

WHAT'S NEW FOR CCS: A US PERSPECTIVE

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Denver, Colorado

CURC Members

Coal Producers

Arch Coal, Inc.*
Cloud Peak Energy Resources LLC
Lignite Energy Council
Peabody Energy*

Equipment Suppliers

B&W Power Generation Group, Inc.*
Caterpillar Global Mining
General Electric*
Mitsubishi Heavy Industries America,
Inc. (MHIA)

Labor Unions

United Mine Workers of America
International Brotherhood of Boilermakers
International Brotherhood of Electrical
Workers

NGOs

ClearPath Action
CoalBlue Project

Research Organizations

Battelle
Electric Power Research Institute (EPRI)
Gas Technology Institute
University of North Dakota Energy &
Environmental Research Center

State Organizations

Energy Industries of Ohio
Greater Pittsburgh Chamber of
Commerce
Illinois Coal Association
Kentucky Energy & Environment Cabinet
Southern States Energy Board
West Virginia Coal Association
Wyoming Infrastructure Authority

Technology Developers

NET Power

Trade Associations

American Coal Council
American Coalition for Clean Coal
Electricity (ACCCE)
Edison Electric Institute (EEI)
National Rural Electric Cooperative
Association (NRECA)

Universities

Lehigh University
Ohio State University
Pennsylvania State University
Southern Illinois University
University of Kentucky/CAER
University of Wyoming
West Virginia University

