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

Status and Projections of CCUS Policies and R&D

NASEO Energy Policy Outlook Conference

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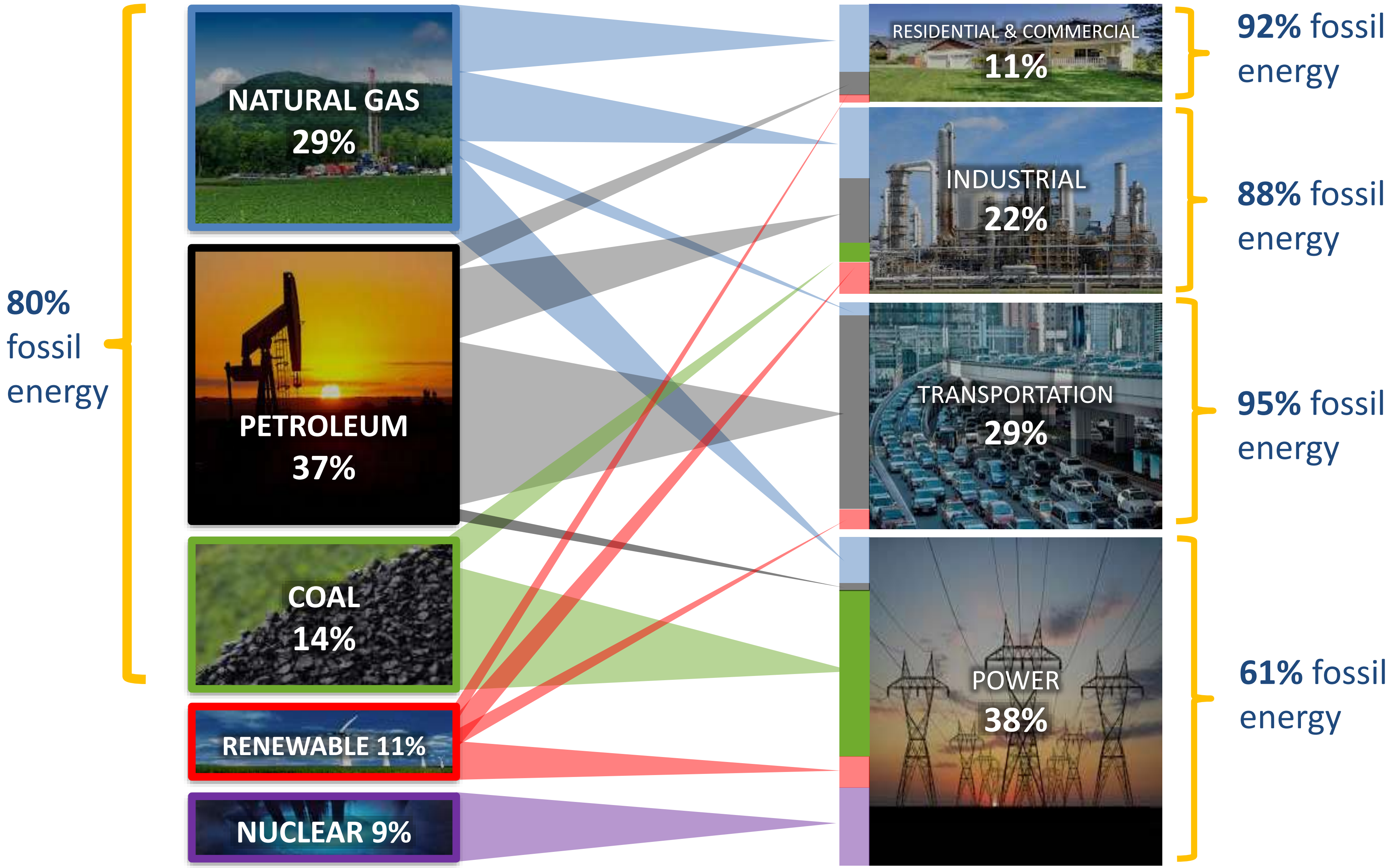
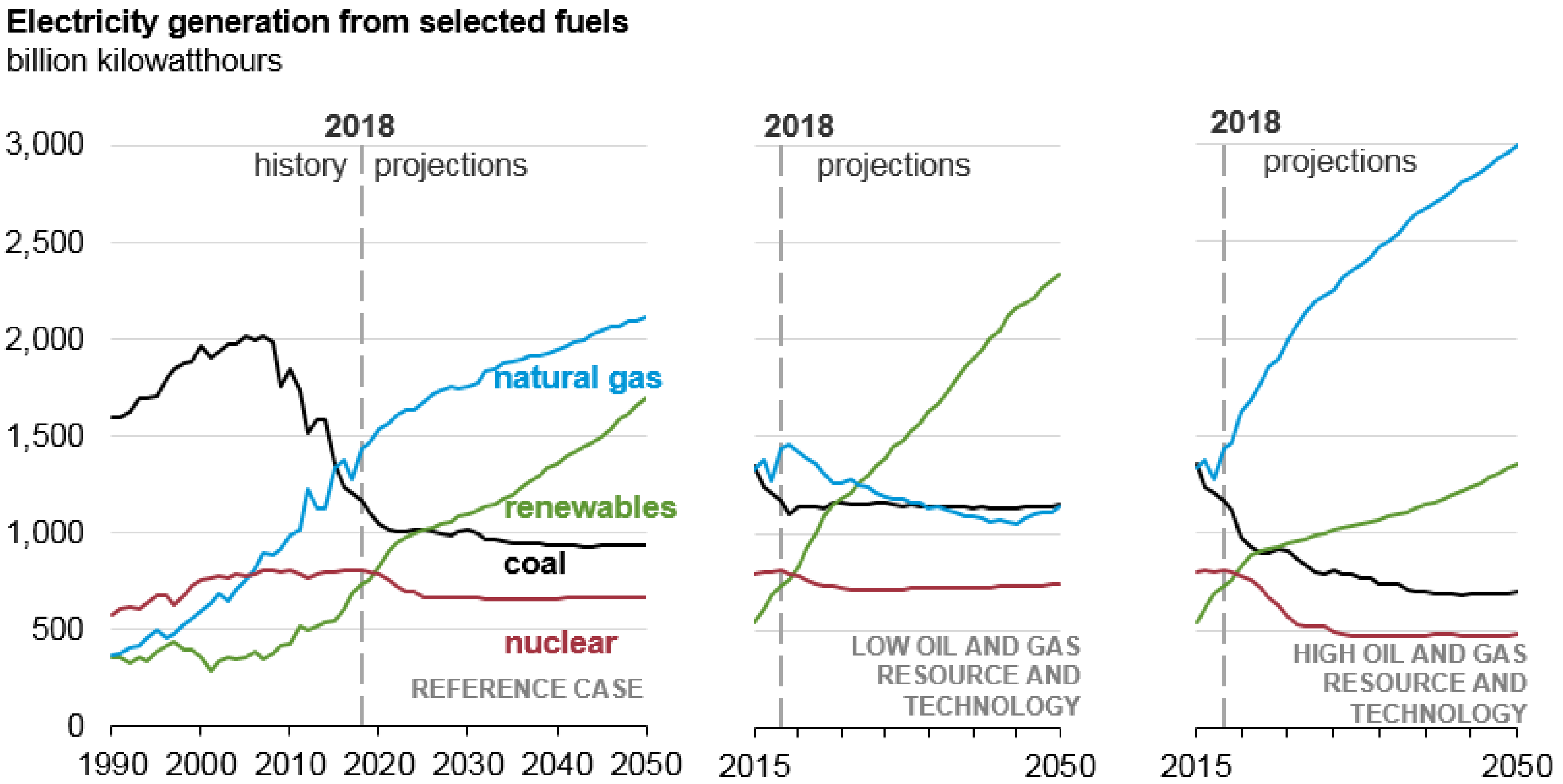
In current U.S. energy mix fossil critical in all domestic sectors



