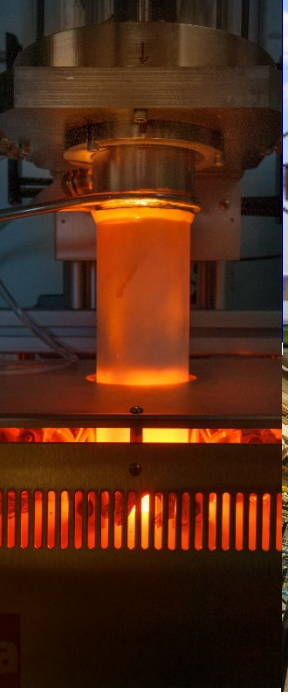
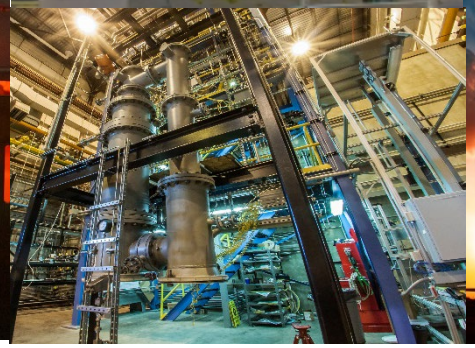
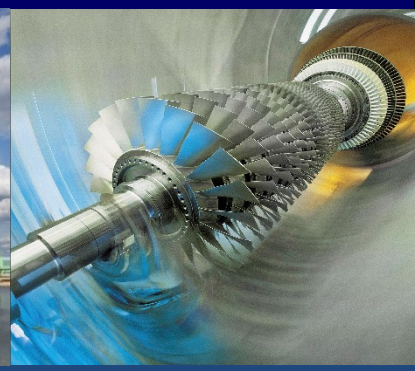




U.S. DEPARTMENT OF ENERGY | Office of Fossil Energy

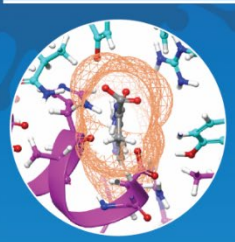
# 21st Century Coal

March 25, 2020


**Steven Winberg**
Assistant Secretary
Office of Fossil energy

# COVID-19: Harnessing DOE's Resources

## HOW DOE AND OUR LABS ARE COMBATING COVID-19



**UNDERSTANDING THE STRUCTURE –**
DOE scientists are studying the components of the virus so we can determine how to fight it.

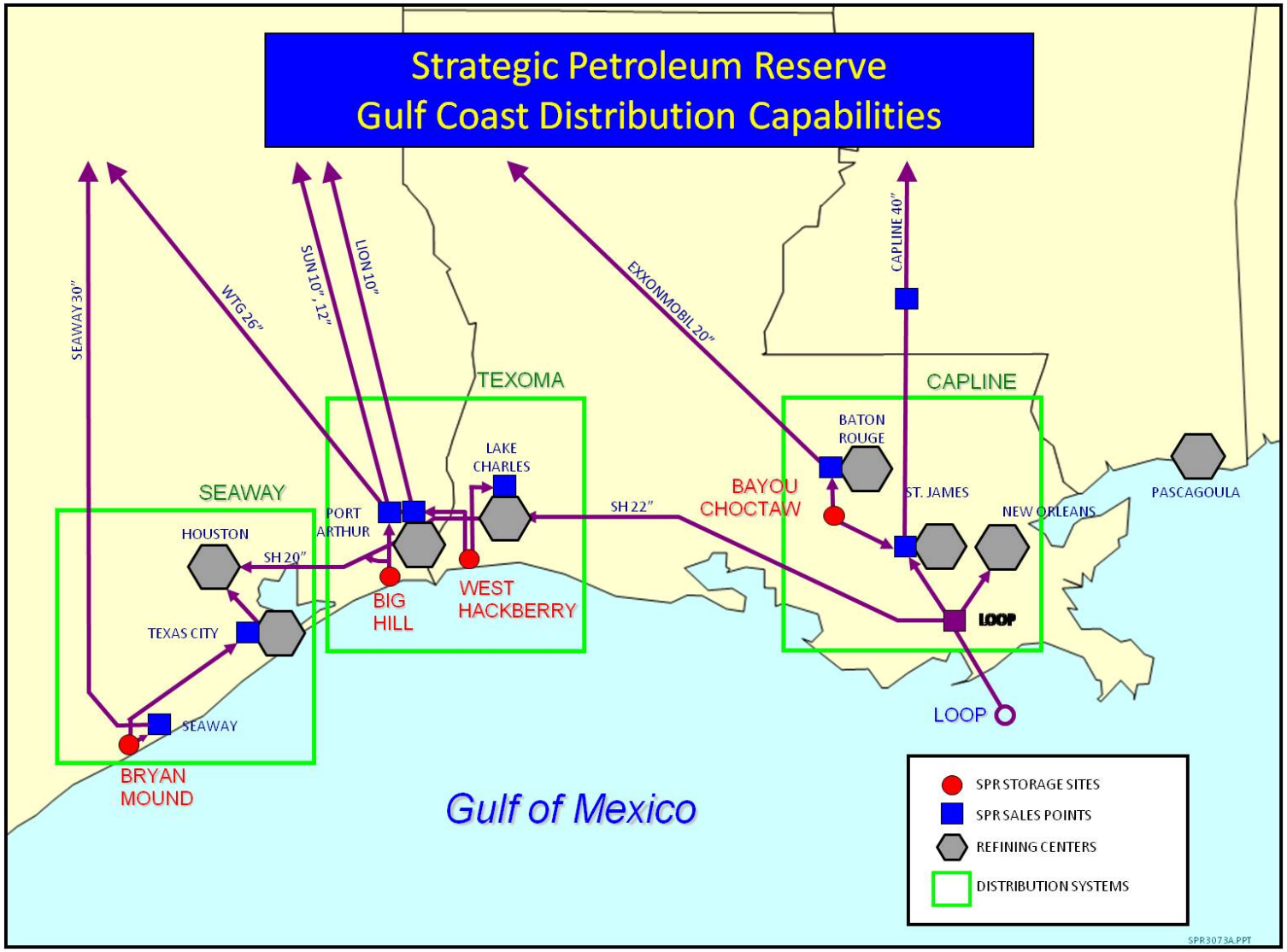
**MODELING EPIDEMICS –**
DOE scientists use previous experience they gained modeling Smallpox, Anthrax and Ebola spread to understand how COVID-19 might behave.


**SCREENING DRUGS –**
Our supercomputers are allowing us to expedite testing, screen more than 8,000 drug compounds and found 77 have potential to fight against COVID-19… what took days on Summit would take months with a MacBook.

**COORDINATING AND EXPANDING ACCESS FOR COVID-19 RESEARCH –**
DOE made a nationwide call to the scientific community to utilize our state-of-the-art facilities and technologies to understand and combat COVID-19 together.

**ENERGY.GOV**

# Strategic Petroleum Reserve: Mitigating Impacts of COVID-19 and Disruption in World Oil Markets

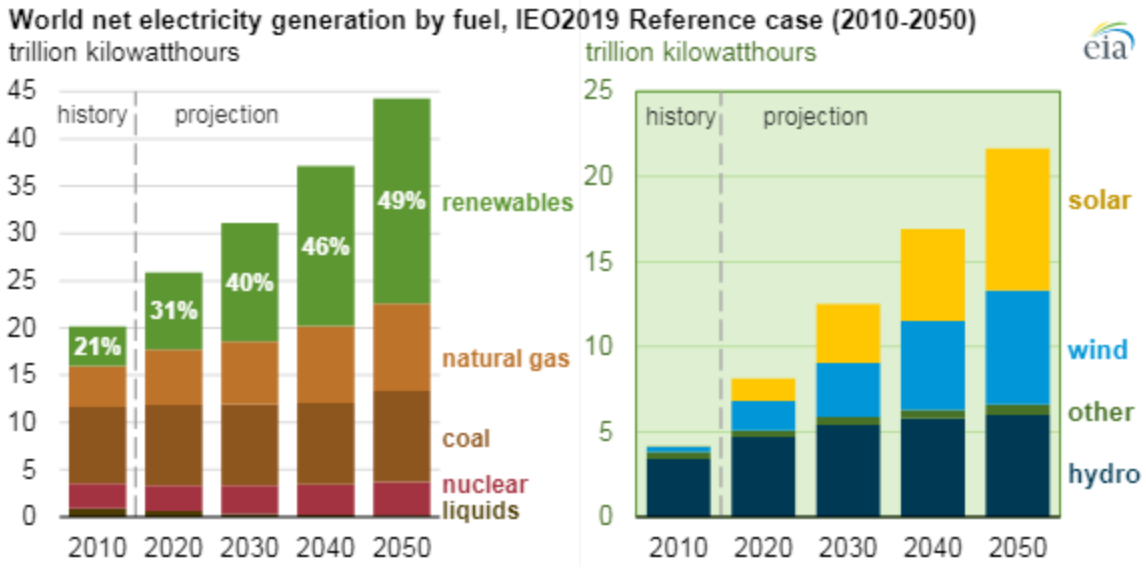


# 21st Century Coal

**The future of coal in the 21st Century depends on four pathways**

- ***Developing Coal FIRST Power Plants of the Future***
- ***Advancing Carbon Capture, Utilization and Storage***
- ***Coal Exports***
- ***Expanding Coal's Value Chain – Commercial Products, Advanced Materials, Rare Earth Elements, and Critical Minerals***