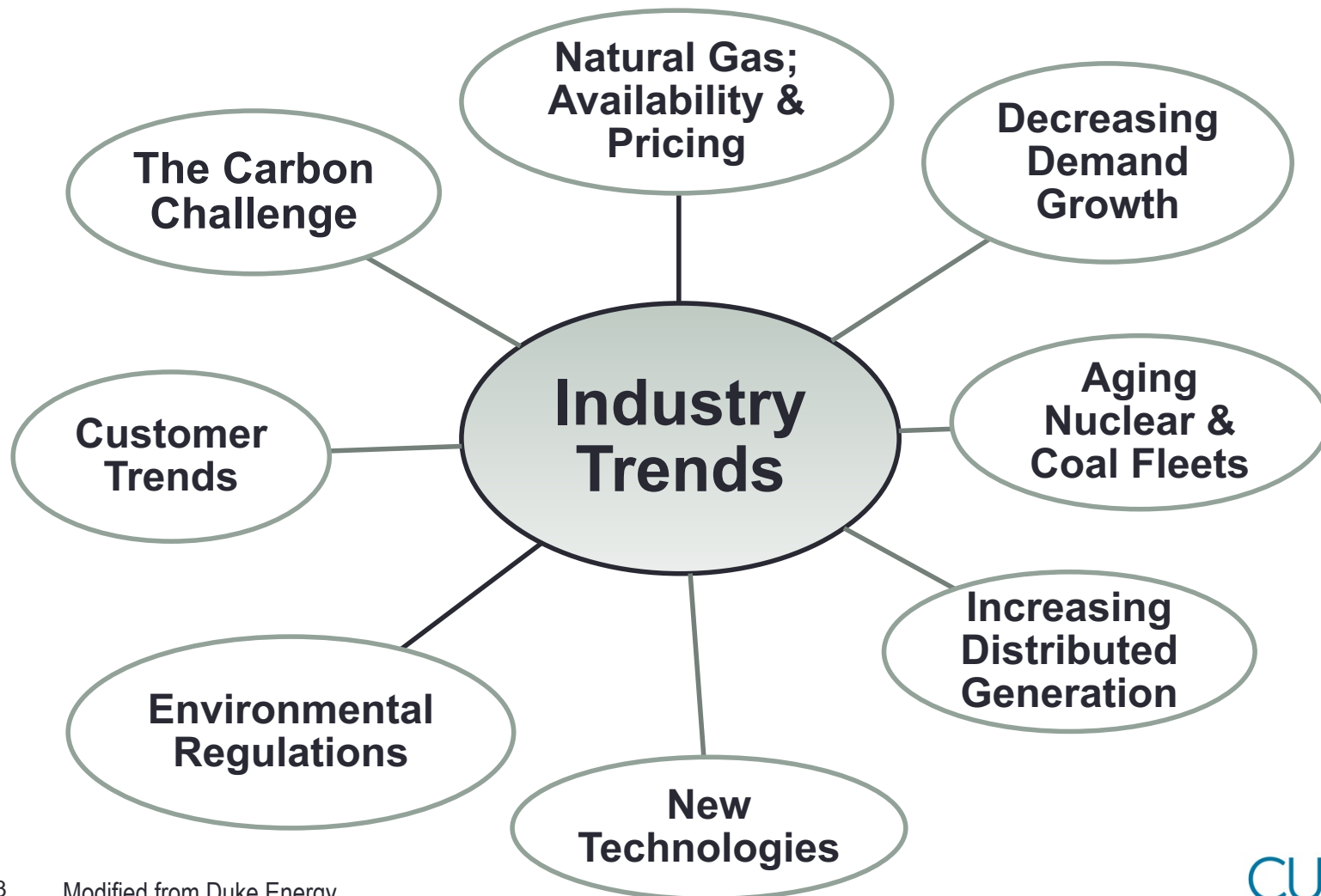
Utilities

American Electric Power (AEP)
Basin Electric Power Cooperative
Duke Energy Services
LG & E and KU Services Company
Southern Company
Tri-State Generation &
Transmission Association

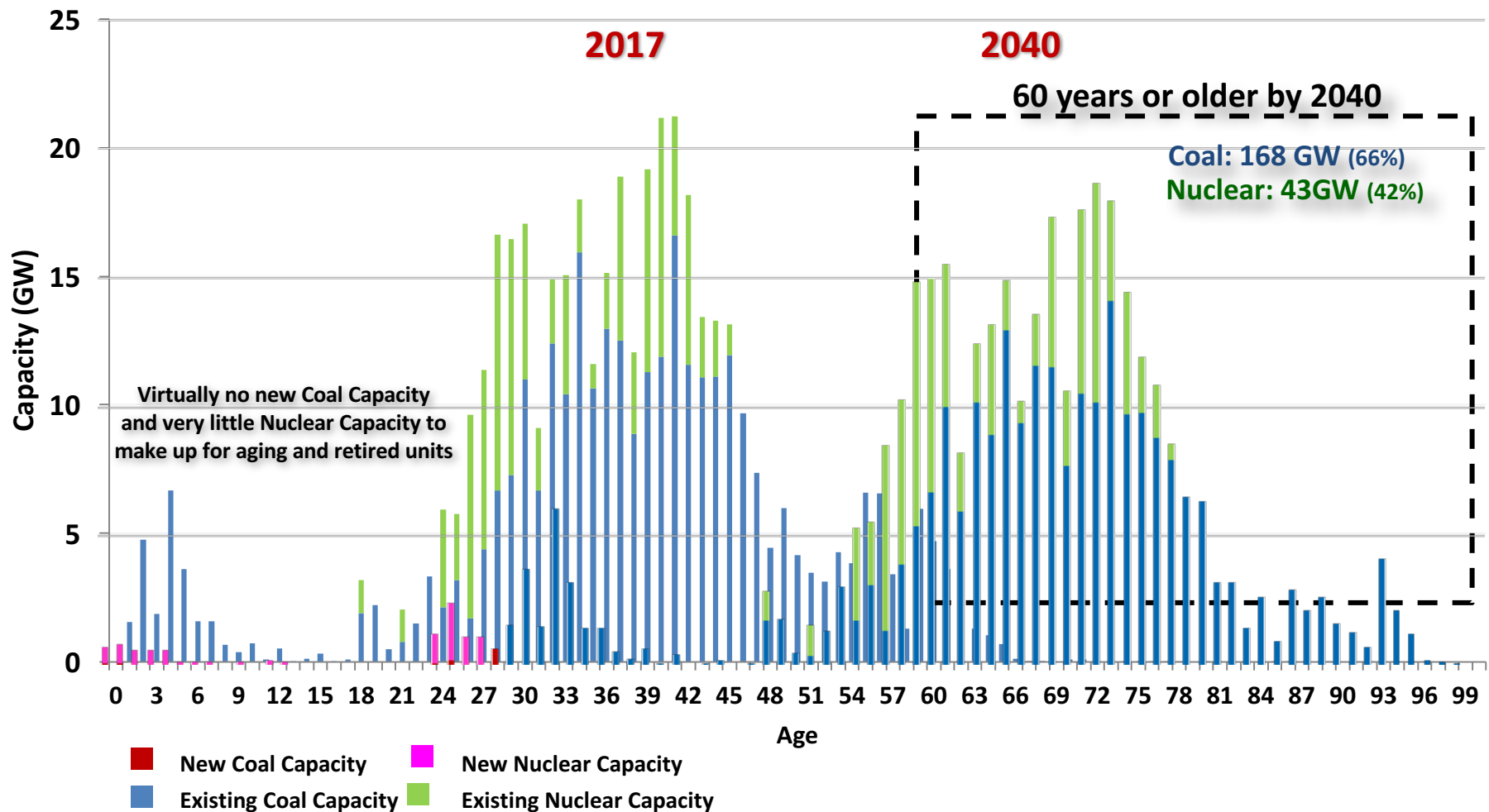
Companies in orange indicate
Steering Committee Members