Data source: U.S. Energy Information Administration (EIA), Monthly Energy Review December 2018

The price of natural gas a key factor in projecting future U.S. energy mix – fossil energy significant in every case



Source: EIA, Annual Energy Outlook 2019

Trump Administration energy priorities

- Boosting domestic energy production
- Grid reliability and resiliency
- Job creation
- Energy security

Achieving these priorities will require advancements in fossil energy technologies given current and projected central role of fossil in energy production



Motivation for Coal-Based Power Plants of the Future R&D

- **Changes to the U.S. electricity industry are forcing a paradigm shift in how the nation's generating assets are operated.**
  - Coal-fired power plants optimized as baseload resources are being increasingly relied on as load-following.
  - Wide-scale retirements of the nation's existing fleet of coal-fired power plants—without replacement—may lead to a significant undermining of the resiliency and reliability of America's electricity supply.
  - The need for considerable dispatchable generation, critical ancillary services, and grid reliability, creates opportunity for advanced coal-fired generation, for both domestic and international deployment.
  - Fundamental changes to operating and economic environment expected into next decade and beyond.

Major carbon capture, utilization and storage (CCUS) demonstration projects

Air Products Facility (Port Arthur, TX) – operations began in 2013

- Built and operated by Air Products and Chemicals Inc. at Valero Oil Refinery
- State-of-the-art system to capture CO_2 from two large **steam methane reformers**
- **5.0 million metric tons of CO_2** captured and transported via pipeline to oil fields in eastern Texas for **enhanced oil recovery (EOR)** since March 2013

Petra Nova CCS (Thompsons, TX) – operations began in 2017

- Joint venture by NRG Energy, Inc. (USA) and JX Nippon Oil and Gas Exploration (Japan)
- Demonstrating Mitsubishi Heavy Industries' solvent technology to **capture 90% of CO_2 from 240-MW flue gas stream** (designed to capture/store 1.4 million metric tons of CO_2 per year)
- **2.2 million metric tons of CO_2** used for **EOR** in West Ranch Oil Field in Jackson County, Texas since January 2017

ADM Ethanol Facility (Decatur, IL) – operations began in 2017

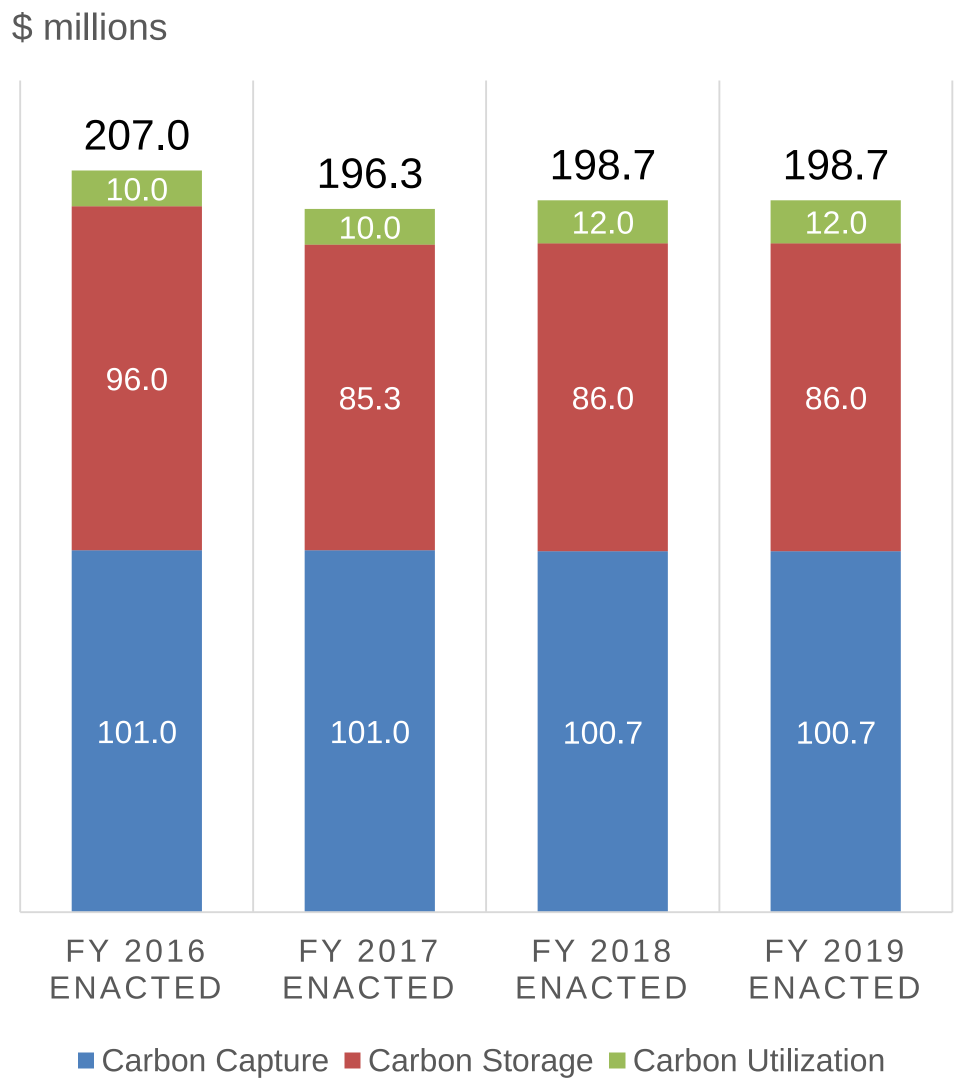
- Built and operated by Archer Daniels Midland (ADM) at its existing biofuel plant
- CO_2 from **ethanol biofuels production** captured and stored in **deep saline reservoir**
- **First-ever CCS project** to use new U.S. Environmental Protection Agency (EPA) Underground Injection **Class VI well permit,** specifically for CO_2 storage
- **1.0 million metric tons of CO_2** captured, **0.8 million metric tons** of which **stored**, since April 2017

Federal investment in CCUS R&D

Carbon capture
R&D and scale-up technologies for capturing CO_2 from new and existing industrial and power-producing plants