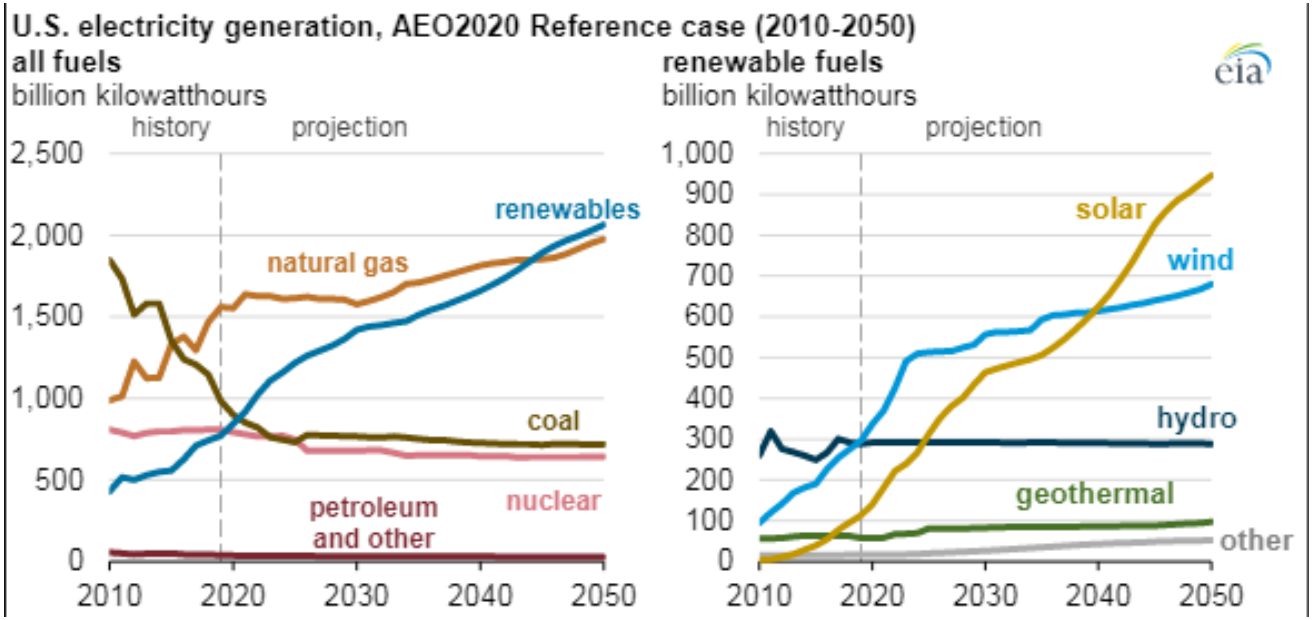
# Outlook for Global Energy Consumption to 2050




Source: U.S. Energy Information Administration, International Energy Outlook 2019

# Outlook for U.S. Coal-Fired Power Generation

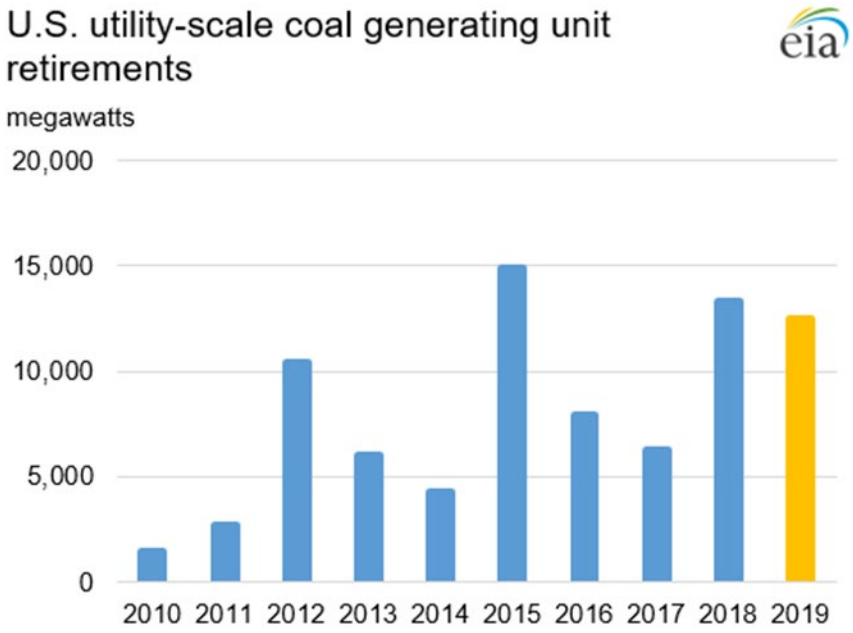
## Coal's share of U.S. power generation declines over the next 30 years




Source: U.S. Energy Information Administration, Annual Energy Outlook 2020

# Coal Plants Retiring

## Coal plant retirements over the past decade have reduced coal-unit capacity by more than 78,000 MW




*Data for 2019 are preliminary. Megawatts represent summer capacity of generating units.*

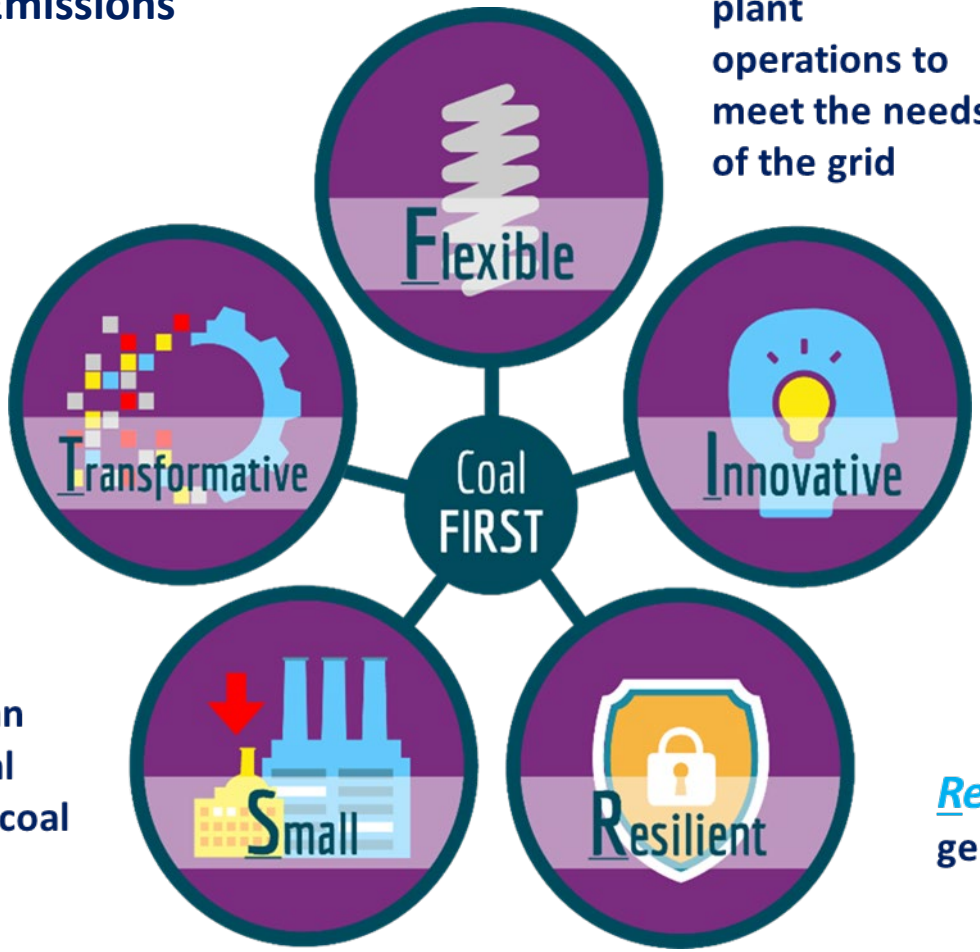
Source: U.S. Energy Information Administration

