Staff Subcommittee on Clean Coal and Carbon Management

Sunday, February 9, 2020

GLOBAL STATUS OF CCS 2019

TARGETING CLIMATE CHANGE

GLOBAL CCS INSTITUTE

Lee Beck
Senior Advisor
Lee.beck@globalccsinstitute.com

URGENT ACTION IS REQUIRED TO ACHIEVE CLIMATE CHANGE TARGETS

CARBON CAPTURE & STORAGE IS VITAL

REALITY CHECK

- **Goal and consequences are clear.** To limit global temperature rises to 1.5°C above pre-industrial levels, the world must reach net zero emissions by around 2050.

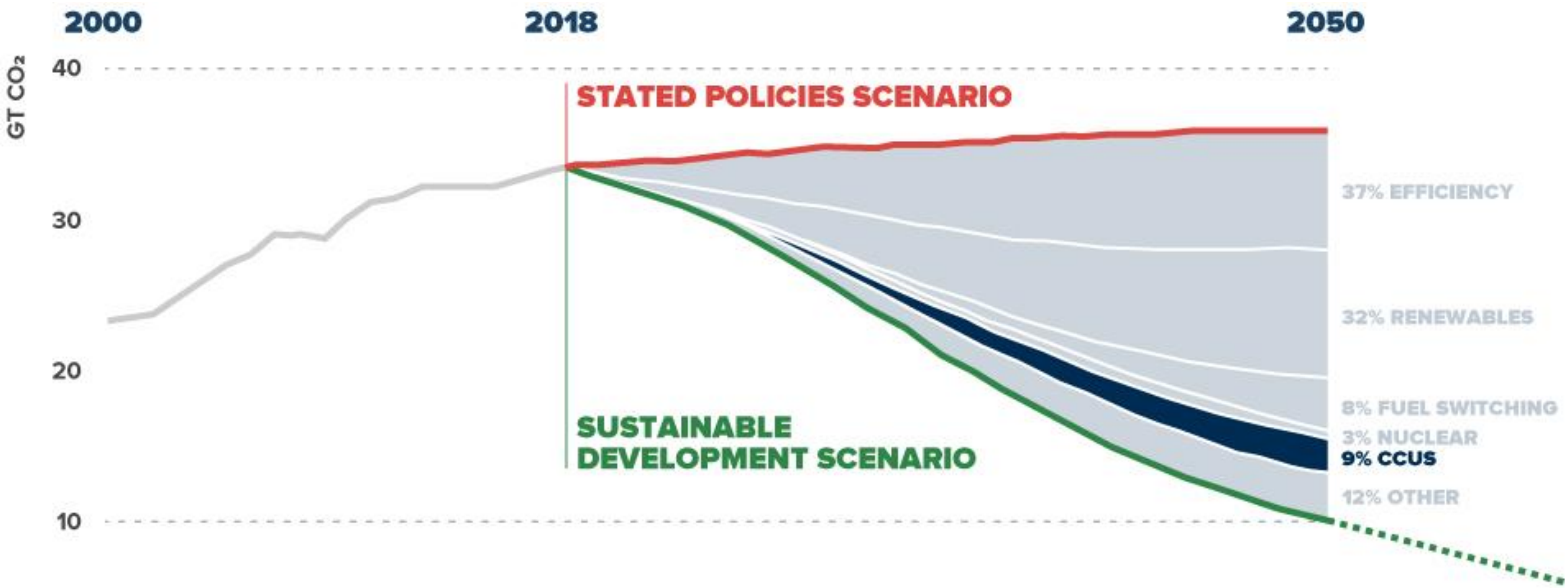
- **Progress slow.** Despite clear need for action on climate change, and rapid take-up of renewable energy, progress in curbing emissions has been slow.

- **Emissions growing.** Energy-related CO_2 emissions rose 1.7 per cent globally in 2018. Rhetorical commitments greater than policy or financial commitments.

- **Fossil fuels entrenched.** Approximately 80 per cent of primary energy is supplied by fossil fuels, the same as 50 years ago.

- **Overshoot likely.** Most modelling scenarios show significant deployment of negative emissions technologies required.

REALITY CHECK



GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

THE CASE FOR CARBON CAPTURE

VITAL: to reduce emissions to net-zero by mid-century and achieve global climate change targets

VERSATILE: diverse applications contributing to climate targets by: mitigating emissions, removing CO2 from atmosphere, and producing clean hydrogen

PROVEN: large-scale operation since 1970s; current capture capacity of 40 Mtpa; over 260 Mt of anthropogenic CO_2 captured and stored to date

ENABLER: a conduit to a new clean energy economy (e.g., clean hydrogen, chemicals, fertiliser production)

MOMENTUM BUILDING

- 51 large-scale CCS facilities
- 100 Mtpa of CO_2 captured and stored
- 260 million tonnes of anthropogenic CO_2 stored to date

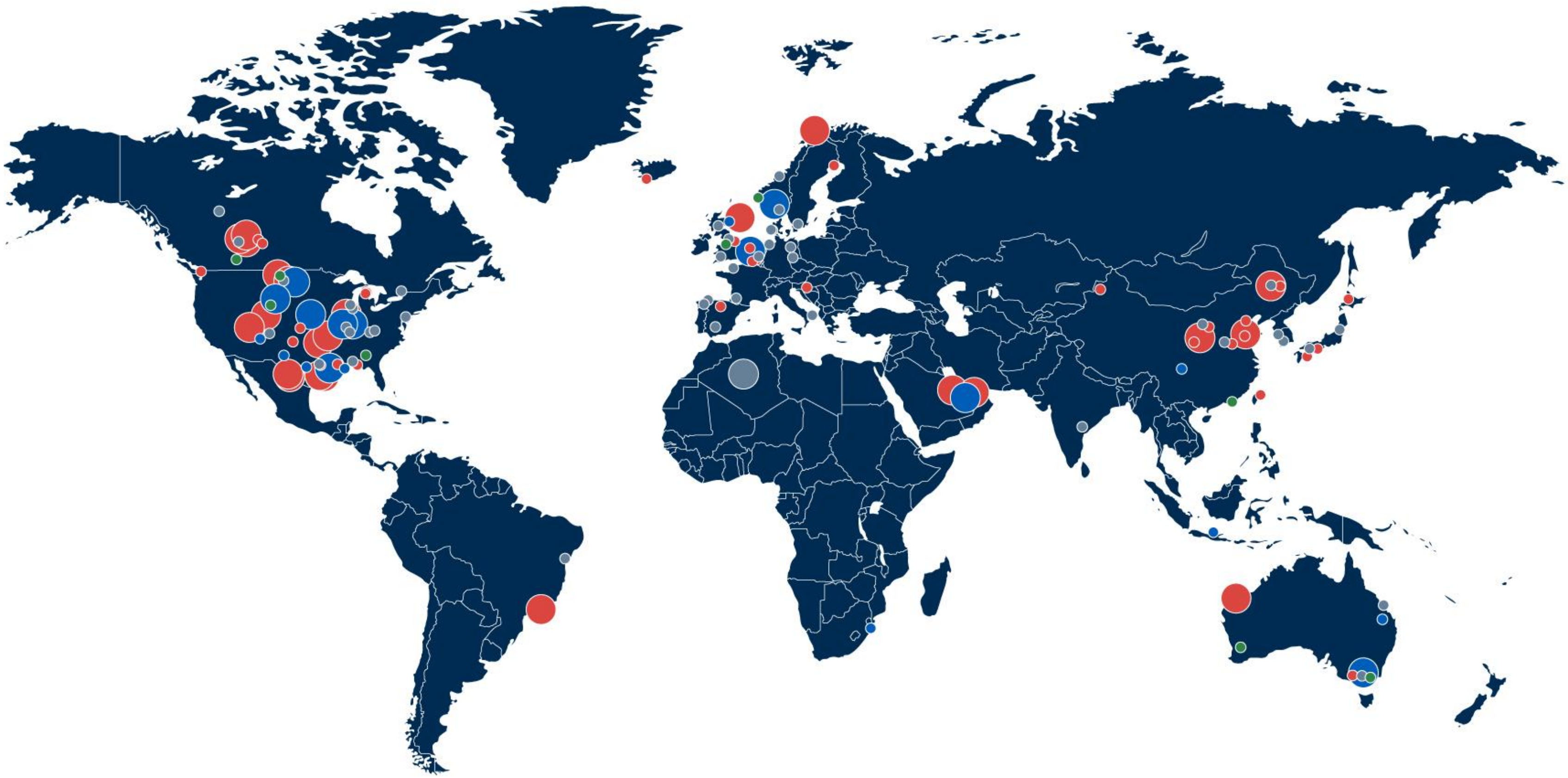
	OPERATING	IN CONSTRUCTION	IN DEVELOPMENT
April 2019	18	5	20
	+1	-1	+8
Current	19	4	28