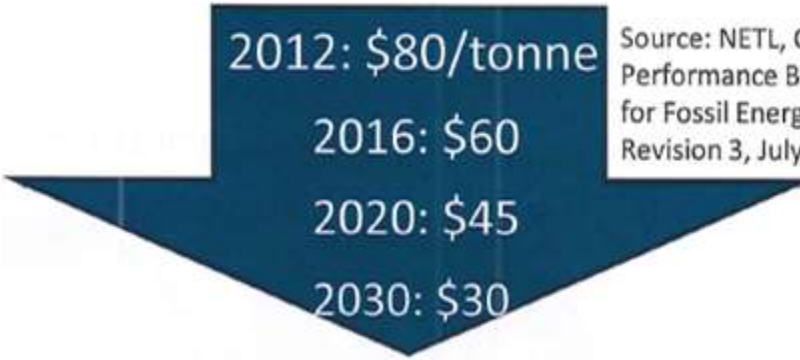
CO_2 utilization
R&D and technologies to convert CO_2 to value-added products

Carbon storage
Safe, cost- effective, and permanent geologic storage of CO_2



High-level R&D program goals and challenges

- Reduce the cost of capture by 50%
  - Capital cost
  - Energy penalty
  - Integration or process intensification



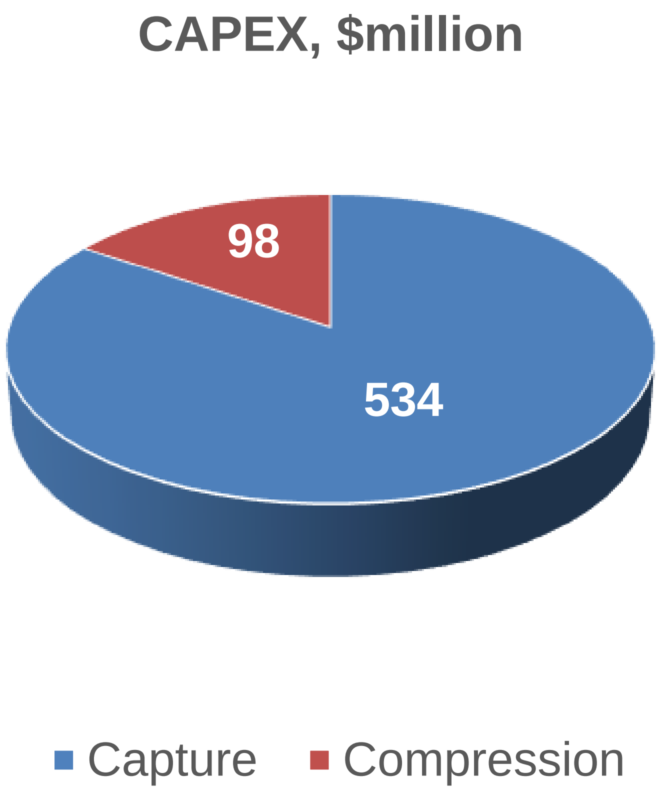
Source: NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

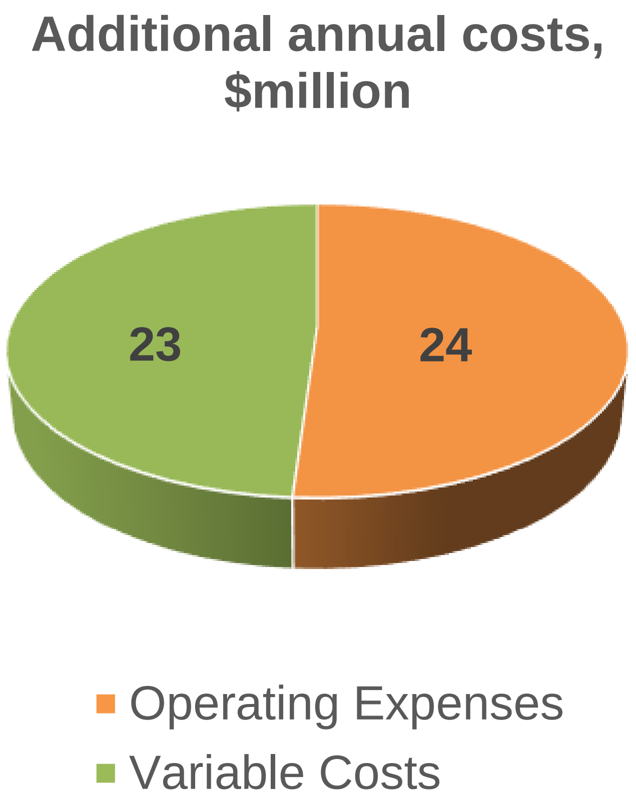
- Develop viable carbon utilization alternatives
  - Reduce capital cost
  - Reduce energy requirements
  - Lifecycle assessment
- Reduce the risk of geologic storage – improve monitoring and simulation
  - Higher resolution and quantification (e.g., accurate characterization of faults and fractures)
  - Geomechanics (pressure and state of stress)
  - Cost / uncertainty / enabling real-time decision making

CCS and CCUS value chains

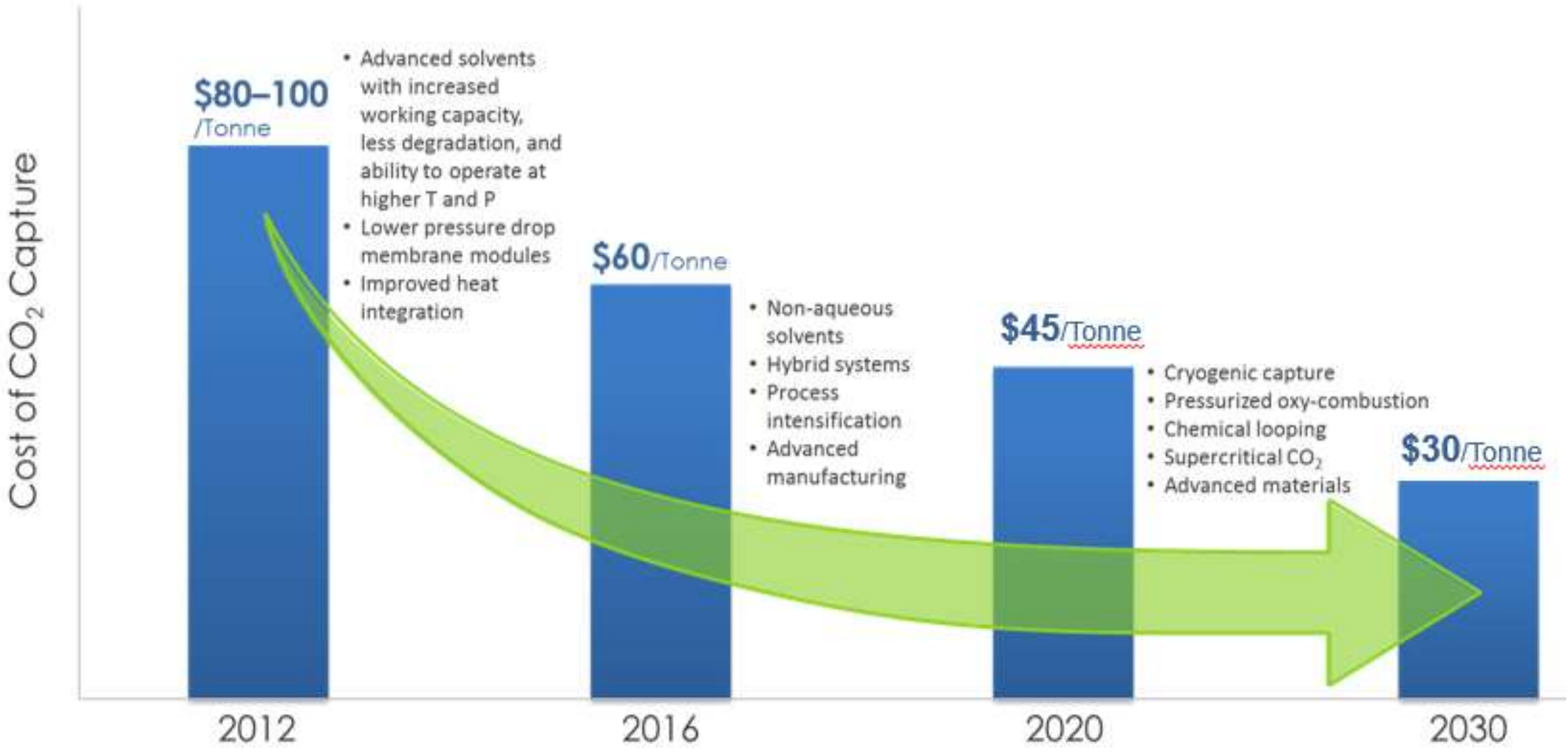
Source: National Energy Technology Laboratory (NETL), Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

