Creating the 21st Century Energy Ecosystem

NATIONAL ENERGY TECHNOLOGY LABORATORY

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U.S. DEPARTMENT OF ENERGY

Fossil Energy: Foundational to Economic Growth

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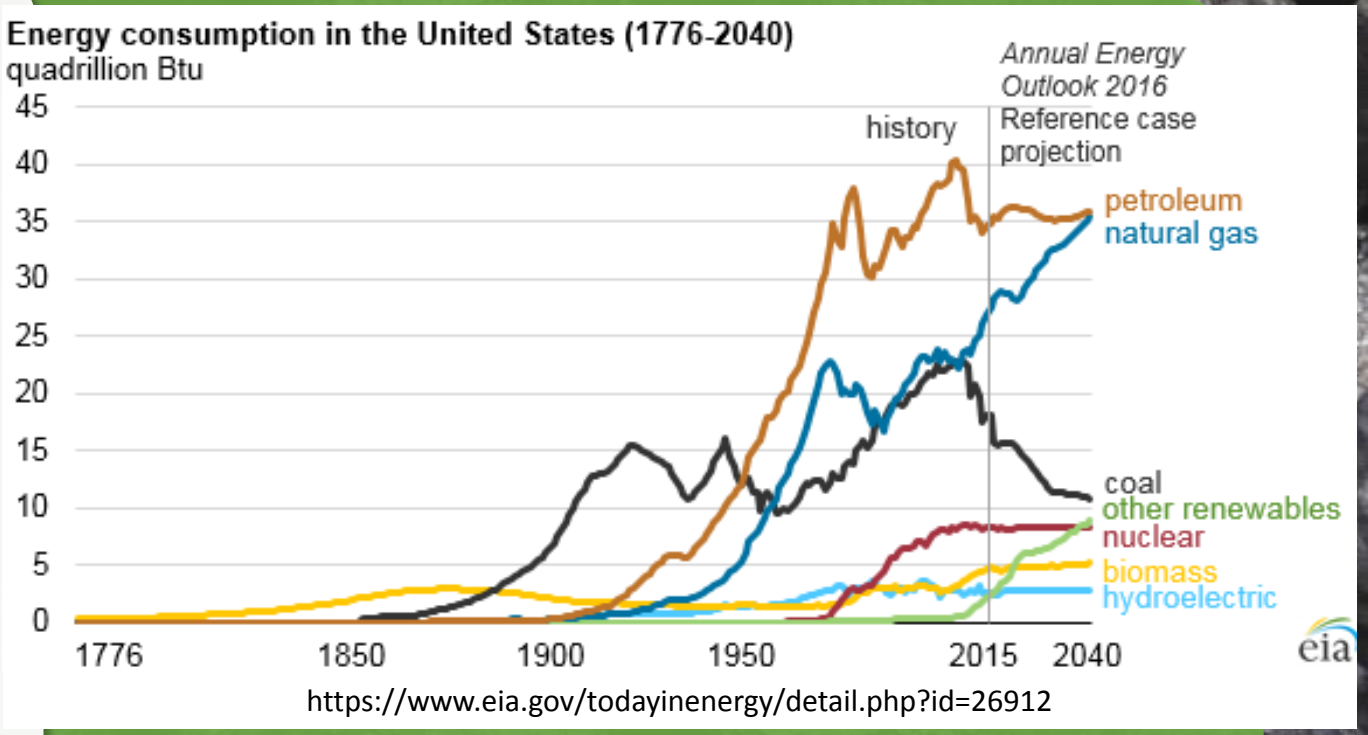
Foundation

- Fossil fuels provide 80%+ of U.S. demand
- Affordable, safe, secure, and sustainable energy is essential to quality of life