Facilities added

- ABU DHABI CCS PHASE 2 (I)
- CLEAN GAS PROJECT (P)
- WABASH (I)
- OXY/WHITE ENERGY ETHANOL (BF)
- PROJECT TUNDRA (P)
- DRY FORK (P,S)
- CARBONSAFE ILLINOIS (P,S)
- OXY/CARBON ENGINEERING DAC (S)
- INTEGRATED MID-CONTINENT (S)
- ECO2S (S)

GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

CCS FACILITIES – 2019



LARGE SCALE CCS FACILITIES IN OPERATION & CONSTRUCTION

LARGE SCALE CCS FACILITIES IN ADVANCED DEVELOPMENT

LARGE SCALE CCS FACILITIES COMPLETED

LARGE SCALE = >400,000 TONNES OF CO_2 CAPTURED PER ANNUM

PILOT & DEMOSTRATION SCALE FACILITY IN OPERATION & CONSTRUCTION

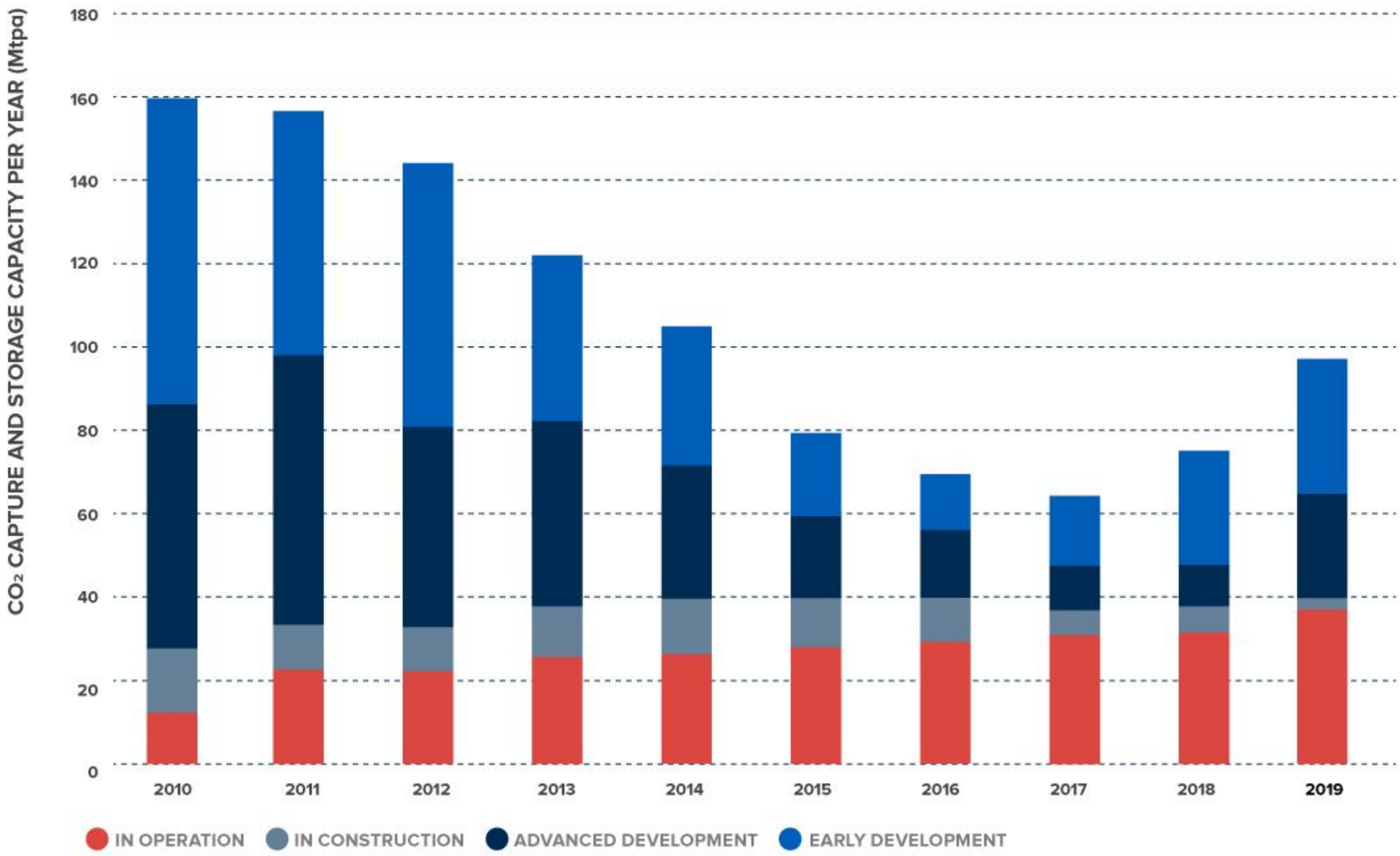
PILOT & DEMOSTRATION SCALE FACILITY IN ADVANCED DEVELOPMENT