Cost of capture and compression





Carbon capture program goals



Carbon capture R&D pathways

Pre-Combustion

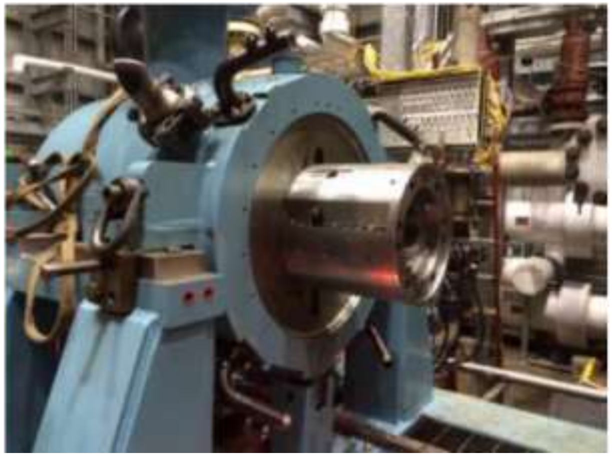
- ❑ *Solvents*
- ❑ *Sorbents*
- ❑ *Membranes*
- ❑ *Hybrid processes*
- ❑ *Water-gas shift reactor*

Post-Combustion

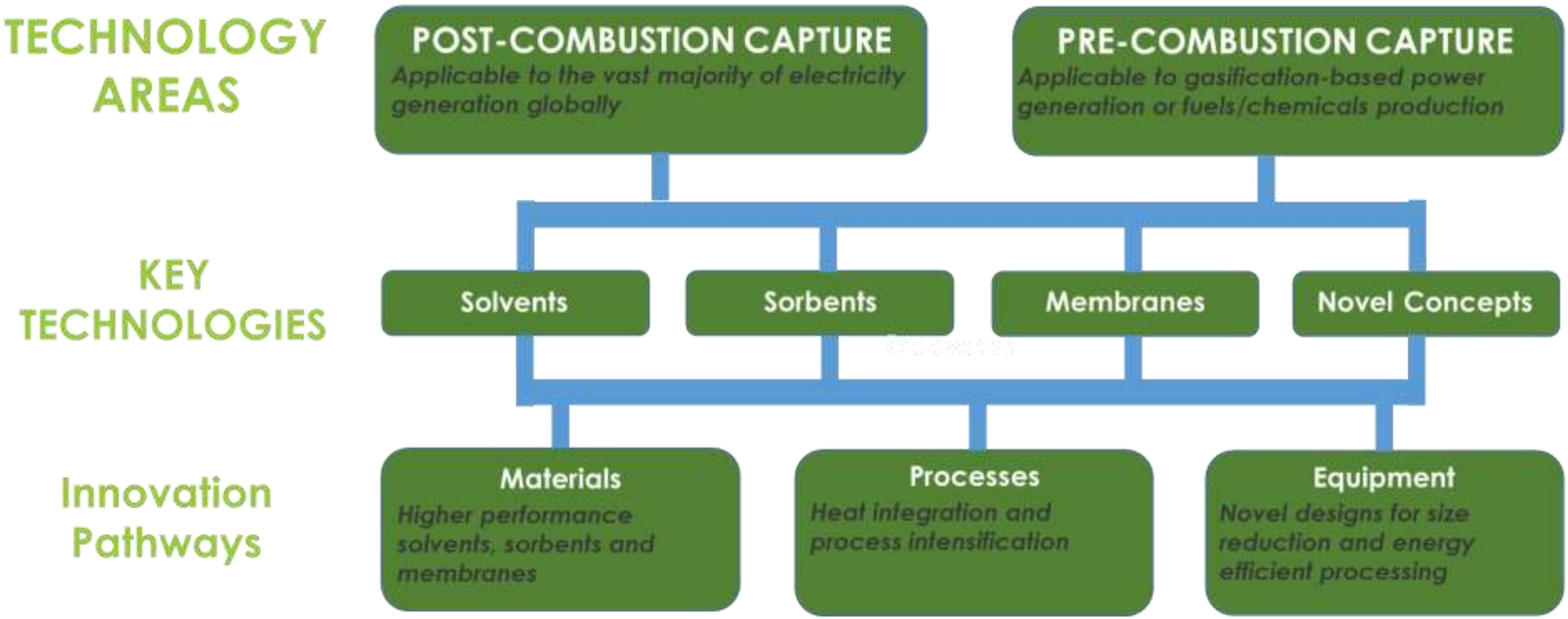
- ❑ *Solvents*
- ❑ *Sorbents*
- ❑ *Membranes*
- ❑ *Hybrid processes*

Advanced Compression

- ❑ *Intra-stage cooling*
- ❑ *Cryogenic pumping*
- ❑ *Supersonic shock wave compression*



Carbon capture R&D program structure and focus



Key challenges for carbon storage deployment

- Geomechanics
  - Induced seismicity
  - Caprock and wellbore fracture mechanics
- Improved accuracy of characterization of faults and fracture networks
- Improved accuracy of assessment of stress state
- Reservoir management strategies and technologies (e.g., pressure and plume management, intelligent/autonomous monitoring systems and sensors)
- Tools for experts and non-experts
  - Data infrastructure
  - Modeling and simulation tools for regulators and would-be operators
  - Protocols and tools for post-injection site care