*CURC Leadership Council

What is Driving Power Sector Technology Innovation in the U.S.?



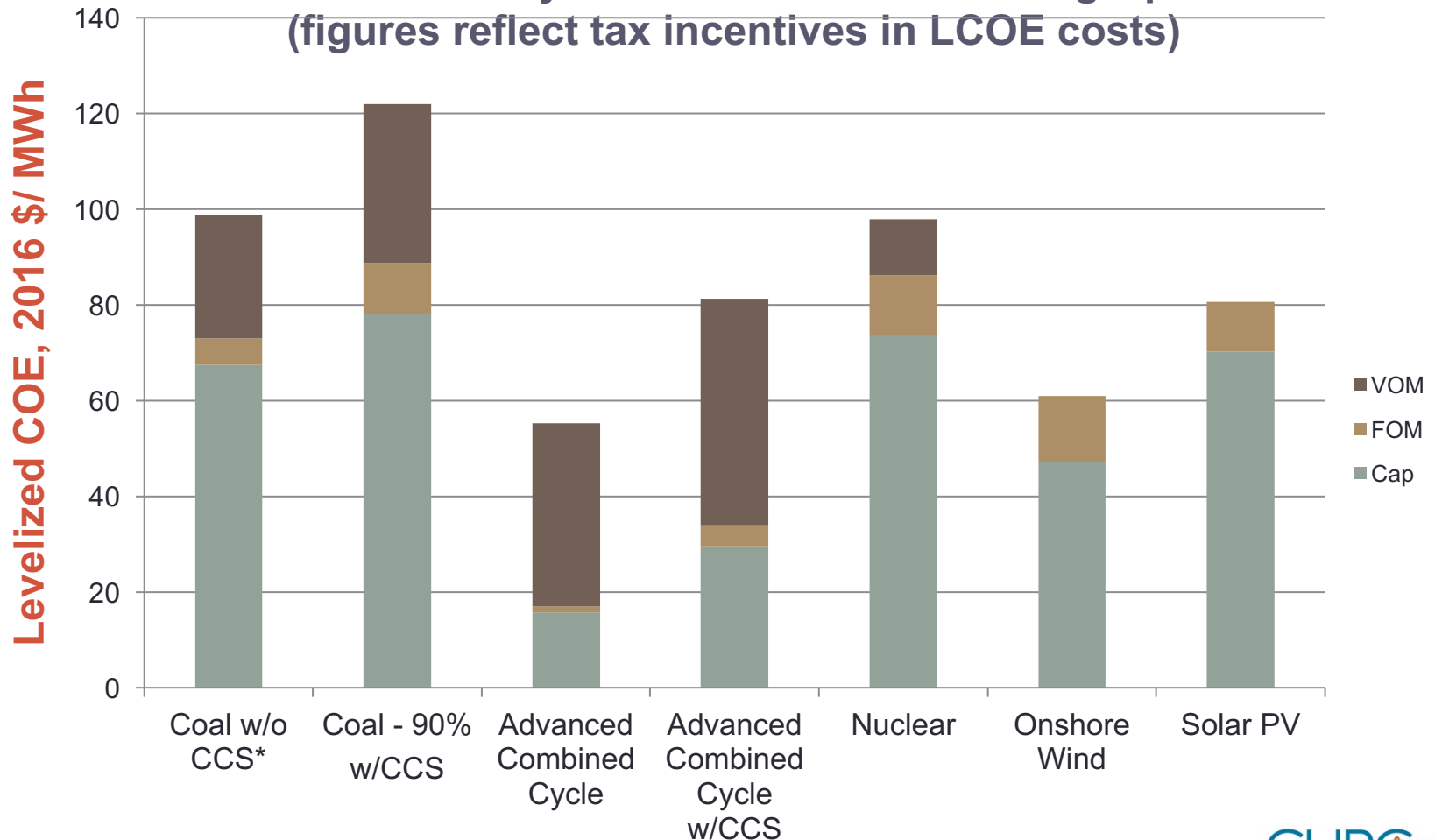
99% Existing US Baseload Capacity Aging Out in 20 Years – Opportunity for CCUS?