PILOT & DEMOSTRATION SCALE FACILITY COMPLETED

TEST CENTRE

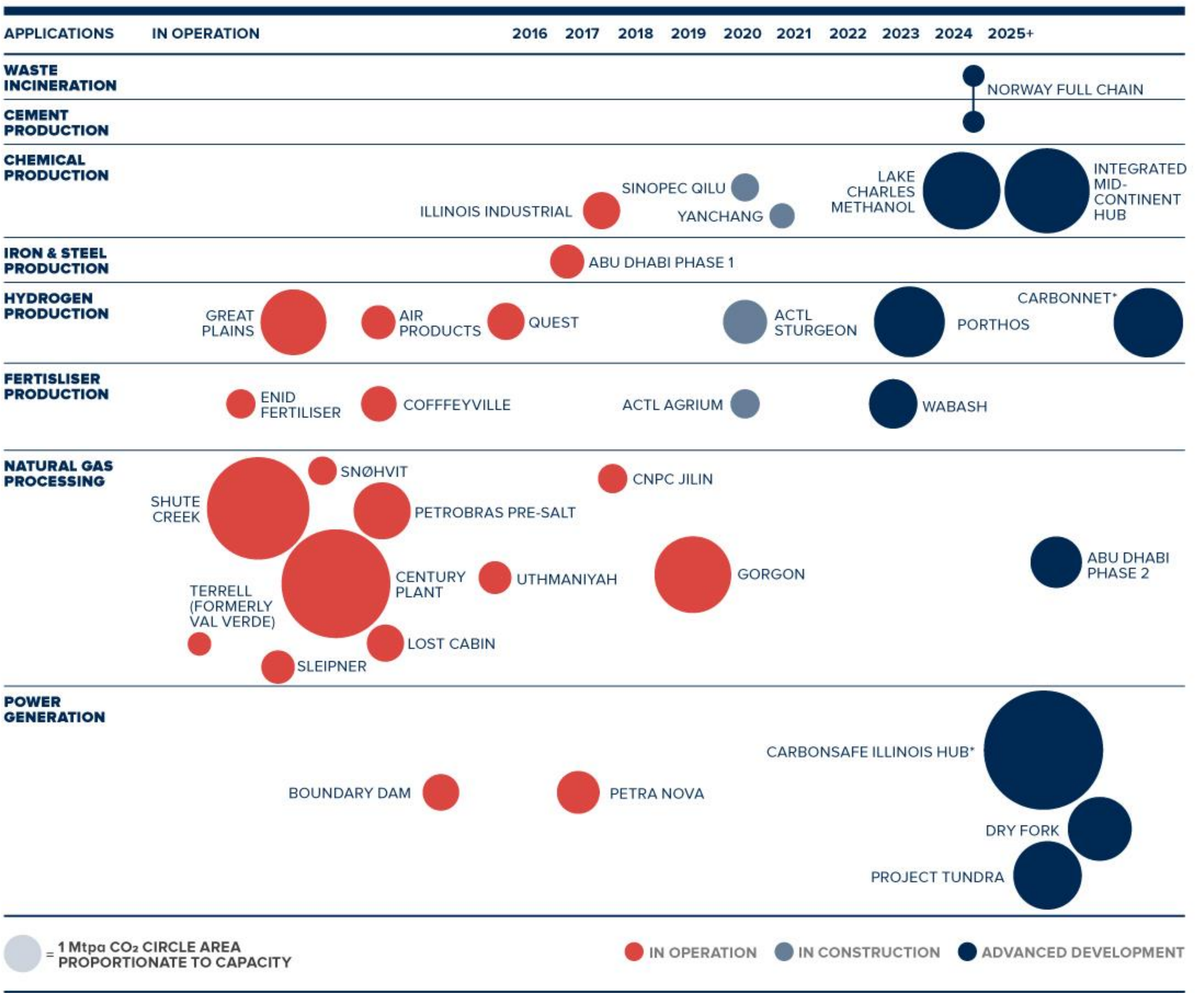
GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

CCS DEVELOPMENT/DEPLOYMENT ON UPSWING



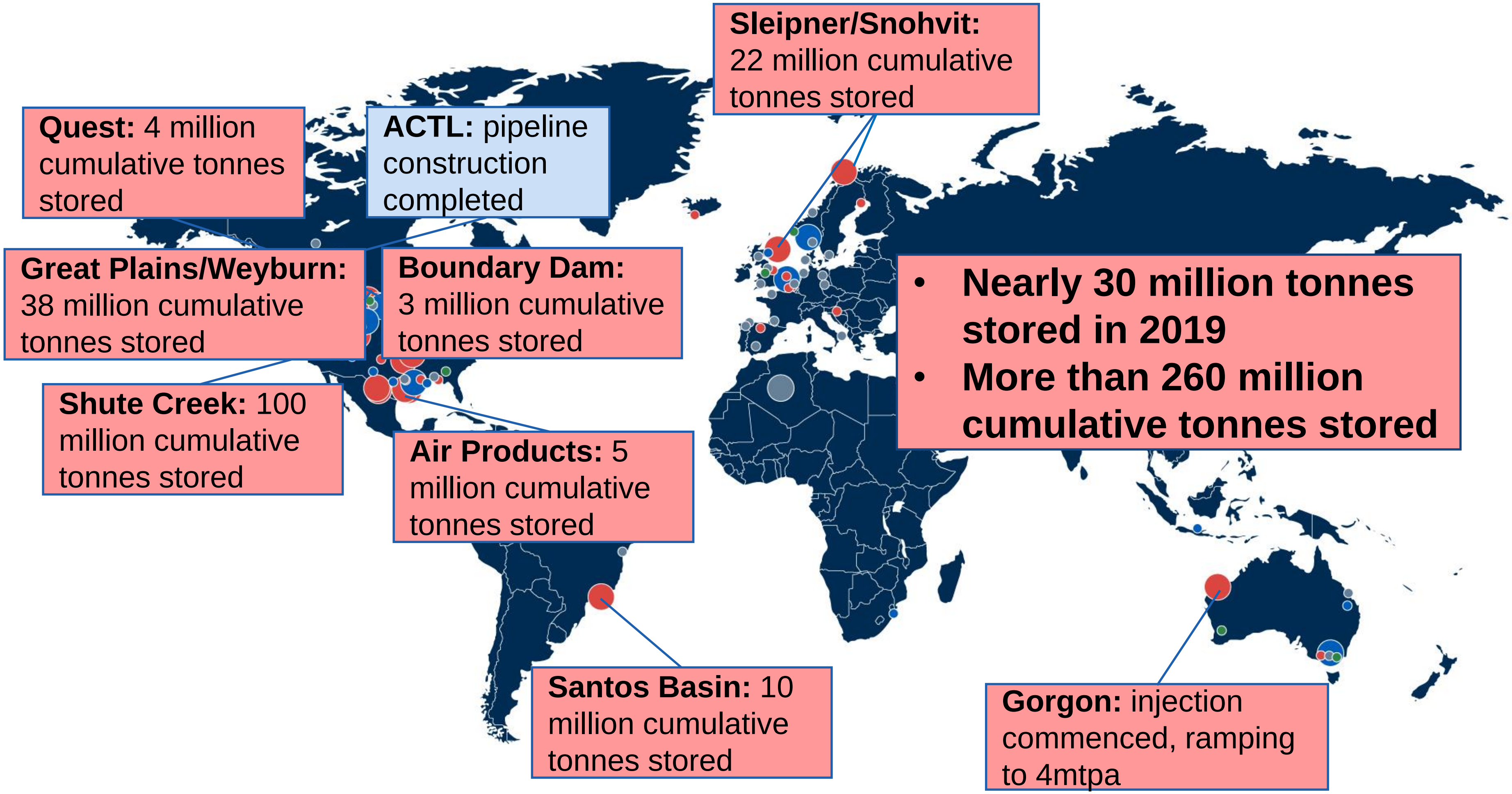
GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

LARGE-SCALE CCS FACILITIES, BY SECTOR



GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

2019 MILESTONES



LARGE SCALE CCS FACILITIES IN OPERATION & CONSTRUCTION

LARGE SCALE CCS FACILITIES IN ADVANCED DEVELOPMENT

LARGE SCALE CCS FACILITIES COMPLETED

LARGE SCALE = >400,000 TONNES OF CO_2 CAPTURED PER ANNUM

PILOT & DEMOSTRATION SCALE FACILITY IN OPERATION & CONSTRUCTION

PILOT & DEMOSTRATION SCALE FACILITY IN ADVANCED DEVELOPMENT

PILOT & DEMOSTRATION SCALE FACILITY COMPLETED

TEST CENTRE

GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

AMERICAS

CCS FACILITIES IN THE AMERICAS

This region is home to **13 of the world's 19 large-scale operating CCS facilities.**