# Coal FIRST: The Future of Coal-Fired Power Generation

**Secure, Stable, Reliable Power, & Zero or Near-Zero Emissions**

***Flexible*** **coal plant operations to meet the needs of the grid**

***Transforms*** **how coal technologies are designed and manufactured**




***Innovative*** **and cutting-edge components; improved efficiency and zero or near-zero emissions**

***Smaller*** **than conventional utility-scale coal plants**

***Resilient*** **power generation**

# Impacts of Modularizing the Fleet

**Technology Impact:**

- Advanced manufacturing
- High Performance Computing
- Regional opportunities
- Faster development
- Higher availability with lower maintenance costs

**Business Impact:**

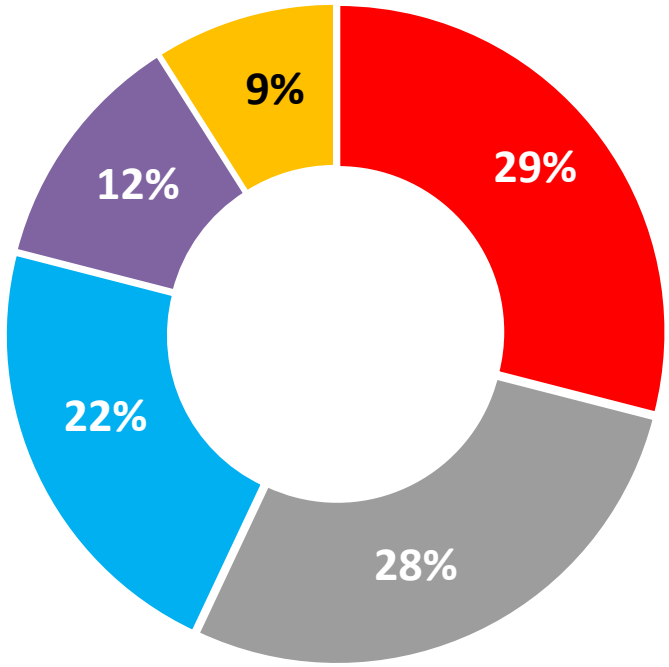
- Increased investment flexibility.
- Lower finance risk
- Capex/Opex reduction

**Environmental Impact:**

- Reduced greenhouse gas emissions through footprint reduction
- Better conform to site specific resources and environmental needs and/or beneficial opportunities

# Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017

**Total Emissions in 2017 = 6,673 million metric tons (MMT) of $CO_2$ equivalent.**

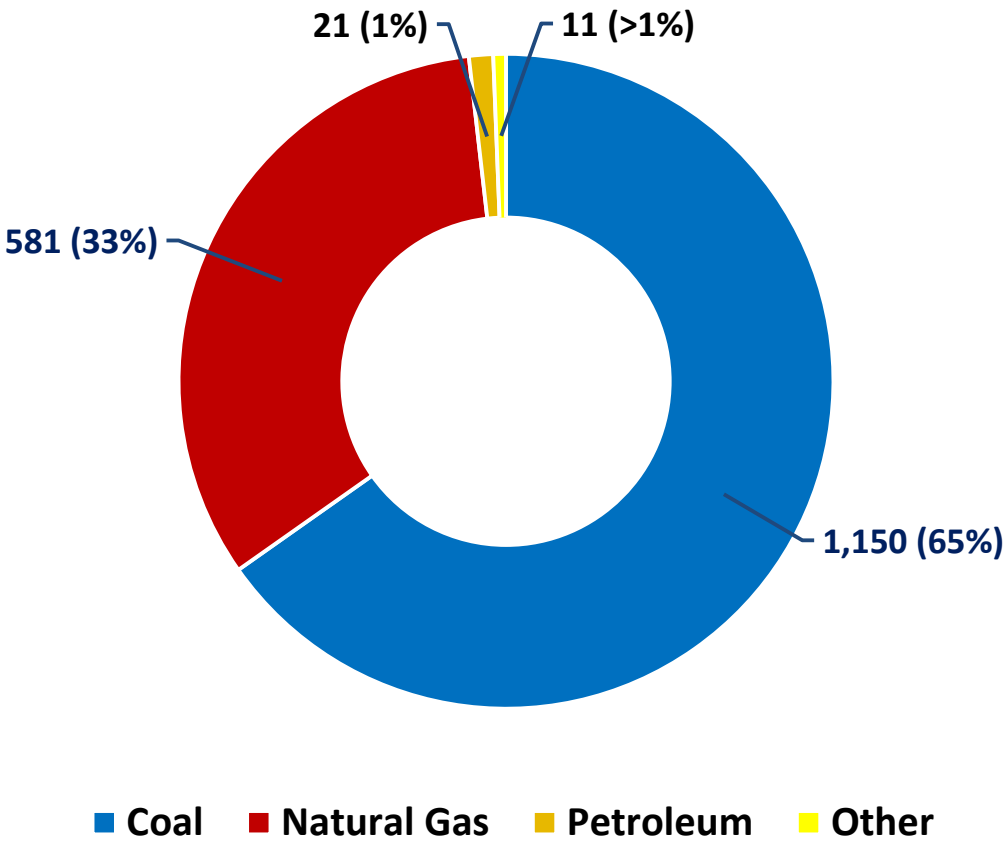



- Transportation (29%)
- Commercial and Residential (12%)
- Electricity (28%)
- Agriculture (9%)
- Industry (22%)

Source: International Energy Agency

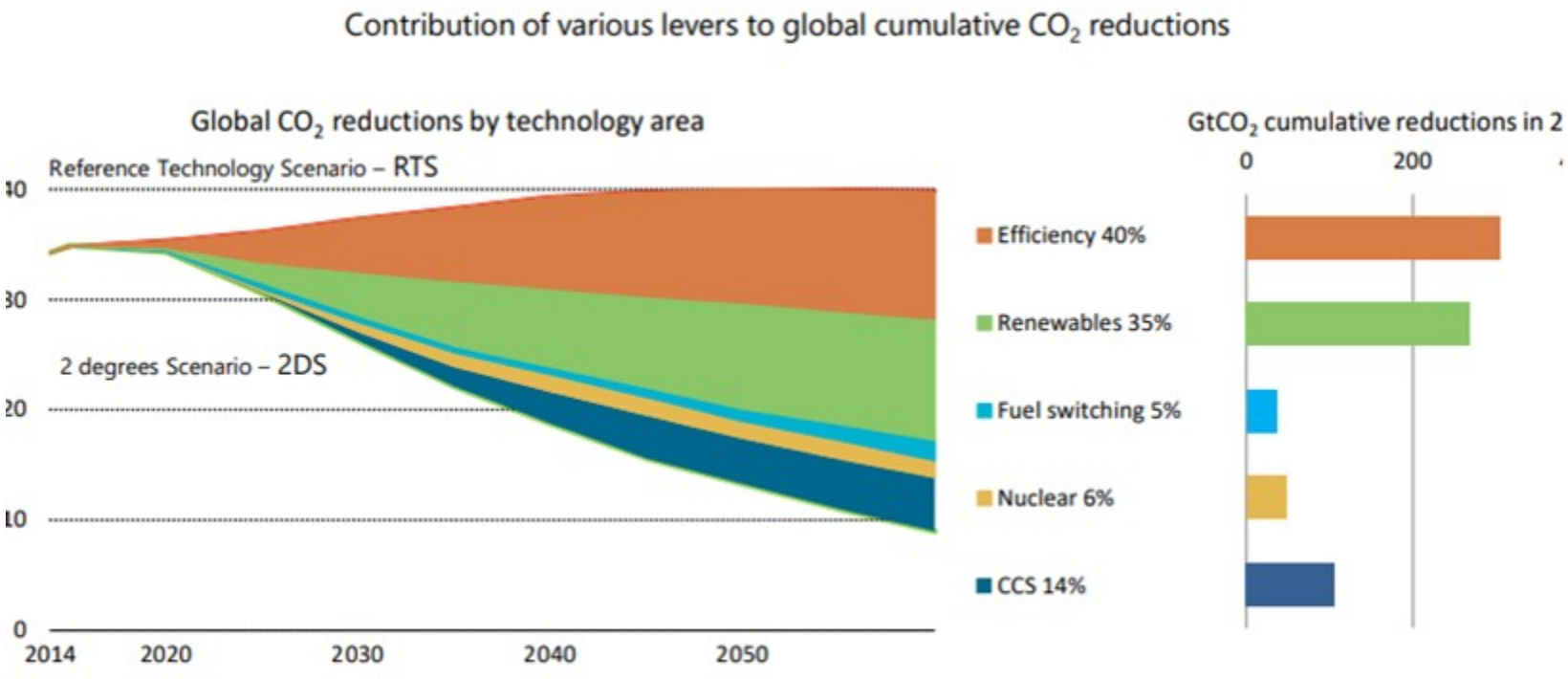
# Total GHG Emissions from Power Generation by Source (2018)