Opportunities

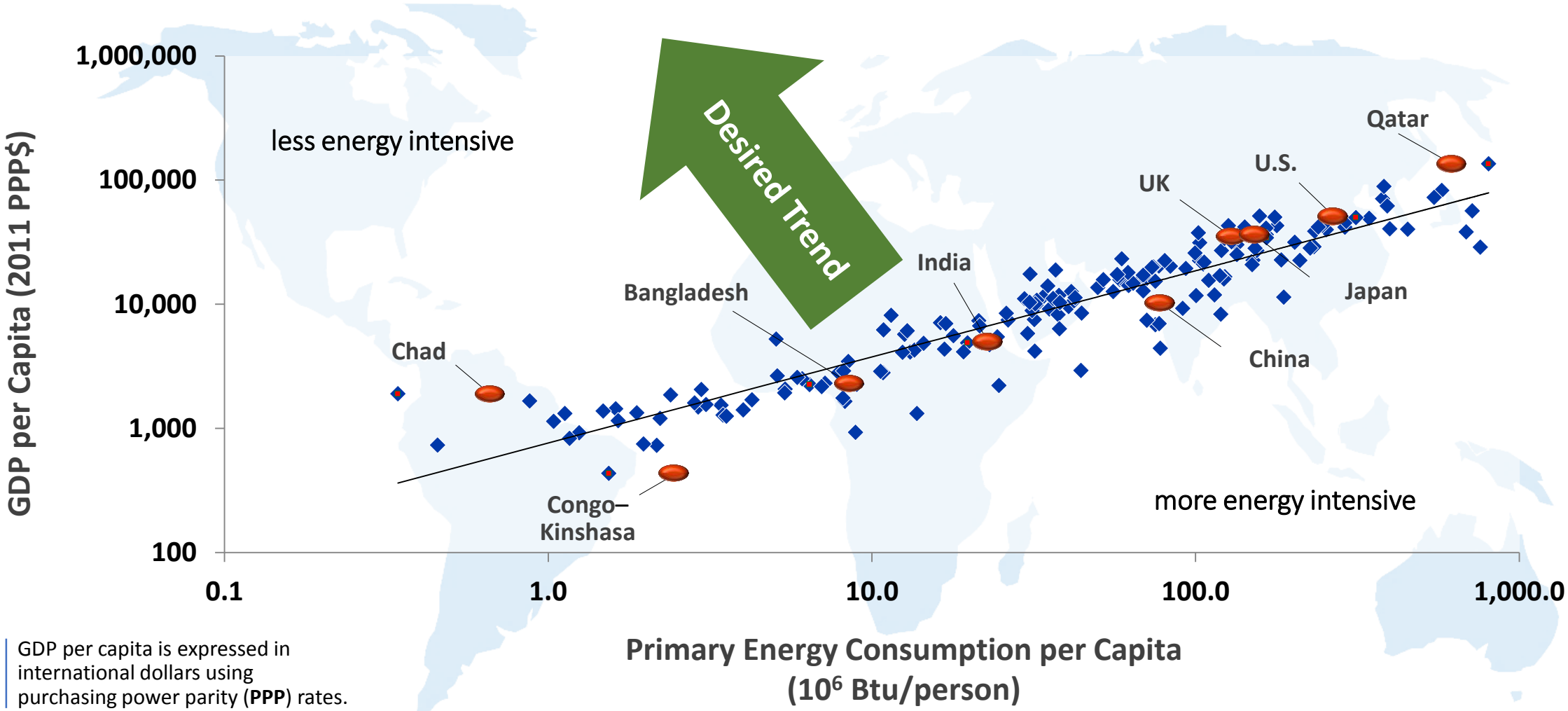
- Innovate for enduring economic prosperity and technical leadership
- Advance resource development, energy conversion, and manufacturing to create jobs



https://www.eia.gov/todayinenergy/detail.php?id=26912

Transition to Innovation

Transition to Innovation



GDP per capita is expressed in international dollars using purchasing power parity (**PPP**) rates.

Energy consumption: DOE EIA, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=44&pid=44&aid=2, accessed 12/01/14.
GDP: UNDP, http://hdr.undp.org/en/content/gdp-per-capita-2011-ppp, accessed 12/01/14.