ACTIVE STATES

In the US, states that are active in CCS incentives and progression are: **California, Montana, Texas, North Dakota, Louisiana and Wyoming.**

CO_2 CAPTURE

These facilities combined capture **29.9 Million tonnes per annum (Mtpa) of CO_2.**

CO_2 29.9 Mtpa

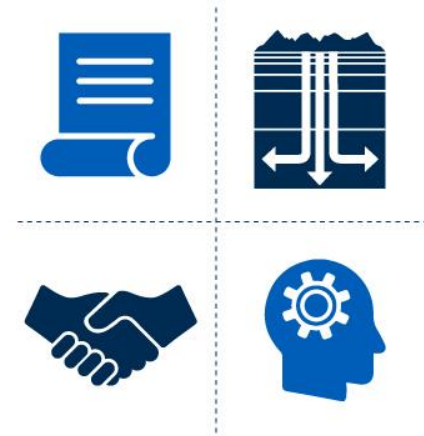
NEW WAVE OF FACILITIES

In 2019 the Global CCS Institute added 8 new large-scale facilities in the Americas to our database.

8 NEW FACILITES

ADVANCING CCS

In this region, CCS deployment is supported by **strong policy frameworks, abundant geological storage, diverse stakeholder support and a wealth of private-sector experience**



REGIONAL DEVELOPMENTS

Clean Energy Ministerial held in Canada 2019. Canada invested $25 million in Direct Air Capture (DAC).

$25M INVESTED

Brazil stored >3 Mtpa CO_2. Stakeholder interest in advancing CCS use; in coal, natural gas power plants, ethanol sector.

>3 Mtpa CO_2

World Bank CCS Trust Fund funding **two CCS pilot projects in Mexico**; expected to proceed in **early 2020.**

US EMISSIONS PROFILE AND THE POTENTIAL FOR CCS TO MAKE A DIFFERENCE...

Power sector accounts for **28% of the US's greenhouse gas emissions.** In 2019, the Institute added three power plant retrofits to our Institute database. When operational will capture up to a further **10.3 Mtpa of CO_2.**

10.3 $MtCO_2$

ADDED CAPTURE CAPACITY FROM COAL RETROFIT

KEY US POLICY

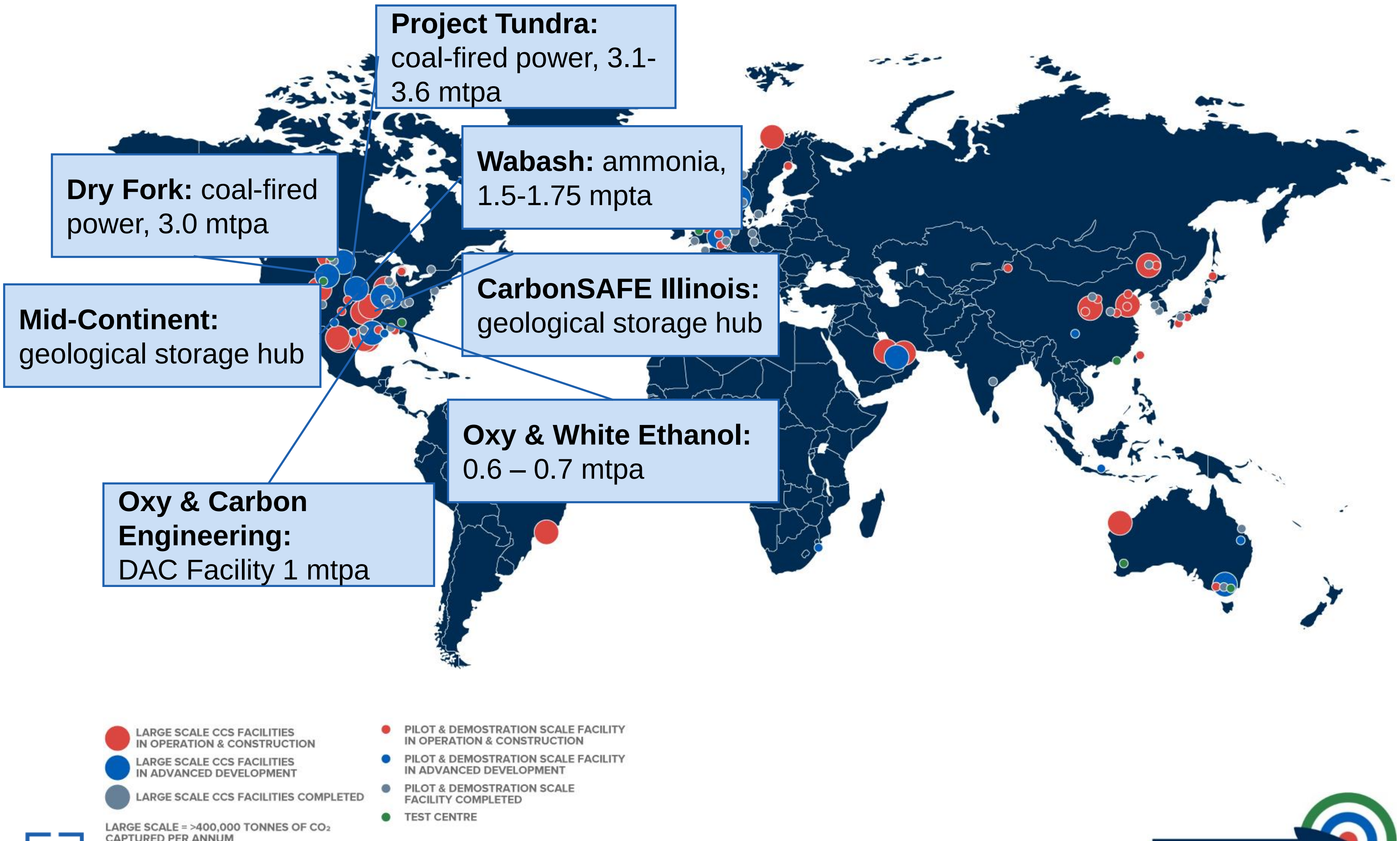
Section 45Q of the Internal Revenue Code **establishes tax credits for storage of CO_2.**

Several CCS supportive bills were introduced in 2019 including the USE IT Act.

California's LCFS is a credit-based trading mechanism applies to CCS projects that lower the emissions intensity of fuels in the California market.

CO_2 STORAGE TAX CREDITS

POLICY PRESENCE LEADS TO PROJECT DEPLOYMENT



GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

EUROPE

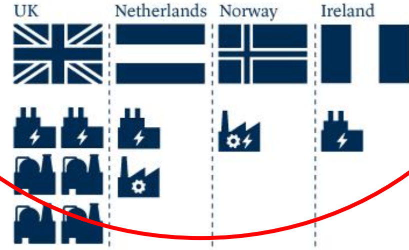
CCS FACILITIES IN EUROPE

2 large scale CCS facilities in operation in Norway, capturing and storing **1.7 million tonnes per annum of CO_2.**

1.7 Mtpa of CO_2

10 large scale CCS facilities in various stages of development (6 in the UK, 2 in the Netherlands, 1 in Norway, 1 Ireland). When operational, these facilities will capture:

20.8 Mtpa of CO_2



CCS facilities in operation and development across **cement, power generation, waste-to-energy and hydrogen production.**

FINANCE

The Innovation Fund; **largest fund available for financing CCS in Europe – 10 billion euros** are hoped to be made available**

€10B

POLICY

CCS is one of the seven building blocks in the European Commission's vision for a climate **neutral Europe by 2050.**

CCS contribution in strategy ranges from **52 to 606 $MtCO_2$ per year in 2050**— a strong case for CCS in supporting Europe's path to a climate neutral economy.