## U.S. $CO_2$ Emissions from Power Generation by Fuel Type (1,763 MMT)



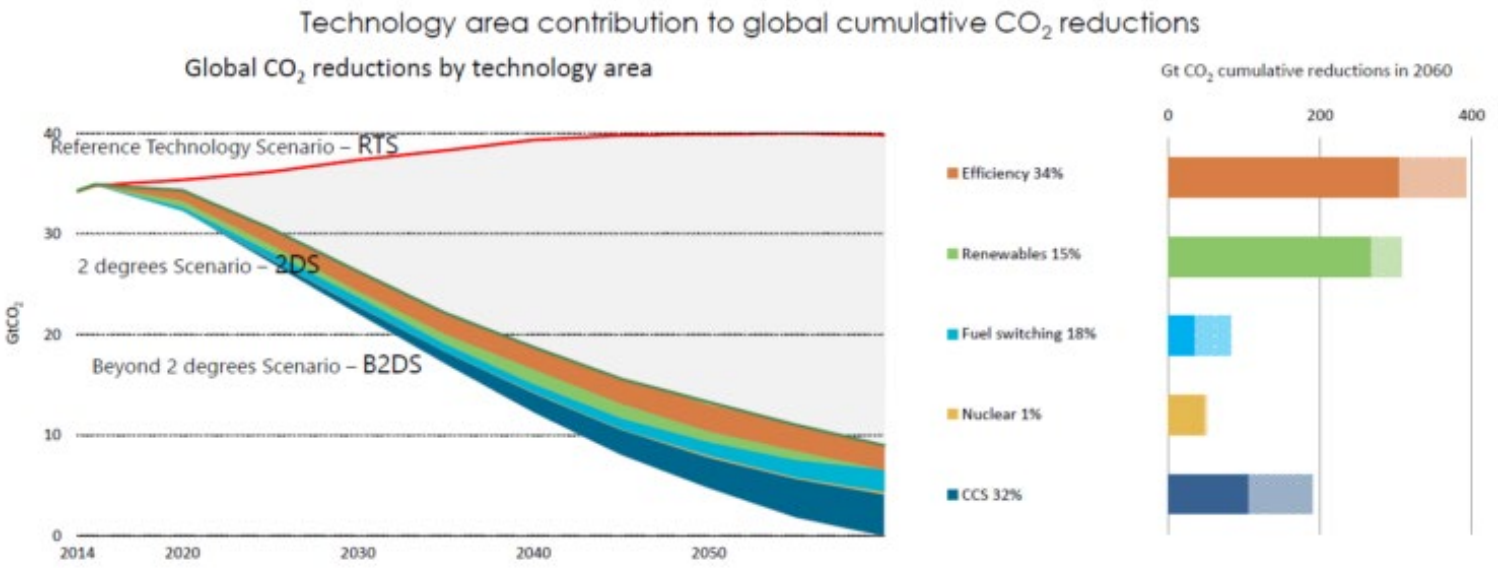

Source: EIA

# Carbon Capture, Utilization, and Storage




Source: IEA

# CCUS Provides a Third of $CO_2$ Reductions in B2D Scenario




Source: IEA

# CCUS R&D Program Goals and Challenges

**Reduce the cost of capture by 50%**

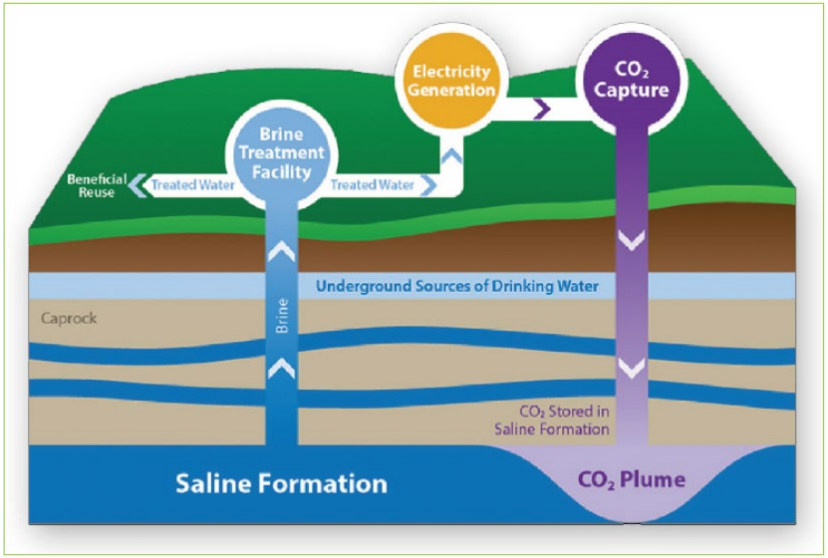
- Capital cost
- Energy penalty
- Integration or process intensification

**Develop viable carbon utilization alternatives ($1T opportunity)**

- Reduce Capital cost
- Reduce energy requirements
- Lifecycle assessment better than existing products

**Reduce the risk of geologic storage – improve monitoring and simulation**

- Higher resolution and quantification (e.g., accurate characterization of faults and fractures)
- Geomechanics (pressure and state of stress)
- Costs/uncertainty/enabling real-time decision making

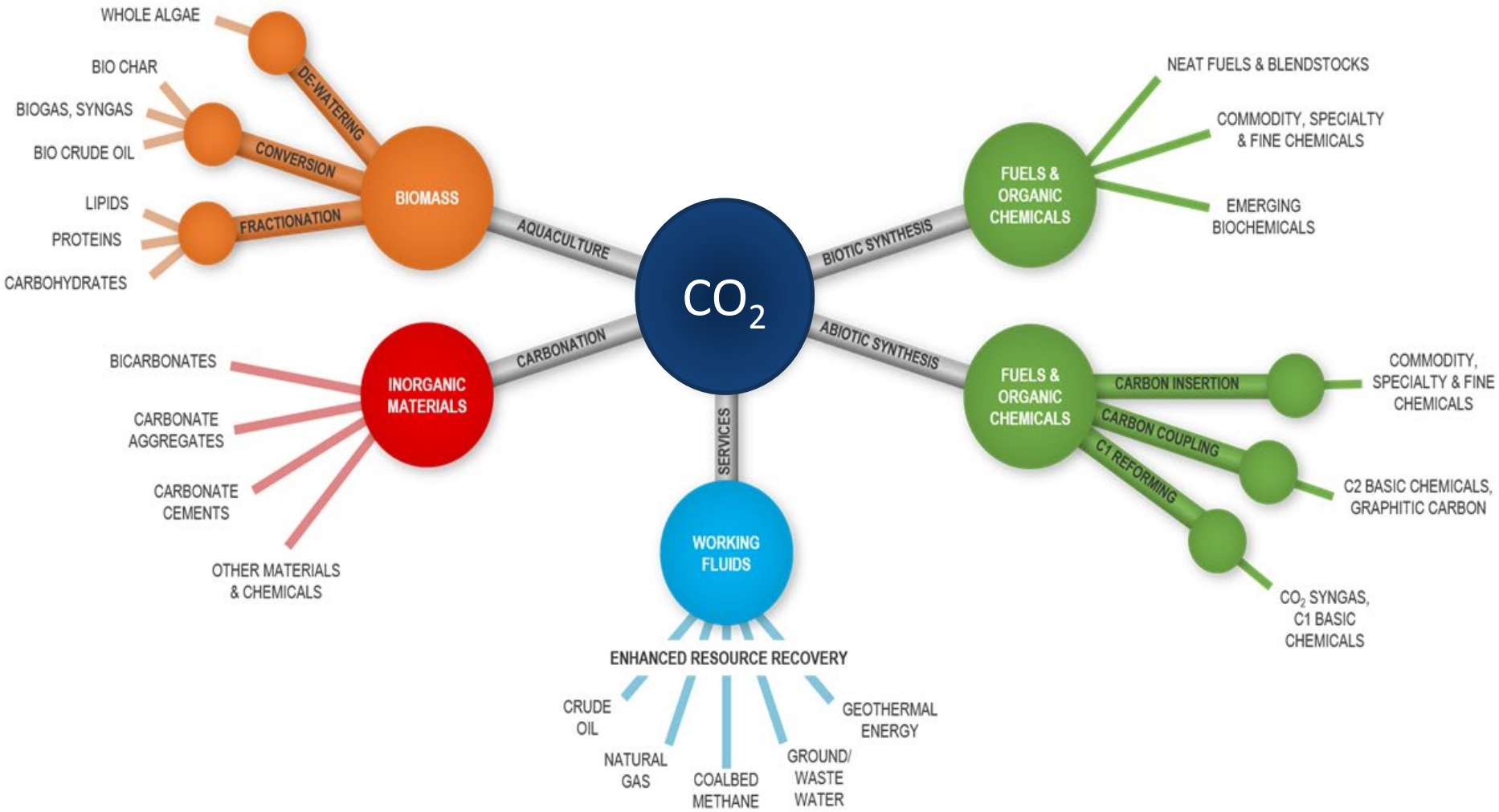



2012:$80/tonne
2016: $60
2020: $40
2030: $30

Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

# Getting Additional Value from $CO_2$

## *Major Carbon Utilization Product Pathways and Potential Products*



# Carbon Capture Can Help Enable a Hydrogen Economy

**Hydrogen enables a number of clean energy and transportation platforms using hydrogen from fossil energy, including oil and gas – AND coal.**