The U.S. CO_2 EOR opportunity

Oil production

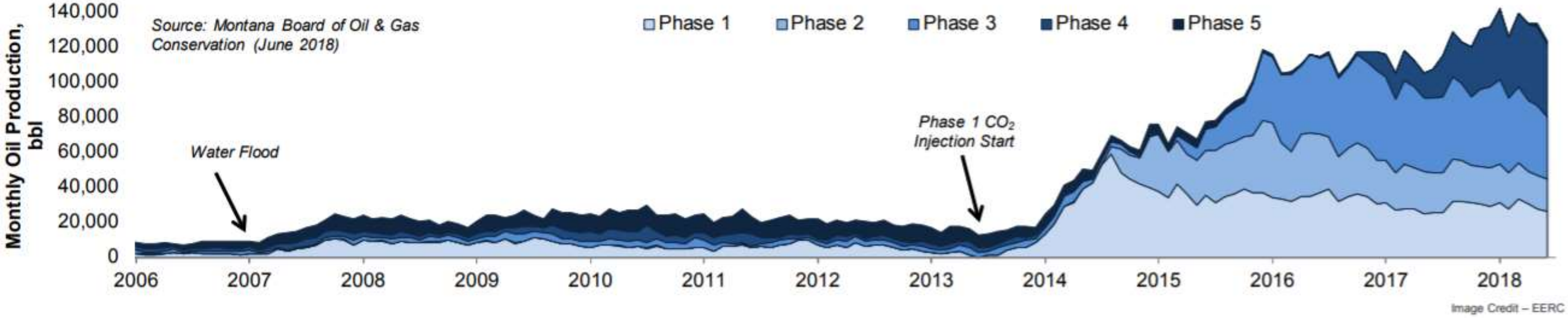
- 300,000 barrels per day (b/d), or 3% of U.S. crude oil production in 2017 used CO_2 EOR with 70 million metric tons (MT) of CO_2
- 390,000 b/d of CO_2-EOR-based oil production expected for 2025

The opportunity

- U.S. recoverable resource CO_2 EOR: 137 billion barrels from conventional oil fields
- +100 billion barrels in unconventional tight oil formations
- 30 billion metric tons of CO_2 would be needed to produce 100 billion barrels of oil
- Market could take additional 250 MT of CO_2 per year for 100+ years → 25+ gigatons of CO_2 capacity and support infrastructure development

Bell Creek Oil Field, Montana

estimated 20-40 million barrels of incremental oil through CO_2-EOR

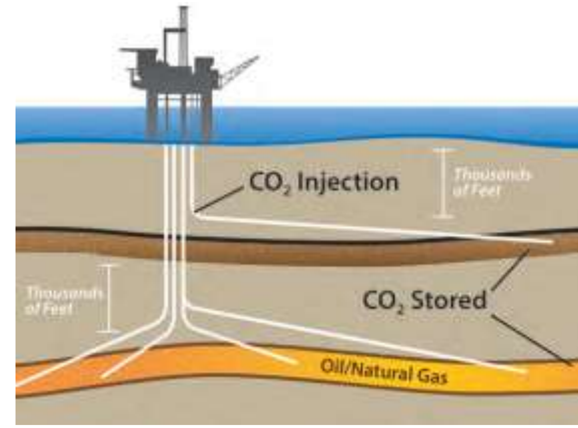


Selected carbon storage infrastructure R&D efforts

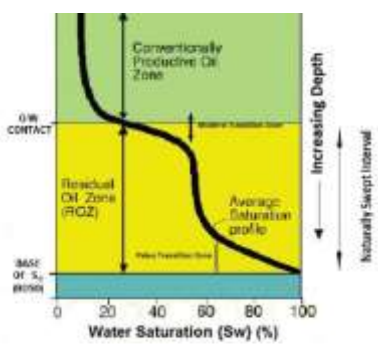
Regional Carbon Sequestration Partnerships (RCSPs)

CarbonSAFE

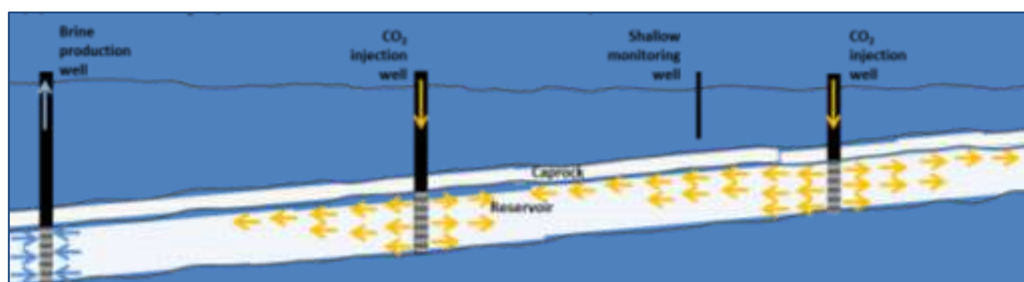
Offshore storage



Unconventional EOR



Brine Extraction Storage Tests (BEST)



Financial incentives for commercial CCUS – 45Q tax credits

Matching "technology push" through R&D with "market pull" through financial incentives

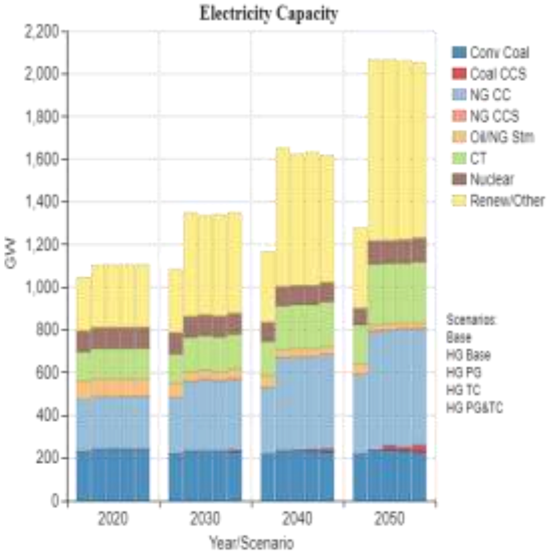
- Tax benefits defined in "45Q" for qualified CCUS projects have been available since 2008
- The February 2018 "Bipartisan Budget Act of 2018" extended and significantly expanded the tax benefits:
  - **Increased the credit amount**:
    $20/ton → up to $50/ton for saline storage, 10/ton → up to $35/ton for EOR
  - **Expanded the qualified carbon oxides** to include carbon monoxide (CO)
  - **Expanded qualified uses** to include CO_2 utilization other than enhanced oil or natural gas recovery
  - **Lowered the qualifying threshold** for the amount of CO_2 captured to allow more industries to participate in the program
  - **Increased the flexibility** to allow credit assignment to capture or disposal facility
  - **Removed the program cap**

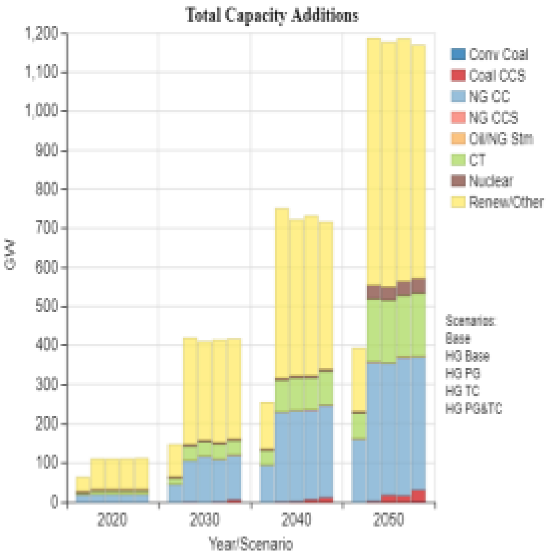
Analyzing the deployment potential for DOE Program Goals and 45Q Tax Credits