HUBS AND CLUSTERS

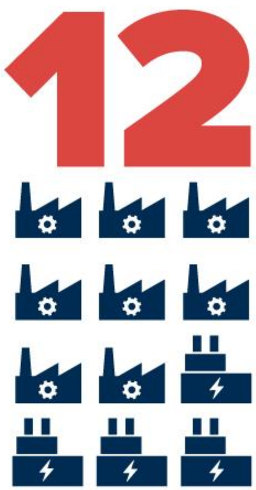
Most CCS projects in Europe are now planned as hubs and clusters.

Capturing CO_2 from clusters of industrial installations, instead of single sources, and using **shared infrastructure** for the **subsequent CO_2 transportation and storage network,** will **drive down unit costs across the CCS value chain.**

ASIA PACIFIC

CCS

Region has **12 large-scale facilities either operating or in various stages of development.**

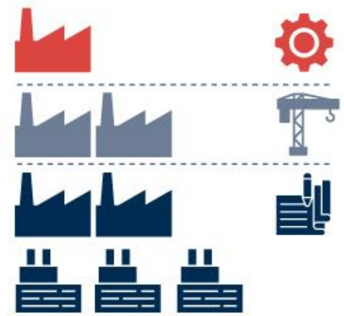


CHINA

China contributes almost one third of the world's CO_2 emissions.

China leads CCS activity across the Asia Pacific.

1 large-scale facility in operation, 2 in construction and 5 in early development.



In 2017, Asia Pacific region was responsible for **72 per cent of the world's coal consumption.**

EMISSIONS PROFILE

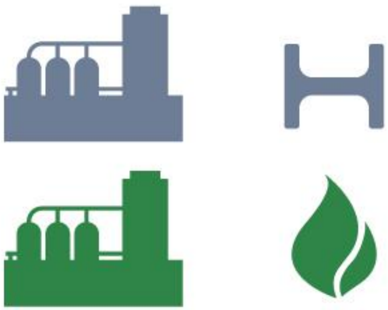
Asia Pacific region is the source of just over **50% of the world's total CO_2 emissions** which is driven by fossil fuel reliance.

Currently 352 GW of coal fired power plants under construction or in planning.

Led by China and India, Asia Pacific economies also produce **more than half of the world's most emissions-intense products**, such as steel and cement.

CENTRAL ASIA AND MIDDLE EAST

2 **large scale CCS facilities** in operation:
1 in **iron and steel production** and
1 in **natural gas processing**



OVERVIEW

Capturing **1.6 Mtpa** of CO_2

Region has **vast and accessible underground storage potential of 5-30 Gigatonnes***

HYDROGEN OPPORTUNITY

Low carbon hydrogen production, from natural gas with CCS, in the Middle East is estimated to cost only **USD1.50/kg**

POLICY AND CCS MOVEMENT

Saudi Arabia and the United Arab Emirates both members of **Mission Innovation and the Clean Energy Ministerial.**

Both countries have committed to **doubling public investment in clean energy research and development** and are participating in the **Clean Energy Ministerial's CCUS initiative.**

CENTRAL ASIA

Rapidly increasing energy demands being driven by **growing population, rising living standards and urbanisation** that is largely met by fossil fuels.

LOOKING AHEAD

- Natural Gas
- Hydrogen
- Power Sector
- BECCS
- Direct Air Capture (DAC)
- CO2 Utilization
- CCS Innovation
- Industry Transition to Net-Zero

GLOBAL STATUS OF CCS 2019 TARGETING CLIMATE CHANGE

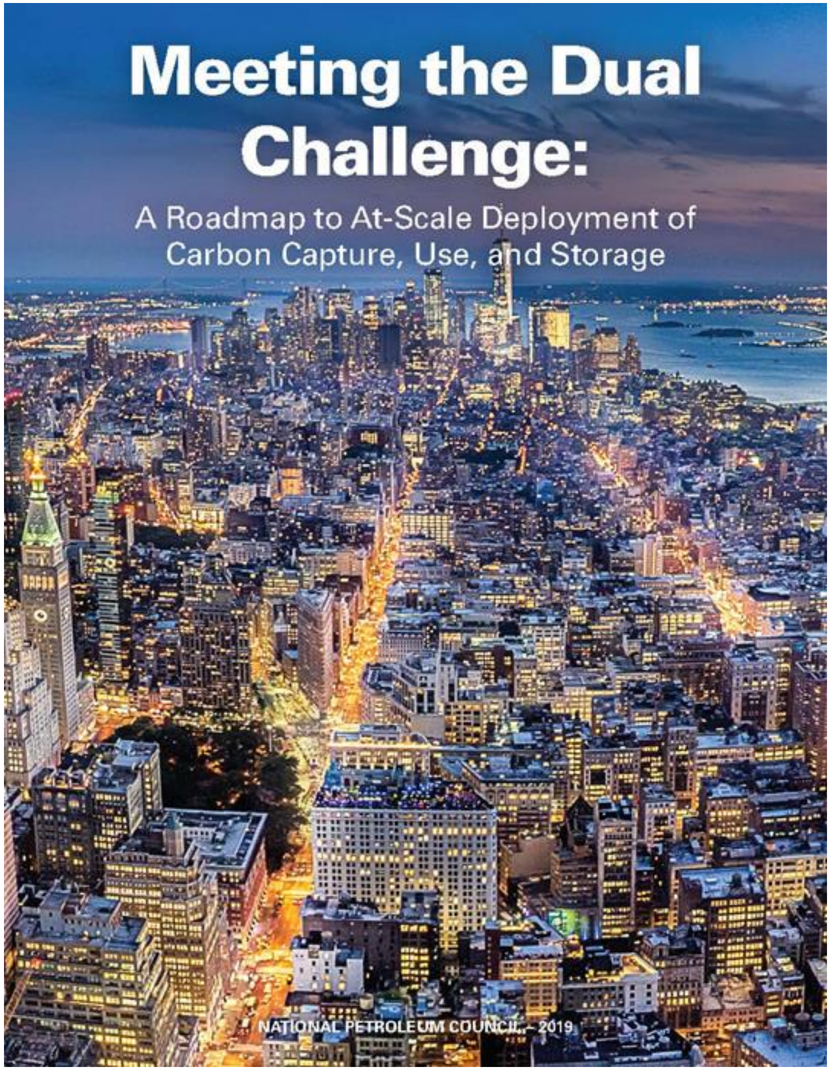
National Petroleum Council

Meeting the Dual Challenge:
A Roadmap to At-Scale Deployment of Carbon Capture, Use, and Storage

www.dualchallenge.npc.org

NARUC Staff Subcommittee on
Clean Coal
February 9, 2020

Jan W. Mares, Resources for the Future
On behalf of the National Petroleum Council



What is the National Petroleum Council (NPC)

Origins	Continuation of WWI government / industry cooperation
Purpose	Sole purpose is to advise U.S. Secretary of Energy and Executive Branch by conducting studies at their request
Organization	A federally chartered, self-funded Advisory Committee; not an advocacy group, does not lobby
Membership	Broad and balanced. Approximately 200 members from all segments of the oil and gas industries and many outside interests
Study Participants	Diverse interests and expertise relating to the topic being addressed
Study Reports	All NPC advice is provided in reports approved by its members and is available to the public. Reports can be viewed and downloaded at not cost from the NPC website – www.npc.org

In September 2017

The Secretary of Energy requested the NPC conduct a study

- Define the potential pathways for integrating CCUS at scale into the energy and industrial marketplace.
- The Secretary asked the Council to consider:
  - Technology options and readiness
  - Market dynamics, economics and financing
  - Cross-industry integration and infrastructure
  - Policy, legal and regulatory issues
  - Environmental footprint
  - Public acceptance

The request asked five key questions

1. What are **U.S. and global future energy demand outlooks**, and the environmental benefits from the application of CCUS technologies?