**Steam methane reforming primary source of H2**

**(~ 95% of global production).**

**Hydrogen production from gas and coal with CCUS can reduce emissions to near zero at lowest cost.**

**Market opportunities:**

- **Transportation vehicles**
- **Clean energy**
- **Energy storage**
- **Clean products**

**R&D Opportunities:**

- **Materials embrittlement**
- **Autothermal and gasification**
- **Electrolysis, turbines, SOFC**
- **Hydrogen storage**
- **Conversion technologies**
- **Hybrid Systems**


Cavern and Pipeline system connected to 11 out of 14 refineries

Praxair Canada Inc. – Calgary, Alberta, Canada -4-

# Cost of Hydrogen from Fossil Energy Sources

## Fossil Energy is the lowest cost source of hydrogen, even with CCUS

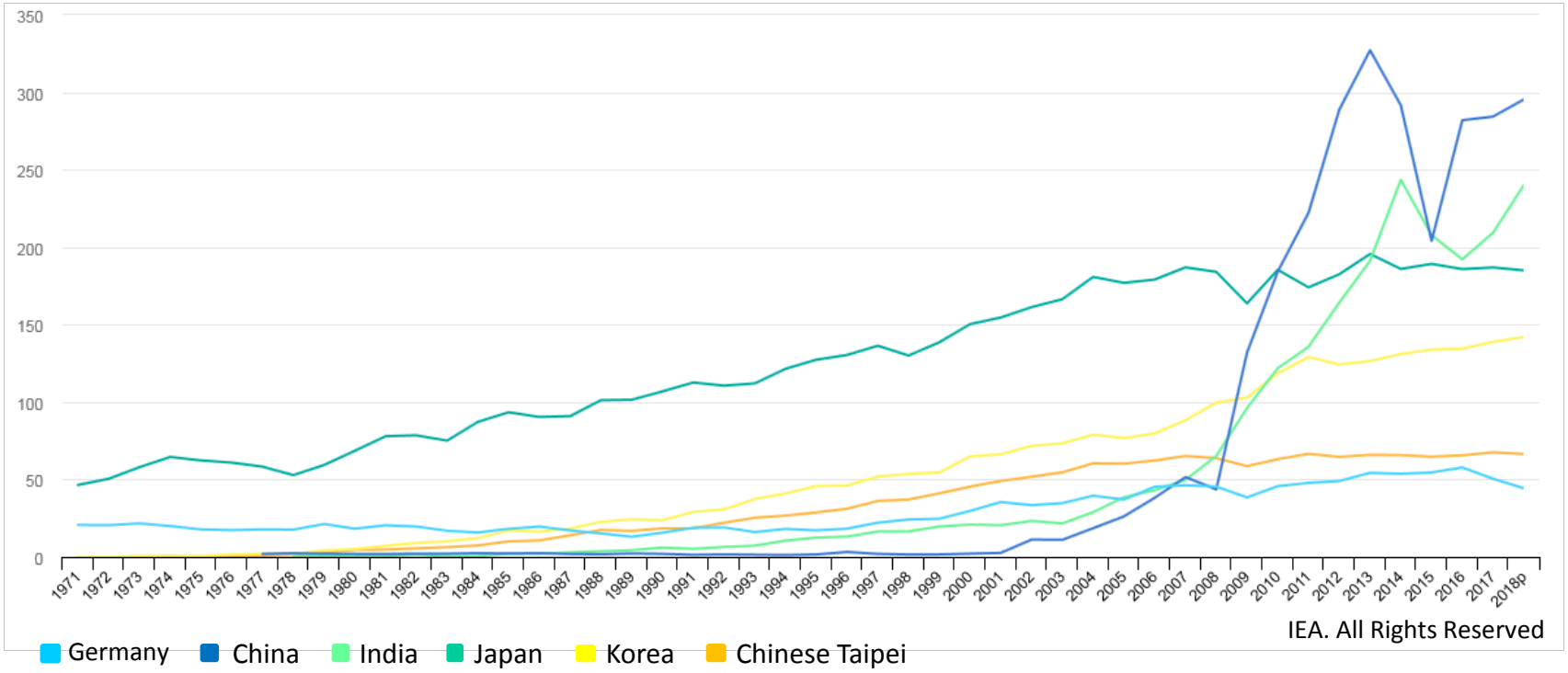
| $H_2$ Cost & Efficiency | | | | |
|---|---|---|---|---|
| References: | $H_2$A Levelized Cost of $H_2$ Production Case Studies (costs assume high volume manufacturing) | | | |
| SOURCE | Levelized cost of Hydrogen ($/kg $H_2$)* | $/MMBtu (2016$)* HHV | LHV | Production System Efficiency (%) |
| Electrolysis (H2O) | 5.2 | 38.4 | 45.5 | 61-67% |
| Natural gas reforming (Ref NG Cost) | 1.2 | 8.5 | 10.1 | 72-74% |
| Natural gas reforming (High NG Cost) | 1.5 | 11.0 | 13.0 | 72-74% |
| Natural gas reforming w/CCS (Ref NG Cost) | 1.6 | 11.6 | 13.7 | 72-74% |
| Natural gas reforming w/CCS (High NG Price) | 1.9 | 14.0 | 16.6 | 72-74% |
| Coal gasification | 1.5 | 10.8 | 12.8 | 56% |
| Coal gasification w/CCS | 2.1 | 15.6 | 18.4 | 53% |

Fossil Energy

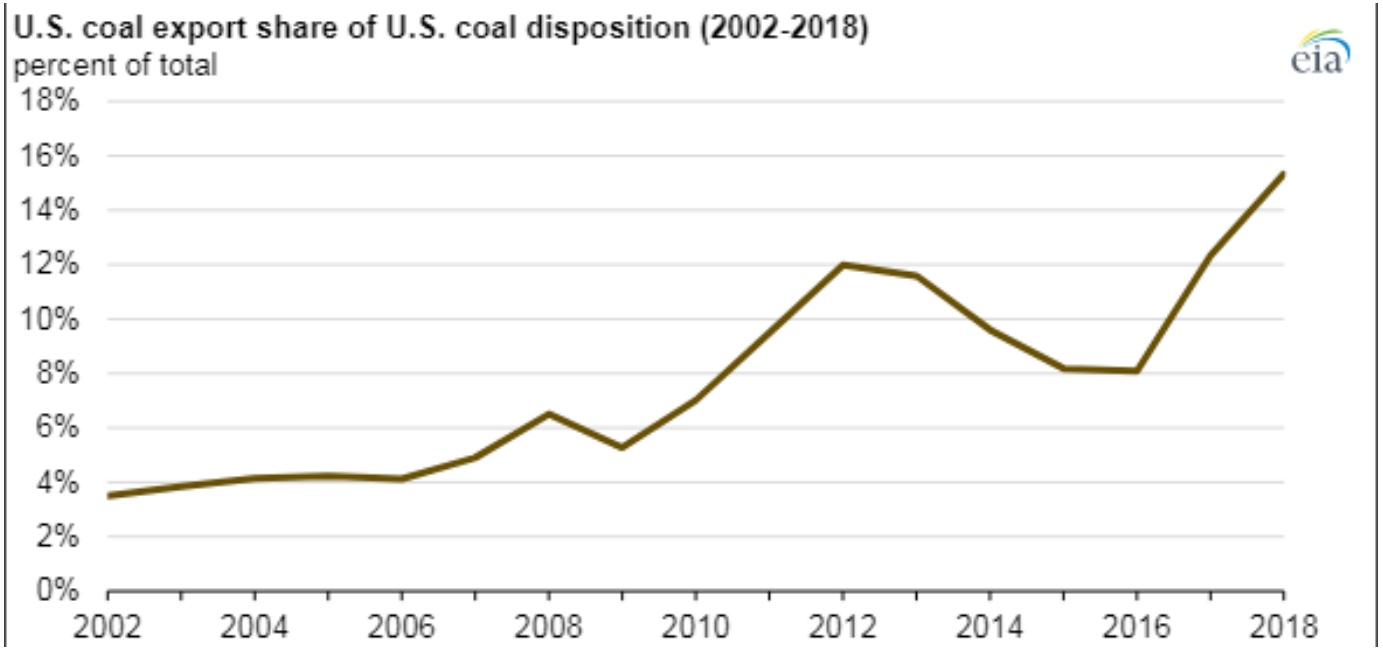
# Global Coal Trade – Opportunities for U.S. Coal