National Energy Technology Laboratory

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SECURE & REVITALIZE the Energy Infrastructure

- Authorities to develop, implement, and manage public-private partnerships
- Technical expertise to assess, analyze, and resolve technical needs and challenges

Enduring Economic Prosperity

REINVIGORATE Jobs & Manufacturing

- Technical expertise to improve manufacturing competitiveness
- Capabilities and authorities to implement workforce development programs

REALIZE Full Value of Domestic Energy Resource

- Inform energy policy
- Enable full resource utilization

ATTAIN Energy Dominance

- Expand oil, gas, and/or coal exploration and production
- Capabilities to unlock future resources (*Methane Hydrates*)

Initiatives to Revitalize and Grow Fossil

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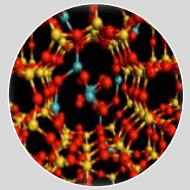
Carbon Storage

Carbon Capture

Sensors

Advanced Materials

Advanced Computing



Advanced Energy Systems

Accelerating Development through Full Spectrum RD3

Enhanced Resource Production

Environmentally Prudent Development

Transmission & Delivery

Methane Hydrates

Coal Technology Thrusts

Increase the performance, efficiency, and availability of existing and new coal-fueled power generation.

Tap the full potential of abundant fossil energy resources in an environmentally sound manner.

- More efficient and reliable power plants
- Novel and cost-effective coal conversion
- Reduced water usage and impacts
- Smaller power plant systems footprint
- Cost effective carbon capture systems
- Safe and effective carbon storage
- Advanced materials for extreme power plant environments
- Advanced Manufacturing
- Modeling and Simulation

Full Spectrum: Discovery to Commercialization

Hg Control Technology from Concept (1992) to Commercial Reality (2008)