2. What **R&D, technology, infrastructure, and economic barriers** must be overcome to deploy CCUS at scale?

3. How should **success be defined**?

4. What actions can be taken to **establish a framework that guides public policy and stimulates private-sector investment** to advance the deployment of CCUS?

5. What **regulatory, legal, liability or other issues should be addressed** to progress CCUS investment and to enable the U.S. to be global technology leaders?

CCUS deployment at scale

Will mean:

- Moving from 25 to **500 Million tonnes per annum** of CCUS capacity over 25 years
- Infrastructure buildout equivalent of **13 million barrels per day** capacity
- Incremental investment of **$680 billion**
- Support for **236,000 U.S. jobs** and **GDP of $21 billion** annually

Will require:

- Improved **policies**, **incentives**, **regulations** and **legislation**
- Broad-based **innovation** and **technology** development
- Strong **collaboration** between **industry** and **government**
- Increased **understanding** and **confidence** in CCUS

Study Organization

National Petroleum Council (NPC)

Study Committee
~60 members representing various industries, academia, NGOs, e-NGOs

Steering Committee
12 member committee chaired by BP America and US Department of Energy

Coordinating Subcommittee

Chair: Cindy Yeilding (BP)
Deputy Chair Nigel Jenvey (G-C)

Leslie Savage (RCTx)
Bill Elliott (Bechtel)
Brian Donovan (VLO)
Bob Perciasepe (C2ES)
Pierre Germain (Total)

Jan Mares (RFF)
JF Poupeau (SLB)
Roxann Walsh (SO)
Guy Powell (XoM)

Tim Wiwchar (Shell)
Brian Chase (Chevron)
Fiji George (Cheniere)
John Gunn (XoM)

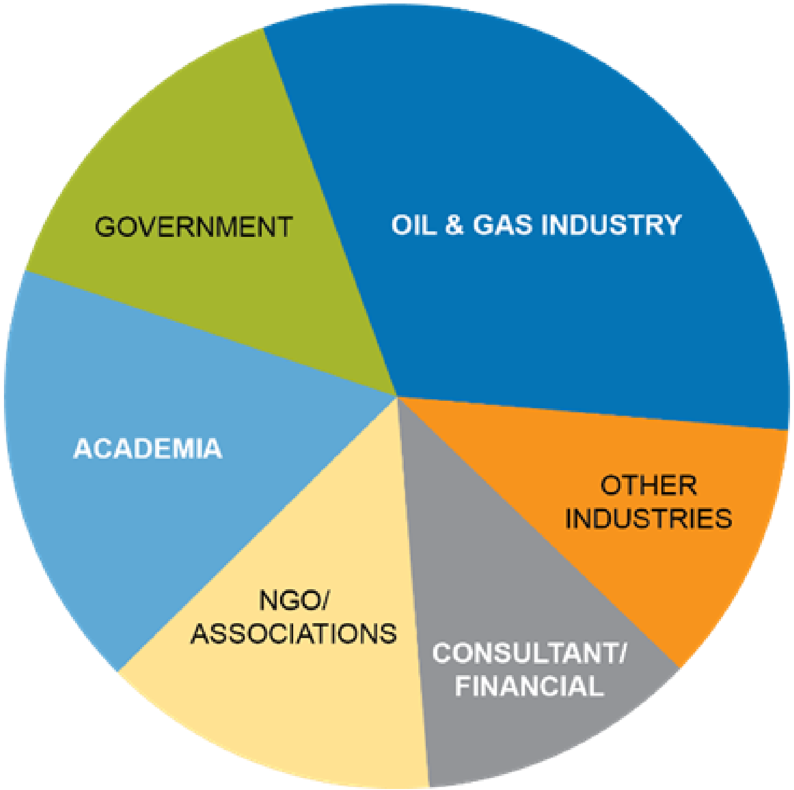
Scott Anderson (EDF)
Jody Elliott (OXY)
Jeffrey Brown (BBE&E)
Steiner Eikass (Equinor)
Jason Bordoff (Columbia)

Cochair: Steve Winberg (DOE)
Deputy Chair Jarad Daniels (DOE)

- Energy & Emissions Landscape Task Group
- CCUS Technologies Task Group
- Enabling Factors for Deployment Task Group
- Roadmap to Deployment Team
- Integrative Economics Team

Participation

- Over two-thirds of study participants came from outside the oil and gas industry.
- The Coordinating Subcommittee membership of 22 individuals represented upstream and downstream oil & gas, LNG, biofuels, power, EPC, NGO, and state and federal governments.
- Overall study team included over 300 participants from more than 110 different organizations and included 17 international members.



Report structure

Report Summary (Volume I)

- Transmittal letter
- Report outline
- Preface
- Executive Summary, Roadmap and Recommendations

Appendices

A. Request Letter and NPC Description
B. Study Group Rosters

Description of Web-only materials

Analysis of CCUS Deployment At-Scale (Volume II)

- **Chapter 1:** The Role of CCUS in Future Energy Mix
- **Chapter 2:** CCUS Supply Chains & Economics
- **Chapter 3:** Policy, Regulatory & Legal Enablers
- **Chapter 4:** Stakeholder Engagement

Appendices

C. CCUS Project Summaries
D. Integrated Economic Analysis

Abbreviations & Acronyms

Analysis of CCUS Technologies (Volume III)

- **Technology Introduction**
- **Chapter 5:** CO_2 Capture
- **Chapter 6:** CO_2 Transport
- **Chapter 7:** CO_2 Geologic Storage
- **Chapter 8:** Enhanced Oil Recovery
- **Chapter 9:** CO_2 Use

Appendices

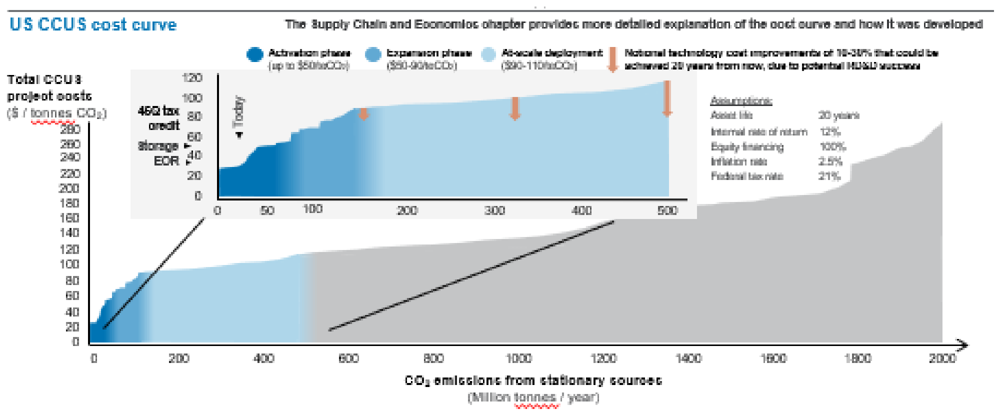
E. Mature CO_2 Capture Technologies
F. Emerging CO_2 Capture Technologies
G. CO_2 EOR Case Studies
H. CO_2 EOR Economic Factors and Considerations