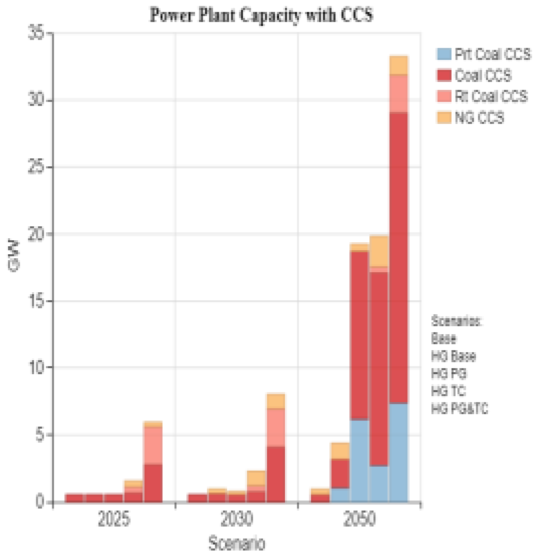
- Effectiveness of DOE Program Goals and 45Q Tax Credits on technology deployments analyzed
- Analysis performed using the National Energy Modeling System (NEMS) – Capture Storage Utilization and Transport (CTUS) Model
- The set of scenarios evaluated are described as follows:
  - ***No CPP Reference Case (Base):*** The AEO2017 Reference case without the Clean Power Plan.
  - ***High Economic Growth Case (HG Base):*** High economic growth with 2.6% per year increase in GDP with high electricity demand of 2% per year, CCUS technologies reflecting no federal R&D;
  - ***CCUS Program Goal Case (HG PG):*** High Economic Growth case with CCUS technologies reflecting federal R&D program goals.
  - ***Tax Credit Case (HG TC):*** High Economic Growth case with a 45Q sequestration tax credit that for 12 years provides \$35/ton CO_2 for EOR and \$50 CO_2 sent to geologic storage for power and industrial CCUS projects
  - ***Combined Case (HG PG&TC):*** Tax Credit Case with success of the DOE R&D program goals

Analysis Results:
Electric Capacity and Generation

- High electricity demand leads to significant capacity and generation increases over the next three decades, with significant additions of renewable capacity.
- In the HG PG case, in which the DOE program goals are achieved, 3 GW of coal CCUS capacity is added by 2040 and 19 GW by 2050.
- The 45Q tax credit increases the amount of coal CCUS capacity by 2040 (8 GW), but by 2050 the capacity is similar to the HG PG case (18 GW).
- With both goals and tax credits, the coal CCUS capacity increases to 13 GW and 32 GW in 2040 and 2050 respectively.
- 1 to 2 GW of gas CCUS are also deployed across these cases by 2050.