COMMERCIAL DEPLOYMENT

~150 GW commercially installed

Field testing of Hg sorbents on operating power plants

FULL-SCALE DEMOS

2000-2008

First-of-a-kind Commercial-Scale Demonstrations

TRL 8-9

PROCESS & ENGINEERING DEVELOPMENT

1995-2000

Pre-Commercial Prototype Validated in Relevant Environment

TRL 6-7

Pilot-scale & additive testing

Hg measurements and methods development & testing

APPLIED RESEARCH

1993-1995

Component/Subsystem Validated in Laboratory Environment

TRL 4-5

Sorbent & Hg oxidation system development

Hg emissions characterization

BASIC RESEARCH

1992-1994

Analytical Studies Predict Technology Potential

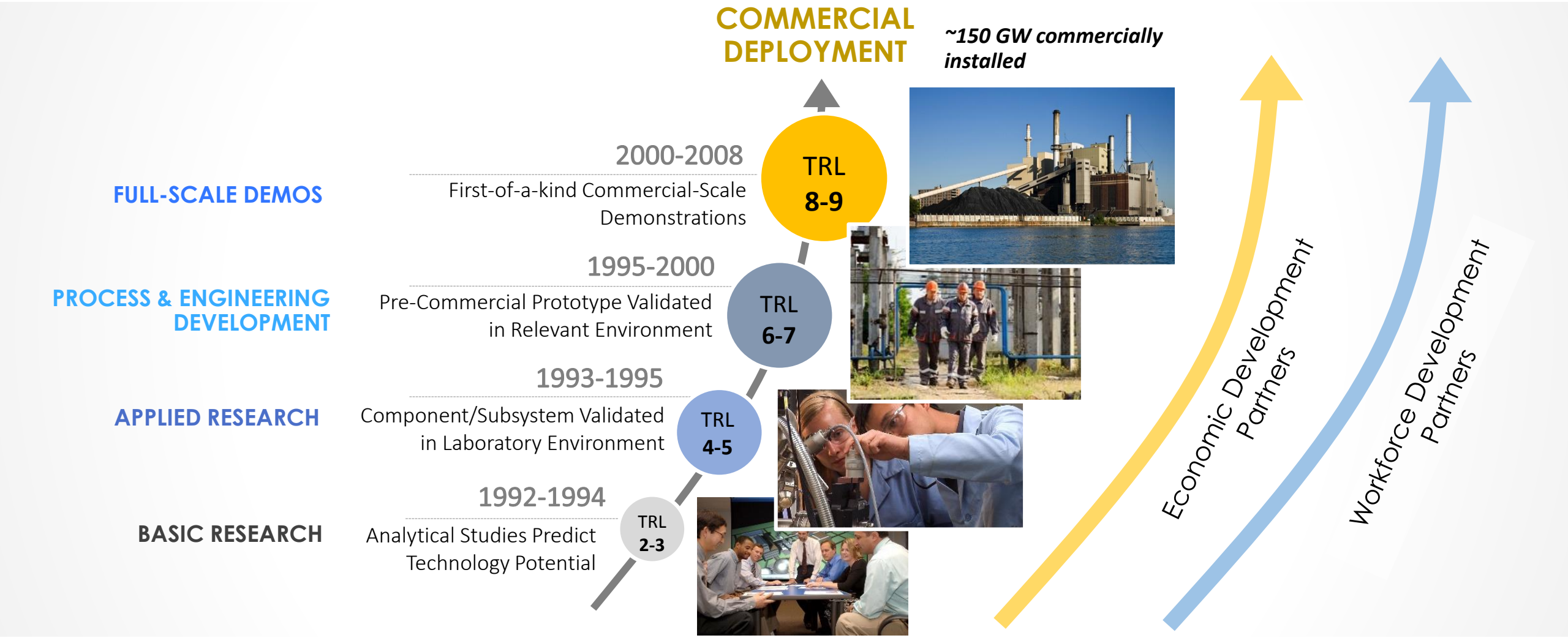
TRL 2-3

Flue gas characterization

Hg speciation

Full Spectrum: Discovery to Commercialization

Hg Control Technology from Concept (1992) to Commercial Reality (2008)



National Carbon Capture Center

Southern Company Services

- Supported Gasification and Capture Technologies – Flexible Test Center
- Development Site for TRIG technology used in CCPI demonstration, Kemper County, MS
- Over 91,000 test hours for technology developers from U.S. and six other countries since 2008 founding of NCCC
- More than 40 developer projects completed
- On-site scale-ups and process enhancements for ten technologies

PROGRESSION FROM LAB TO SMALL PILOT

Lab-Scale Unit

Codexis post-combustion solvent unit

Bench-Scale Unit

Akermin Inc. post-combustion CO2 capture solvent

Small Pilot-Scale Unit

Linde-BASF 1 MWe pilot plant - post-combustion capture solvent technology

Technology Timeline for Petra Nova CO_2 EOR CCS Plant

From Discovery to Commercialization

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NRG W.A. Parish Power Plant – Full Scale Integrated CCS

TRL 9

Government – Industry Partnership to Commercialization

Industry Leading the Effort

TECHNOLOGY MATURATION

Scale
Technology Confidence
Investment

2016
Full Scale Commercialization

TRL 7-8

2011
First-of-a-kind Integrated Coal CCS Small Commercial Scale Plant

First fully Integrated Coal CCS Plant – 500 tons/day Alabama Power

2008
Pre-Commercial Prototype Validated in Relevant Environment

TRL 6-7

First Commercial Plant - w/ Improved KM CDR Process® - 400 tons/day

1994 & 1999
Component/Subsystem Validated – KM CDR Process and Improved Process Validated

TRL 4-5

KM CDR Process® Developed

Early 1990s
Proof-of-Concept Developed – Initial Carbon Capture Development

TRL 2-3

MHI/KEPCO Pilot Plant – 2 tons/day

TRL 9 **COMMERCIALIZATION**
Technology available for wide-scale market use

TRL 8 **COMMERCIAL DEMONSTRATION**
System demonstrated in operational environment

TRL 6-7 **SYSTEM TESTING**
System performance confirmed at pilot-scale

TRL 4-5 **DEVELOPMENT**
Technology component validated/integrated

TRL 1-3 **CONCEPT**
Concept identified/proven at laboratory-scale

Successful Initiative: Petra Nova

Demonstrated the ability of an advanced CO_2 capture system to capture 90 percent of the CO_2 emitted from a flue gas stream equivalent to 240 mega-watts (MWe) in size.