# Global Coal Imports

Total coal imports by major importers, 1971-2018
Mt

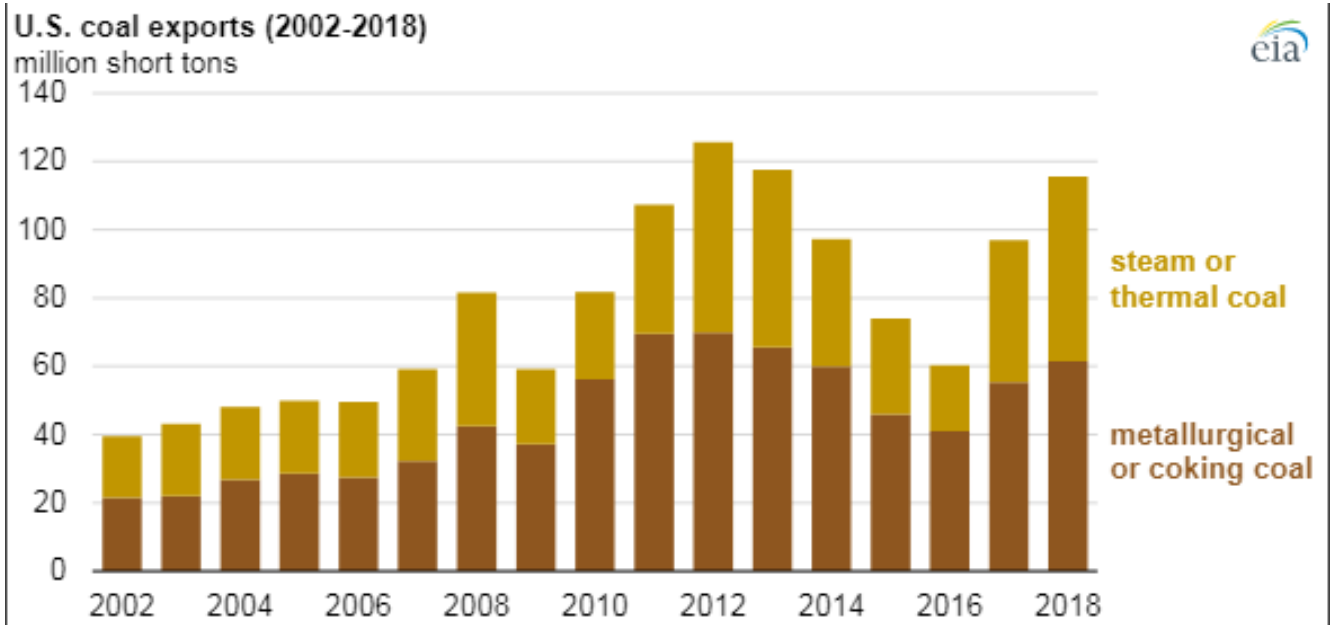


# Exports – Increasing Share of U.S. Coal Disposition




Source: U.S. Energy Information Administration, Annual Coal Report, and the U.S. Department of Commerce, Census Bureau

# Coal Exports – 116 MST in 2018




U.S. Energy Information Administration, Annual Coal Report, and the U.S. Department of Commerce, Census Bureau

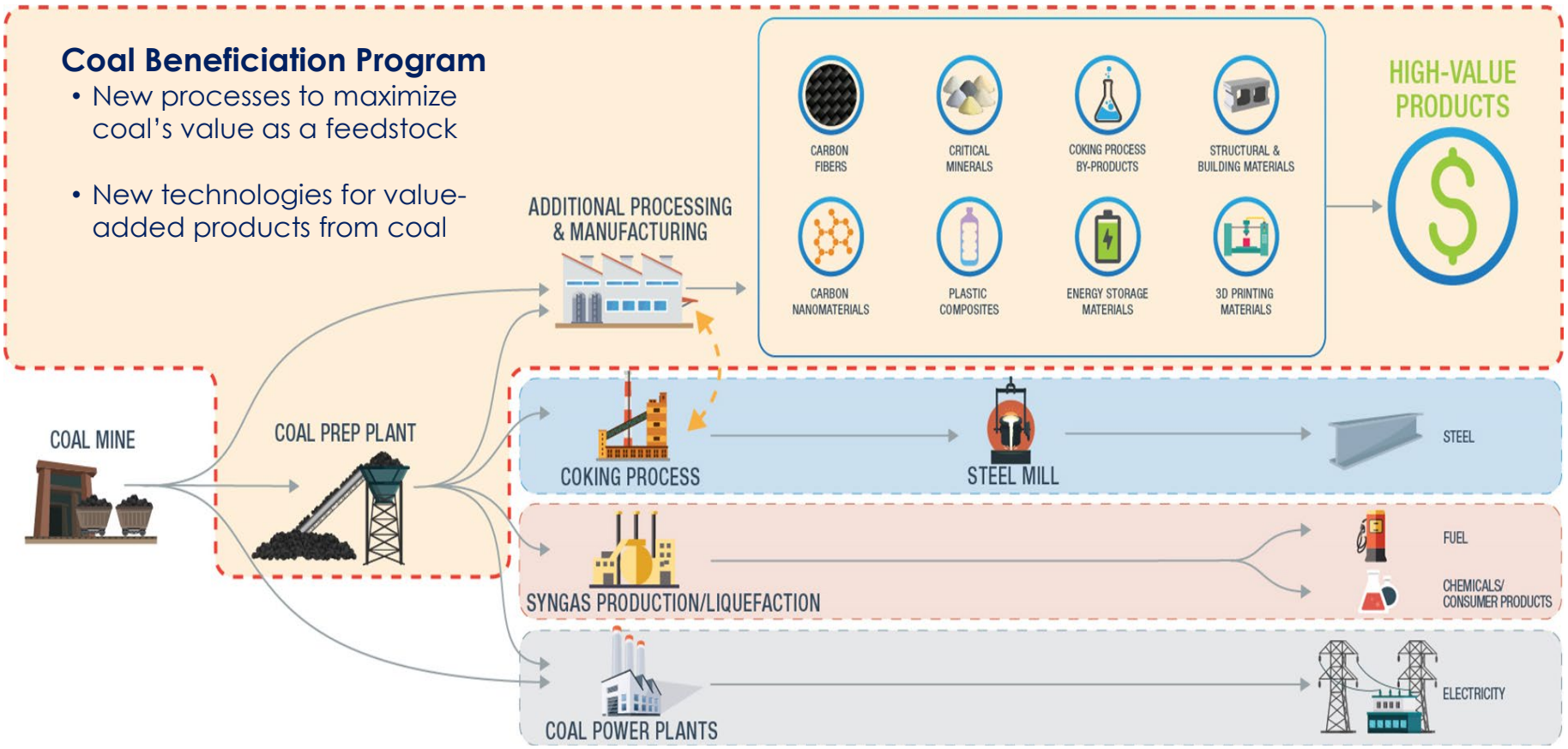
# Coal to Products – A Strong Future for Coal


***Inherent carbon content of coal means it can be used as a feedstock to manufacture a wide range of products and materials***