Abbreviations & Acronyms

Roadmap for CCUS deployment

- The letter from the Secretary included a request for a roadmap of actions needed to drive widespread deployment of CCUS in the U.S. over the next 25 years

- To develop the roadmap, a CCUS cost curve was developed:
  - Assessed the current costs to capture, transport and store the largest 80% of U.S. stationary source CO_2 emissions – source, industry, and location specific and curve uses transparent assumptions
  - Plotted the cost to capture, store and transport one tonne of CO_2 from specific sources against the volume of CO_2 abatement possible – identifies the level of value (incentives, revenue, etc.) needed to enable deployment.



- The roadmap details recommendations in four pathways – financial incentives, regulatory frameworks, technology and capability, and stakeholder engagement and across three phases – activation, expansion and at-scale, designed to achieve widespread deployment.

Findings 1- 4

1. As global economies and populations continue to grow and prosper, the world faces the dual challenge to provide affordable, reliable energy while addressing the risks of climate change.

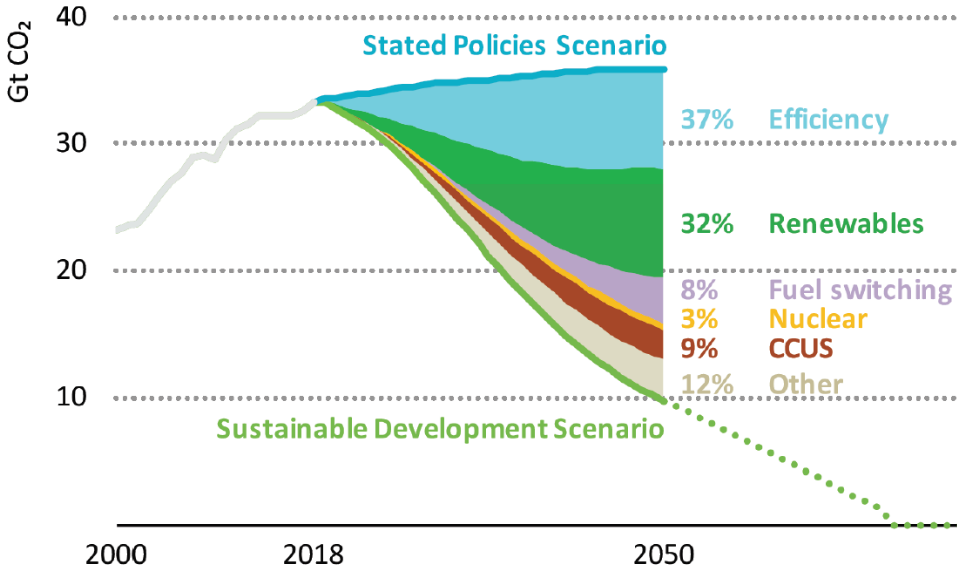
2. Widespread CCUS deployment is essential to meeting the dual challenge at the lowest cost.

3. Increasing deployment of CCUS can deliver benefits and favorably position the United States to participate in new market opportunities as the world transitions to a lower CO_2 intensive energy system.

4. The United States is uniquely positioned as the world leader in CCUS and has substantial capability to drive widespread deployment.

CCUS is a critical element of a clean energy portfolio

IEA analysis demonstrates the critical role of CCUS in a clean energy technology portfolio (IEA, 2019)



"Carbon capture, use and storage holds enormous potential to enable economic growth and create jobs, while ensuring the environment is protected."

-- Jim Carr, Canada's Minister of Natural Resources, June 6, 2017

"Without CCUS as part of the solution, reaching our climate goals is almost impossible."

-- Fatih Birol, Executive Director of IEA, Twitter on Nov 26, 2018

"CCUS is a critical part of a complete clean energy technology portfolio that provides a sustainable path for mitigating greenhouse gas emissions while ensuring energy security."

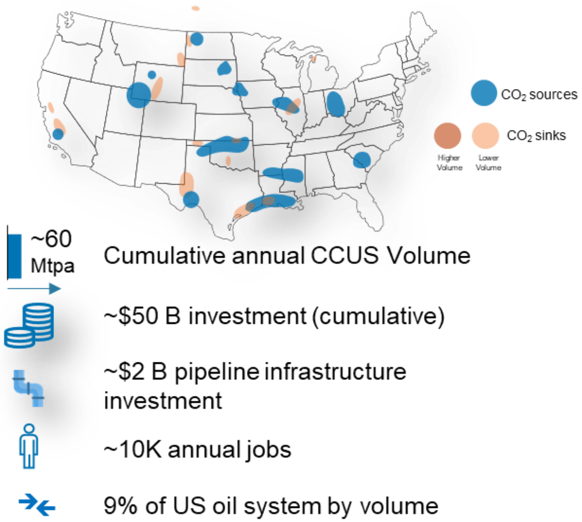
-- International Energy Agency, June 7, 2017

Finding 5: activation

5. Clarifying existing tax policy and regulations could activate an additional 25 to 40 million tons per annum (Mtpa) of CCUS, doubling existing U.S. capacity within the next 5 to 7 years. (No congressional action required)

<u>Recommendations</u>

- IRS to clarify Section 45Q requirements for transferability, secure geologic storage, construction start date, and credit recapture
- DOI and states to establish a process for access to and use of pore space for geologic storage on federal and state lands
- EPA should issue a Class VI permit to drill within six months
- EPA, upon receipt of a completed well report, should review and make any necessary modifications, and issue a Class VI permit to inject within six months
- EPA to undertake planned periodic review of Class VI regulations to align with site-specific risk and performance-based approach



* note: 35mtpa is likely overstated based on current 12 year life of 45Q tax credit – the increase to 20 years does not come until Expansion phase

Finding 6: expansion

6. Extending and expanding current policies and developing a durable legal and regulatory framework could enable the next phase of CCUS projects (an additional 75-85 Mtpa) within the next 15 years.