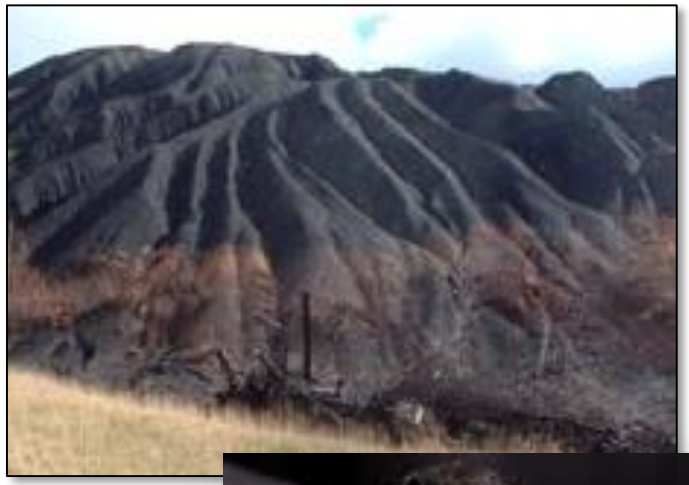
Petra Nova completed final performance testing and began commercial operation on January 10, 2017.

The project is currently delivering CO_2, captured from PGS flue gas, to the West Ranch oil field for EOR operations.

>854,000 tons to date utilized in EOR operations

Largest post combustion capture system in the U.S.

REE Market: REEs from Coal



Annual Global Rare Earth Market

- ~$5B in 2015 (~164,000 tons/year)

U.S. Consumes

- 11% ($550M) or ~18,000 tons/year in 2015

Approximately 750M Tons of Coal Burned in U.S. Annually

- ~75M tons of coal ash generated
  - Average concentration of ~470 ppm REE+Y, yields ~35,000 tons of REE+Y annually
- If completely extracted, potential for generation of REEs from coal exceeds U.S demand

DOE-NETL Rare Earth Elements (REE)

From PPM Scale to Salable 90+% Concentrations

REE
RARE EARTH ELEMENTS
FROM COAL AND COAL BY-PRODUCTS

Process Systems
– Validation / Demonstration / Commercialization –

Separation Technologies
– Science & Technology Development –

Enabling Technologies
– Knowledge Products –

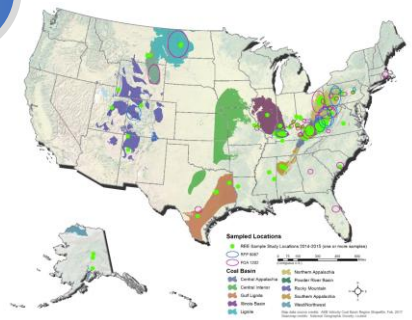
2020
- Bench- & Pilot-Scale Pre-Concentrate Production
- High Purity Product Production

2017
- Commercial Separation Systems – Technology Transfer
- Transformational Concept Development

2016
- Resource Identification, Sampling & Characterization
- Techno-Economic Analysis
- Field/Process Sensors