***Current global market for coal-to-products is estimated to consume 300-400 million tons/year of coal***

National Coal Council *Coal in a New Carbon Age*

# Expanding the Coal Value Chain



# Opportunity – A Paradigm Sift in the Construction Market

Composites Require Holistic Rethink of Manufacture

Carbon Buildings + Cloud-Delivered CAD-CAM for Everyone

Materially-Driven Environmental Agendas – Not Code Driven

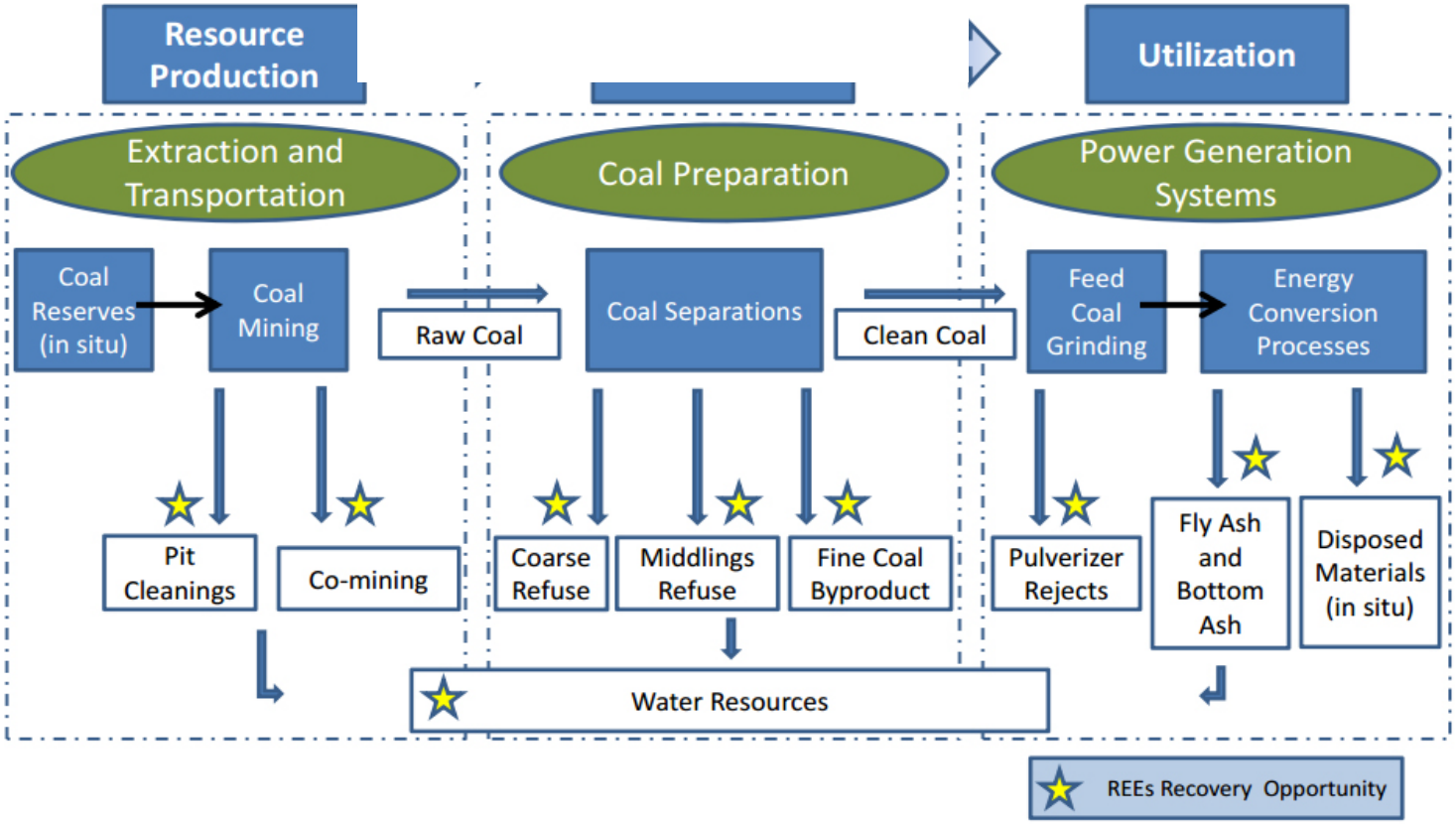
More Upstream Jobs (Materials, CAD-CAM), Less Site Labor

Global Building – 1 Million People Per Week Joining Urban Communities to 2050

Vast Potential Export Market

# Rare Earth Elements from Coal and Coal Byproducts

## Opportunities for REE Recovery Span the Coal Value Chain

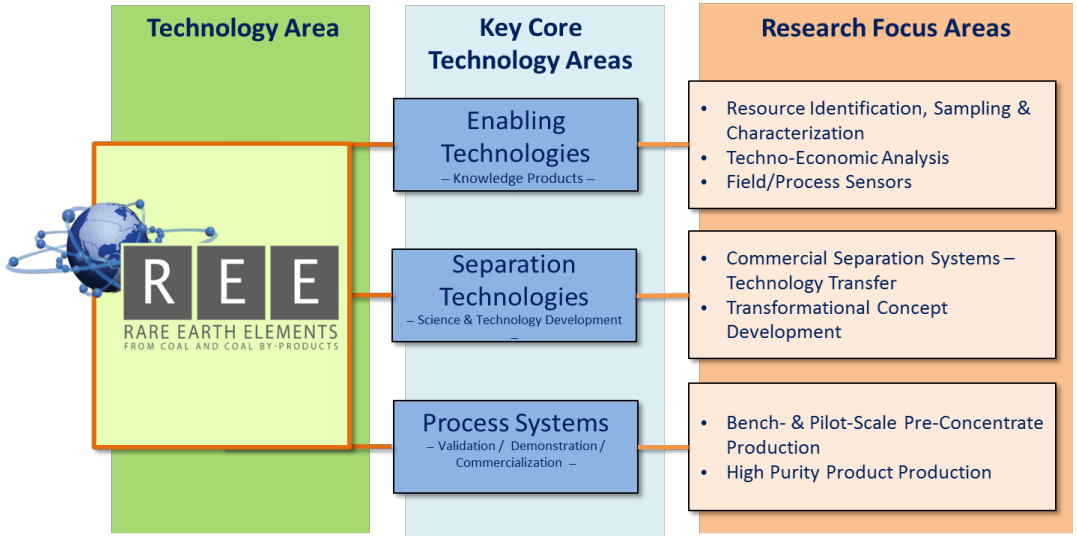


# DOE Critical Minerals Efforts

NATIONAL ENERGY TECHNOLOGY LABORATORY

**Office of Fossil Energy**

**Development of an economically competitive and sustainable domestic supply of rare earth elements (REEs) and critical materials (CMs) to assist in maintaining our Nation's economic growth and National Security**

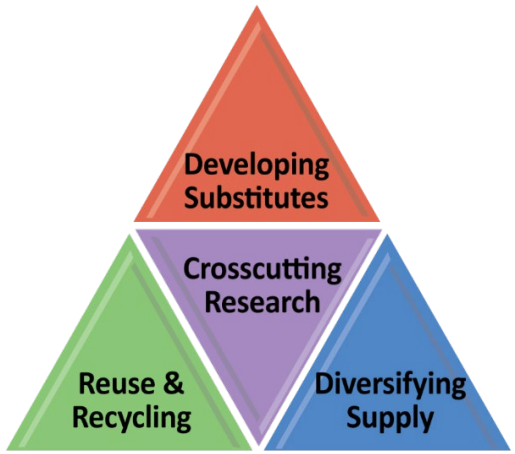



CMI Accelerating Energy Innovations

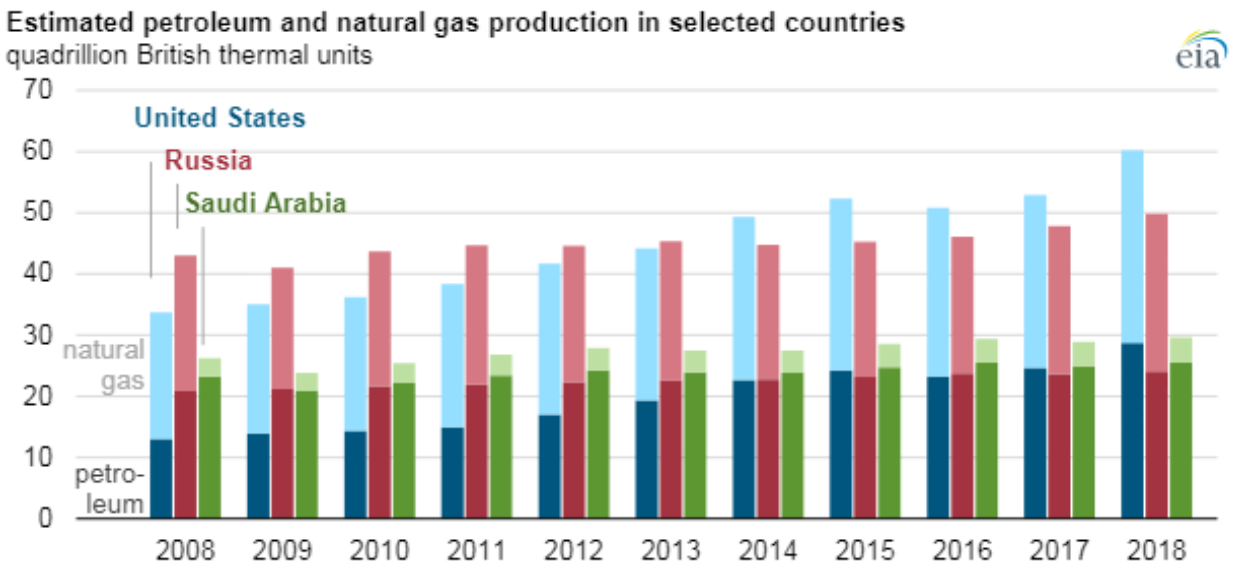
Critical Materials Institute

**Office of Energy Efficiency and Renewable Energy**

**Eliminate materials criticality as an impediment to the commercialization of clean energy technologies for today and tomorrow**