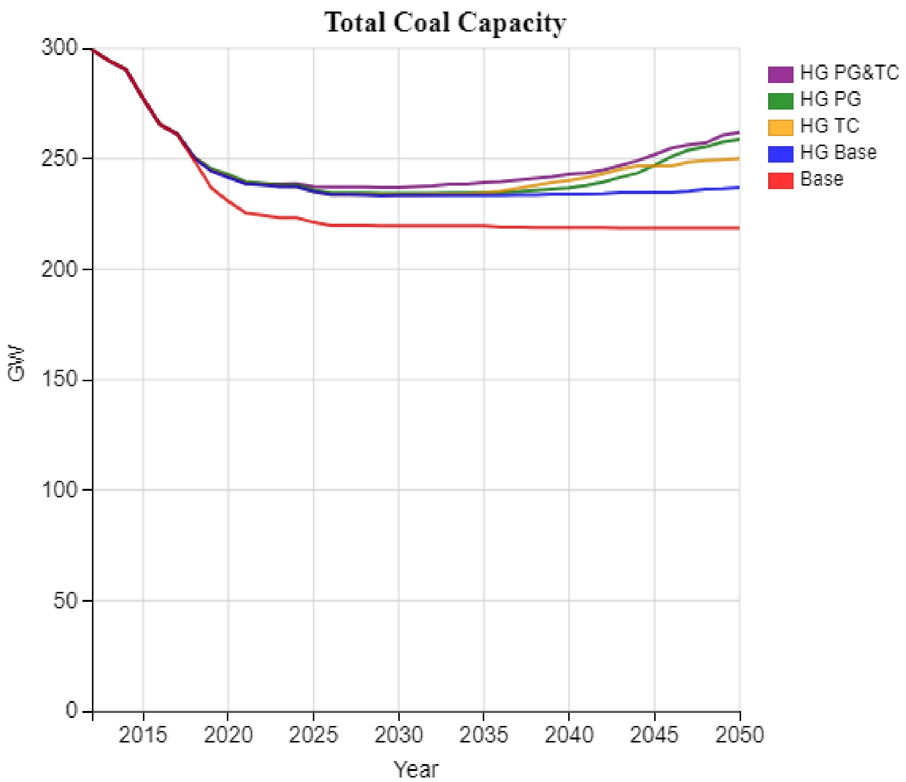


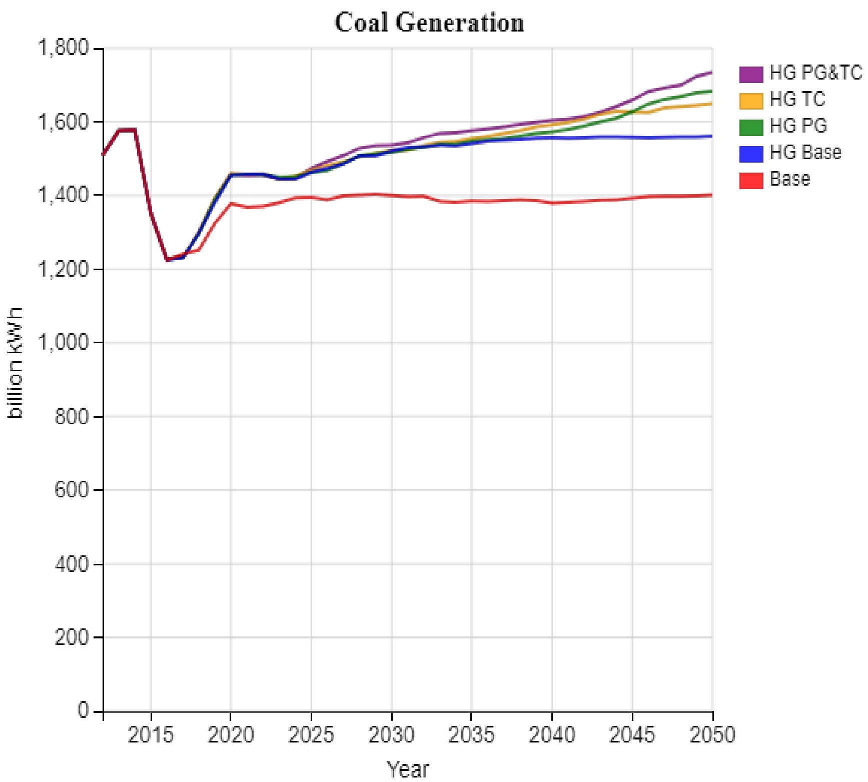




Analysis Results:
Coal Capacity and Generation

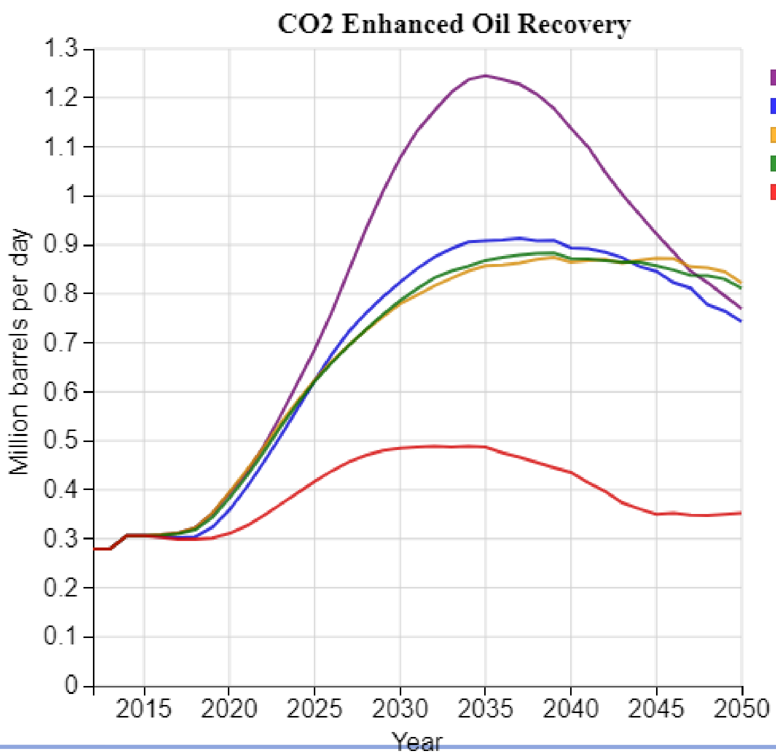
- High economic and electricity demand growth alone preserves some existing coal capacity and generation.
- The tax credits and success of the DOE R&D program are both projected to stimulate new coal with CCUS capacity that leads to increases in coal generation (and consumption).

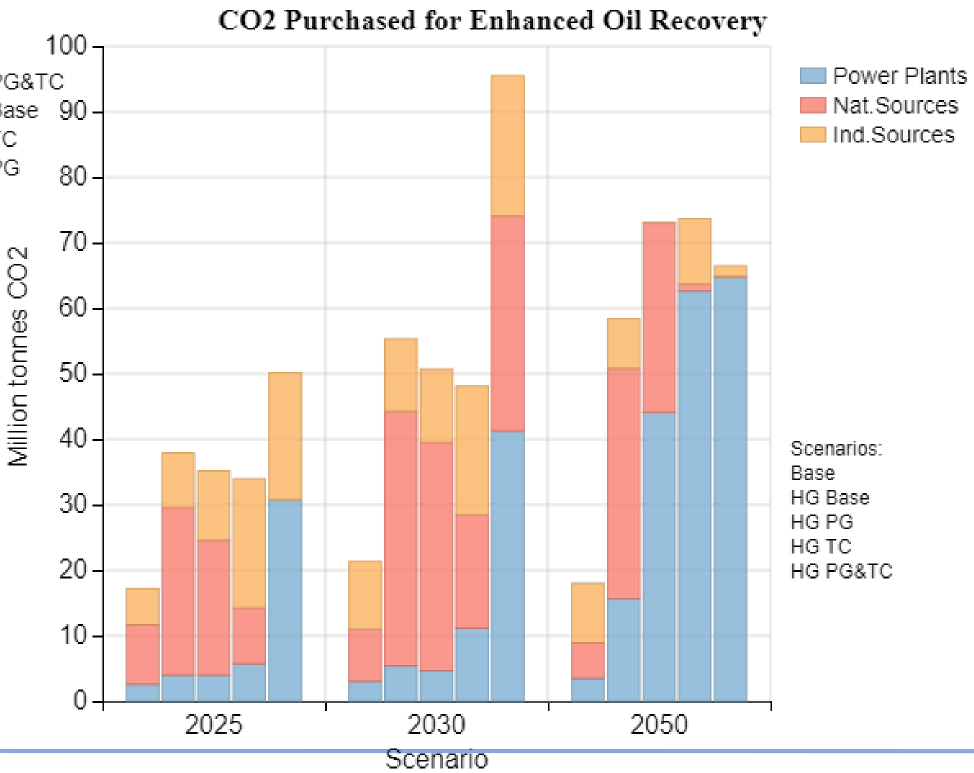




Analysis Results: EOR Production

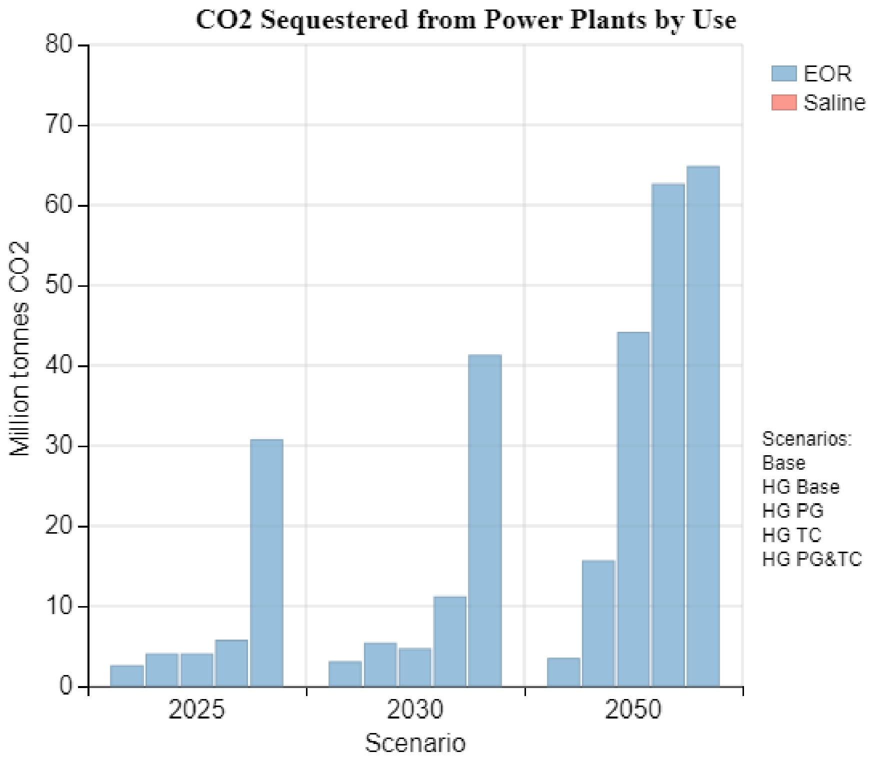
- The lower O&M cost assumptions lead to greater EOR production in all cases relative to the Base.
- The tax credit and the program goals alone have little impact on total EOR production.
- However, the effect of the tax credits and program goals together leads to a significant increase in the CO_2 available from power plants and industrial sources before 2040 and boosts EOR production for a number of years.