2015

2014



***Goal:* Produce 90%+ Purity REEs at Pilot-Scale**

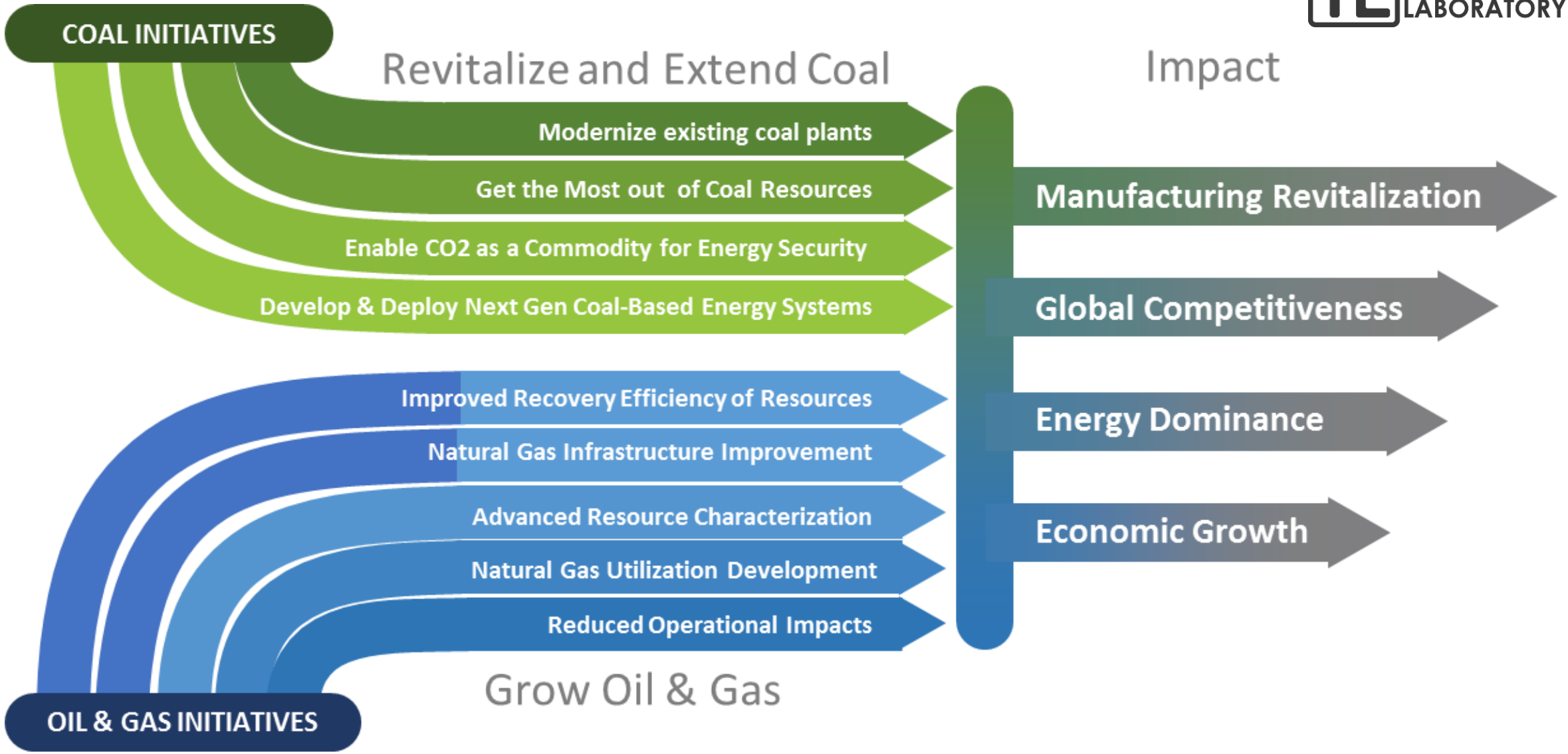
NETL Accomplishments

- **Identified high purity (>1000 ppm) coal-related deposits**
- **Achieved >80% extraction rates from coal wastes (ash, etc.)**
- **Concentrated from ppm-level to near ore quality**
- **Developed sorbents for REE extraction from liquid solutions**

U.S. Coals contain significant amounts of REEs

Feedstock Materials: Coal, Ash, Overburden and Underlying Clays & Shales, Acid Mine Drainage Sludge

Revitalize and Grow the Fossil Value-Chain



Solutions for Today
Options for Tomorrow

Let's Do This Together

www.netl.doe.gov

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