Today, CCUS in US Power Generation is Expensive Compared to Other Options

Levelized Cost of Electricity for New Unit Commencing Operation in 2022

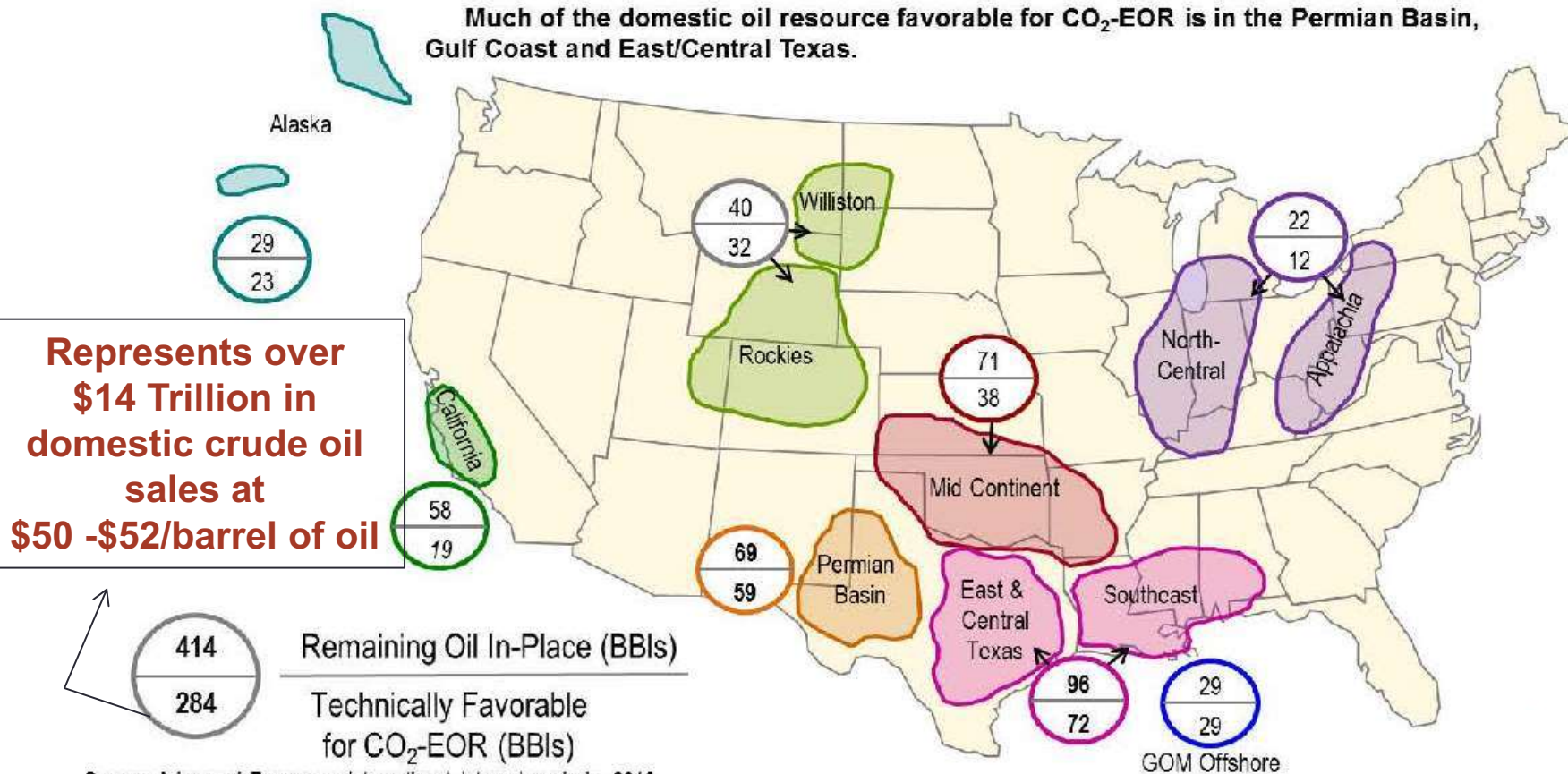
(figures reflect tax incentives in LCOE costs)