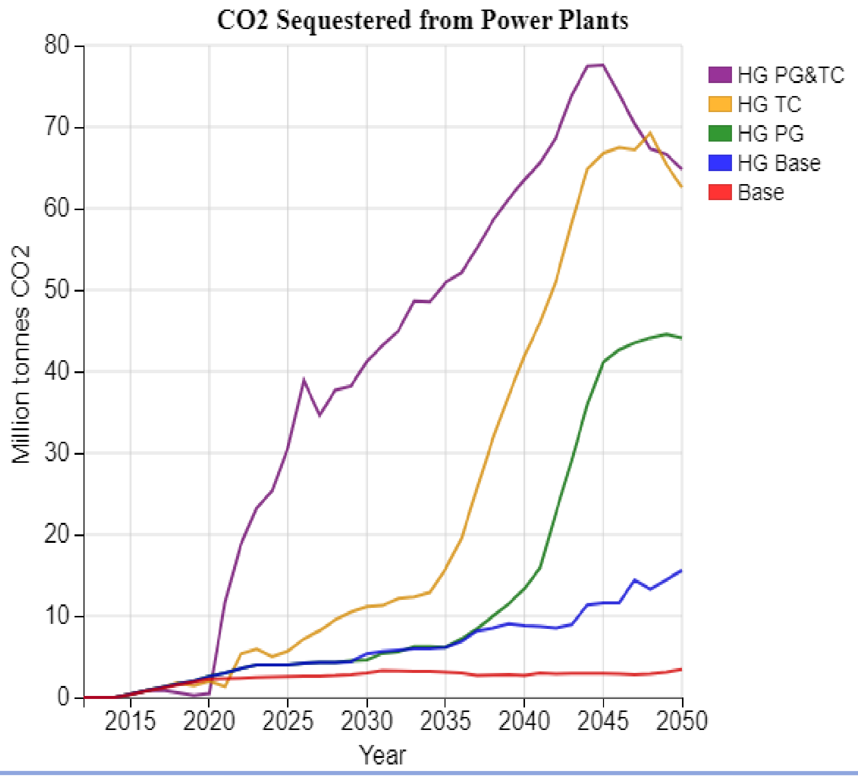




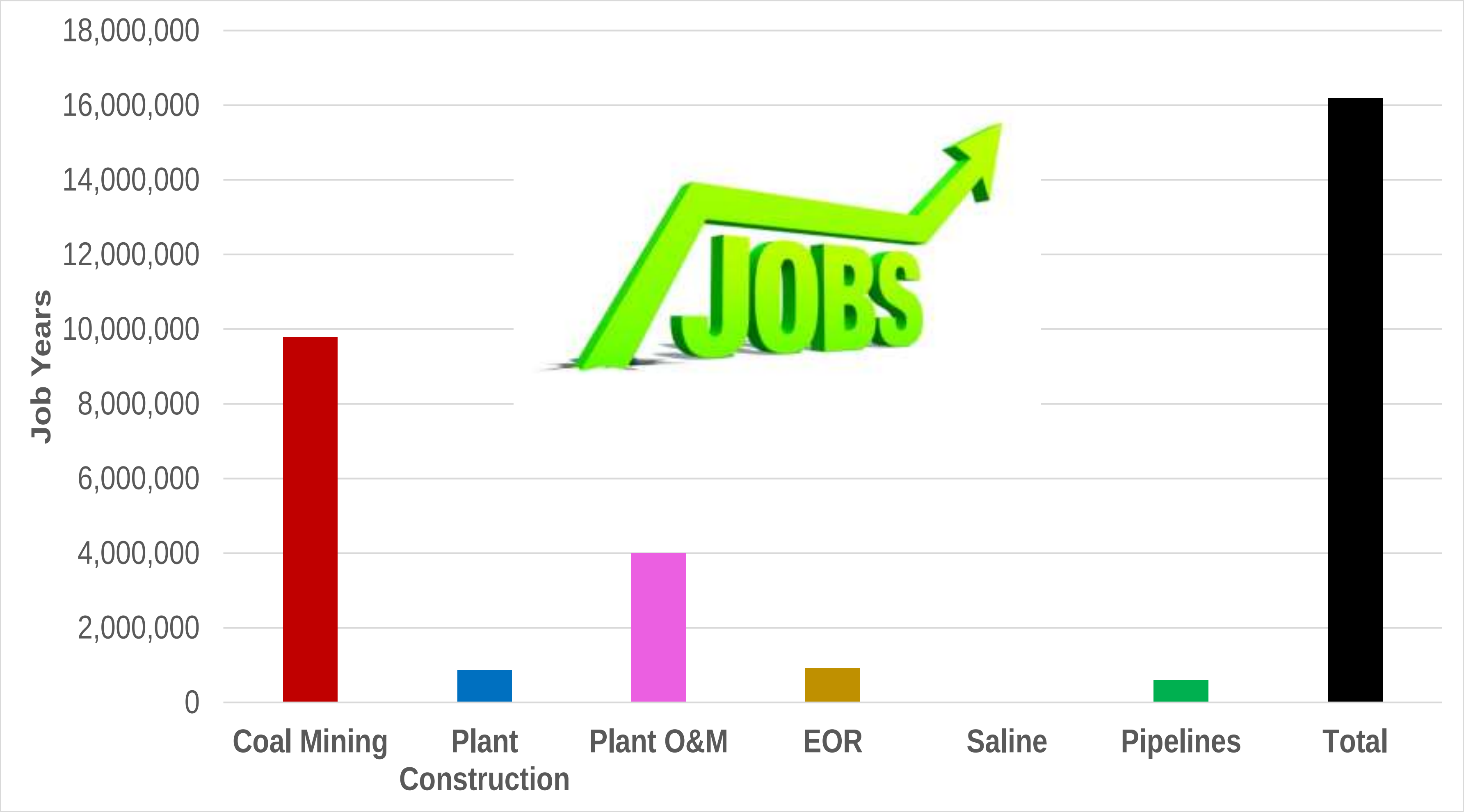
Analysis Results: CO_2 Captured by Source and Destination

- All of the CO_2 captured from power and industrial sources are used for EOR production.
- Once the 12 year duration of the tax credits is over, and if EOR CO_2 demand is insufficient for all the potential CO_2 captured, then power plants cease capturing CO_2 to the extent allowed because there is no penalty for emissions in these cases.





Analysis Results:
Cumulative Employment Impacts of the HG PG &TC Scenario



Conclusions

- The DOE Office of Fossil Energy is pursuing transformative R&D through its Clean Coal and Carbon Management Program that will enable future deployment of CCUS and other advanced technologies.

- The 45Q tax credit provides an additional positive economic incentive for potential CCUS projects

- Implemented in tandem, CCUS R&D and 45Q provide an effective mechanism to enable development of a large scale CCUS infrastructure

- A large scale CCUS infrastructure would support the Administration's goals of boosting domestic energy production, enhancing resilience and reliability of the Nation's grid system, increasing energy security, and resulting in large scale job creation

Thank you!

Questions can be sent to:

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