# U.S. Is the World's Largest Producer of Oil and Natural Gas

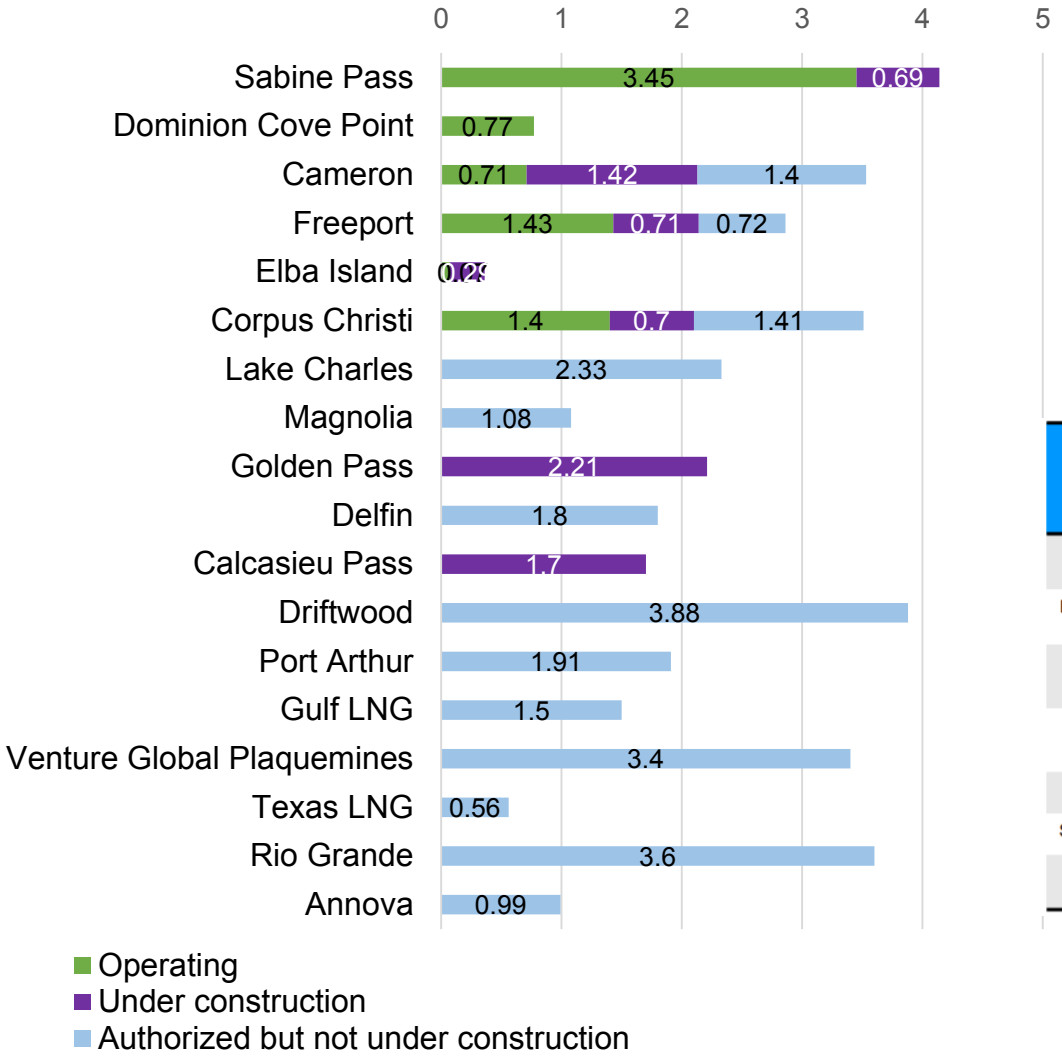



Source: U.S. Energy Information Administration

# LNG Projects and Exports

## PERMITTED U.S. LOWER 48 LNG PROJECTS

**BILLION CUBIC FEET PER DAY (AS OF 2/18/20)**




## U.S. LNG EXPORTS 2/2016 THROUGH 12/2019

| Region | Number of Countries Receiving Per Region | Volume Exported (Bcf) | Percentage Receipts of Total Volume Exported (%) | Number of Cargos* |
|---|---|---|---|---|
| East Asia and Pacific | 7 | 1,369.1 | 36.1% | 400 |
| Europe and Central Asia | 12 | 992.5 | 26.2% | 305 |
| Latin America and the Caribbean** | 11 | 966.7 | 25.5% | 322 |
| Middle East and North Africa | 5 | 226.1 | 6.0% | 66 |
| South Asia | 3 | 235.9 | 6.2% | 69 |
| Sub-Saharan Africa | 0 | 0.0 | 0.0% | 0 |
| **Total LNG Exports** | **38** | **3,790.2** | **100.0%** | **1,162** |

# Appalachian Petrochemical Initiative

## Two Commercial Projects

- **Under Construction**
  - Shell Chemicals Appalachia, LLC
  - $6B ethane cracker with polyethylene production lines
  - Two dedicated ethane pipelines to fractionators
- **Pending Final Investment Decision (FID)**
  - PTT Global Chemicals/Daelim Chemicals
  - $10B ethane cracker with derivatives production
  - Pipeline infrastructure and some storage

## Path Forward

- Coordinate federal economic development efforts, across agencies and with stakeholders, to catalyze private sector investment
  - Communicate the market opportunity and its benefits
  - Continue to create a pro-growth business investment environment
  - Invest in supporting public infrastructure
  - Support workforce development
  - Invest in technology innovation through R&D

# Appalachian Petrochemical Opportunities

## Opportunity

- Ethane and other NGLs
  - Underutilized co-products of the Appalachian shale gas industry
  - Ethane is a principal petrochemical feedstock for a diversity of products
  - Opportunity to drive an Appalachian petrochemical industry renaissance
- Revitalized Appalachian petrochemical industry could support
  - Five world-scale petrochemical crackers
  - A regional pipeline and storage network (the “hub”)
  - Downstream manufacturing facilities

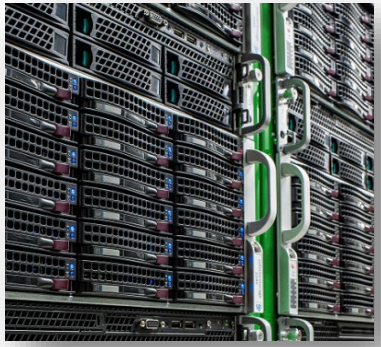
## Economic Benefits

- 100,000 permanent jobs
- $6B annual payroll
- $30B+ private capital investment
- $28B annual revenue
- $3B annual tax revenue

## Energy and Manufacturing Security Benefits

- Geographically diversifies U.S. petrochemical manufacturing base
- Creates expanded shale gas production opportunities
- Creates a lower cost, regional supply point for NGL derivatives

# Evolving Topics in Oil and Gas

| Enhancing Recovery | Natural Gas Utilization | Fracturing Water Reuse | Data Analytics |
|---|---|---|---|
|  |  |  |  |
| Transformational technologies to more effectively characterize and produce natural gas and oil resources | Lower-cost technologies for capturing and utilizing natural gas that would be otherwise vented or flared at the field or well pad level | Reduce cost and improve efficiency of systems for treating fracturing flowback or produced water for beneficial reuse | Addressing critical knowledge gaps in the use of data analytics and machine learning to optimize reservoir management and production operations |

# Oil and Gas Technology Thrusts

## Onshore Unconventional

**Developing technologies to maximize resource recovery and reduce operational impacts in unconventional oil & gas plays.**

## Offshore

**Minimizing the environmental impacts of deepwater and ultra-deepwater oil and gas production.**

## Gas Hydrates

**Characterizing gas hydrate resources and developing ways to tap their massive energy potential.**

## Natural Gas Infrastructure

**Developing technologies and practices to assess and mitigate methane emissions from natural gas transmission, distribution, and storage facilities.**

# For More Information

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