in world
- Operation is a challenge
- 2 oxygen carrier pathways
  - Low-cost carriers (limestone) with modest properties
  - Expensive, custom carriers (composites of iron oxide and other materials)

PROJECTS

1. **Alstom**
2. **Babcock & Wilcox** – prime
   Ohio State University – major sub
3. **U of Kentucky – CAER**
4. **University of Utah**
5. **NETL RIC**

Related Gasification-funded projects:

- **Ohio State (2 projects):** H_2 production from syngas
- **Kentucky:** coal gasification
- **Alstom:** High H_2 syngas generation

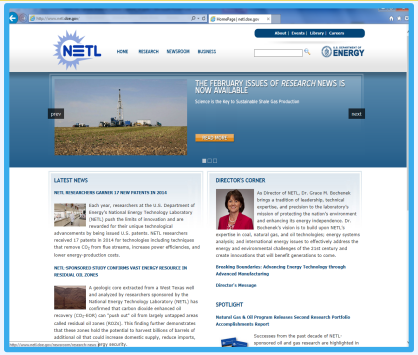
BENEFITS

- Transformational cost reduction potential
- No need for O_2 production
- High CO_2 concentration exhaust
- Uses conventional materials and fabrication techniques
- Leverages large-scale CFB experience, especially with limestone carriers

TECHNOLOGY GAPS

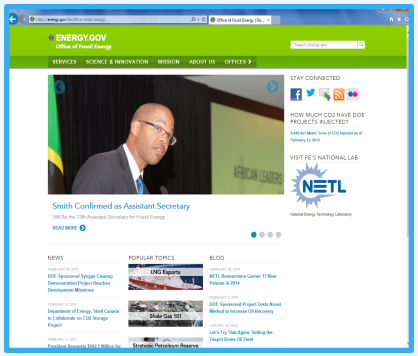
- **Oxygen Carrier Properties**
  - Reactivity Rates
  - Chemical contamination
- **Solids Circulation**
- **Reactor Design**
- **System Engineering**

For More Information About the NETL Advanced Combustion Systems Program



NETL website:

www.netl.doe.gov



Office of Fossil Energy website:

www.fe.doe.gov

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Solutions for Today…..Options for Tomorrow




For More Information, Contact NETL

the ENERGY lab

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