Economic Potential of CO₂-EOR in the US

Regional Distribution of CO₂-EOR Potential

Much of the domestic oil resource favorable for CO₂-EOR is in the Permian Basin, Gulf Coast and East/Central Texas.



Represents over \$14 Trillion in domestic crude oil sales at \$50 -\$52/barrel of oil

Source: Advanced Resources International internal analysis, 2016

Falling Costs for Other Low Carbon

Energy Technologies in the U.S.

120
100
80
60
40
20
0
20

As witnessed by the deployment curve with renewable energy technologies, we know that the costs for new energy technologies

– when coupled with policies to support their successive application into the commercial market –

Will reduce over time and make them competitive in the marketplace. CCUS needs the same level of financial and policy support to do the same.

costs

Each of these technologies has dropped 40-90% in cost in the U.S. since 2008

Indexed Cost reductions since 2008. (Source: energy.gov/fe)

Key Policies and Federal Efforts for CCUS Technology Development

- Existing DOE loan program proposed for elimination
- Federal Funding for DOE Coal CCS R&D Program:

Coal, CCS R&D	FY18
(All figures in millions of dollars)	154

- PetraNova had a \$190 million grant and government backed loans for a \$1 billion project; CURC recommends an annual federal budget of \$600 million to support similarly scaled efforts
- Successful technology commercialization in the power industry will require federal support beyond basic R&D
- Need more federal funding for projects at scale, not less

Congressional Efforts to Create a CCUS Market and Advance Technology

- New Fossil Energy RD&D program authorizations in Senate energy legislation prioritizes CCUS technology efforts including large-scale pilot and demonstration funding
- Current federal incentive efforts fixed on the tax code and targeted at closing cost gap or accessing low cost financing for CCUS:
 - 45Q carbon sequestration credits:
 - S. 1535, the FUTURE Act, led by Senators Heitkamp, Capito, Whitehouse, Barrasso, with a total of 24 co-sponsors
 - H.R. 3761, the Carbon Capture Act, led by Congr. Conaway, with a total of 37 co-sponsors
 - Private Activity Bonds
 - Master Limited Partnerships

New Technologies Under Development in the U.S.

Technology	Methods	Description
Pressurized Oxygen Combustion	Entrained Flow & Fluidized Bed	The combustion of fossil fuels in nearly pure oxygen, rather than air, carbon capture in power plants. Pressurized oxygen-combustion oxygen to the combustion process by separating oxygen from air.
Chemical Looping	MeOx and CaOx	A metal oxide instead of air is used as a carrier to provide the oxygen for combustion in the fuel reactor or boiler.
SCO ₂ Cycles	Indirect & Direct	Replaces steam in traditional rankine cycle with supercritical CO ₂ as the working fluid. Enables compact turbomachinery to be used with higher temperature cycle and results in significantly improved performance.
Advanced Ultrasupercritical Materials	700° C+ and high pressure materials	Development of components using AUSC materials will enable highly efficient combustion systems as well as the sCO ₂ other high temperature and pressure technologies
Carbon Capture	Pre- and post-combustion	Advances in solvents, sorbents and membranes focused on lowering regeneration energy requirements, higher CO ₂ adsorption capacity, improved permeability and selectivity, and lower costs. Hybrids and cryogenic applications under development.
CO ₂ Storage	Onshore and offshore.	Saline, enhanced oil and gas recovery, and other geologies being explored. Focusing on R&D as well as CO ₂ storage infrastructure in the U.S.

Thank you!

Questions:

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