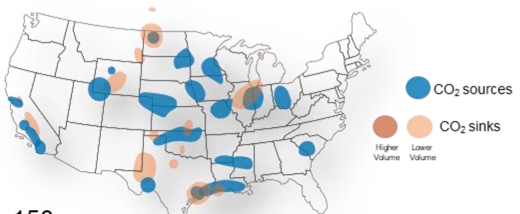
Recommendations

Congress to:

- Amend 45Q to extend construction start date to 2030, increase duration to 20 years, lower volume threshold, and increase credit for saline storage and use
- Expand access to Section 48 tax credits for all projects
- Expand access to MLPs, private activity bonds, and TIFIA eligibility/funding for all projects
- Increase EPA and state regulatory funding to support well permitting and timely reviews
- Amend OCSLA and MPRSA to allow geologic storage in federal waters from all CO_2 sources

Agencies to:

- DOE to create CO_2 pipeline working group made up of relevant agencies and stakeholders to harmonize permitting processes, establish tariffs, grant access, administer eminent domain authority, and facilitate corridor planning
- DOE to convene stakeholder forum to develop a risk-based standard to address geologic storage long-term liabilities
- State policymakers adopt regulation for access, ownership, unitization & fair compensation for storage on private lands



~150 Mtpa Cumulative annual CCUS Volume

~$175 B investment (cumulative)

~$9 B pipeline infrastructure investment (cumulative)

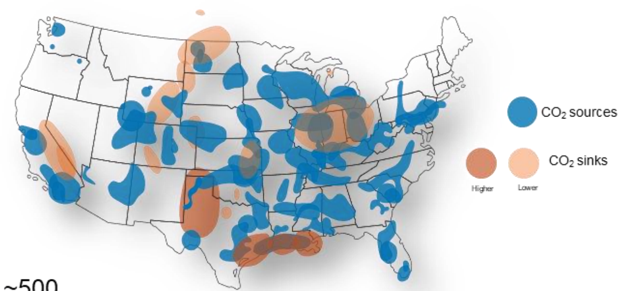
~40K annual jobs (cumulative)

23% of US oil system by volume

Finding 7: at-scale deployment

7. Achieving CCUS deployment at scale, an additional 350-400 Mtpa, in the next 25 years will require substantially increased support driven by national policies.

Recommendation:
To achieve at-scale deployment, congressional action should be taken to implement economic policies amounting to about $110/tonne. The evaluation of those policies should occur concurrently with the expansion phase.



~500 Mtpa — Cumulative annual CCUS Volume

~$680 B investment (cumulative)

~$28 B pipeline infrastructure investment (cumulative)

~230K annual jobs (cumulative)

76% of US oil system by volume

Finding 8: research and development

8. Increased government and private research, development, and demonstration is needed to improve performance, reduce costs, and advance alternatives beyond currently deployed technology.

Recommendation: Congress should appropriate $15 billion of RD&D funding over the next 10 years to enable the continued development of new and emerging CCUS technologies and demonstration of existing technologies.

Technology	R&D (including pilot programs)	Demonstrations	Total	10-Year Total
Capture (including negative emissions technologies)	$500 million/year	$500 million/year	$1.0 billion/year (over 10 years)	$10 billion
Geologic Storage	$400 million/year		$400 million/year (over 10 years)	$4 billion
Nonconventional Storage (including EOR)	$50 million/year		$50 million/year (over 10 years)	$500 million
Use	$50million/year		$50 million/year (over 10 years)	$500 million
Total	**$1.0 billion/year**	**$500 million/year**	**$1.5 billion/year**	**$15 billion**

Findings 9 and 10: public and industry engagement

9. Increasing understanding and confidence in CCUS as a safe and reliable technology is essential for public and policy stakeholder support.

Recommendations:

- Government, industry, and associated coalitions design policy and public engagement opportunities to facilitate open discussion, simplify terminology & build confidence that CCUS is a safe, secure means of managing emissions.
- Oil and natural gas industry remain committed to improving its environmental performance and the continued development of environmental safeguards.

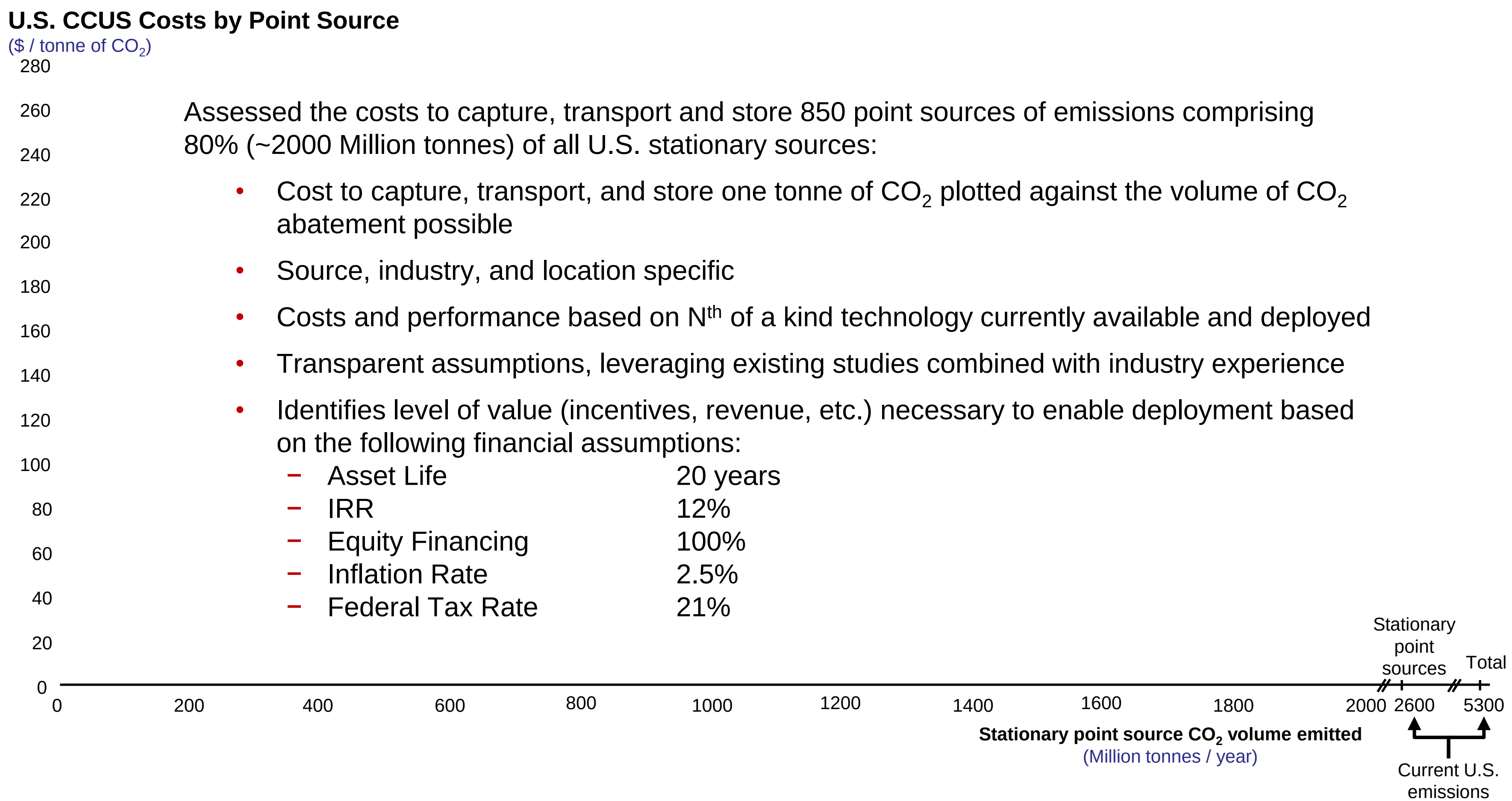
10. The oil and natural gas industry is uniquely positioned to lead CCUS deployment due to its relevant expertise, capability, and resources.

Recommendation:

- The oil and natural gas industry continue investment in CCUS, specifically:
  - Current and next generation capture facilities
  - Development of new technologies
  - CO_2 pipeline infrastructure needed for EOR and saline storage
  - RD&D for advancing CCUS technologies

Key messages

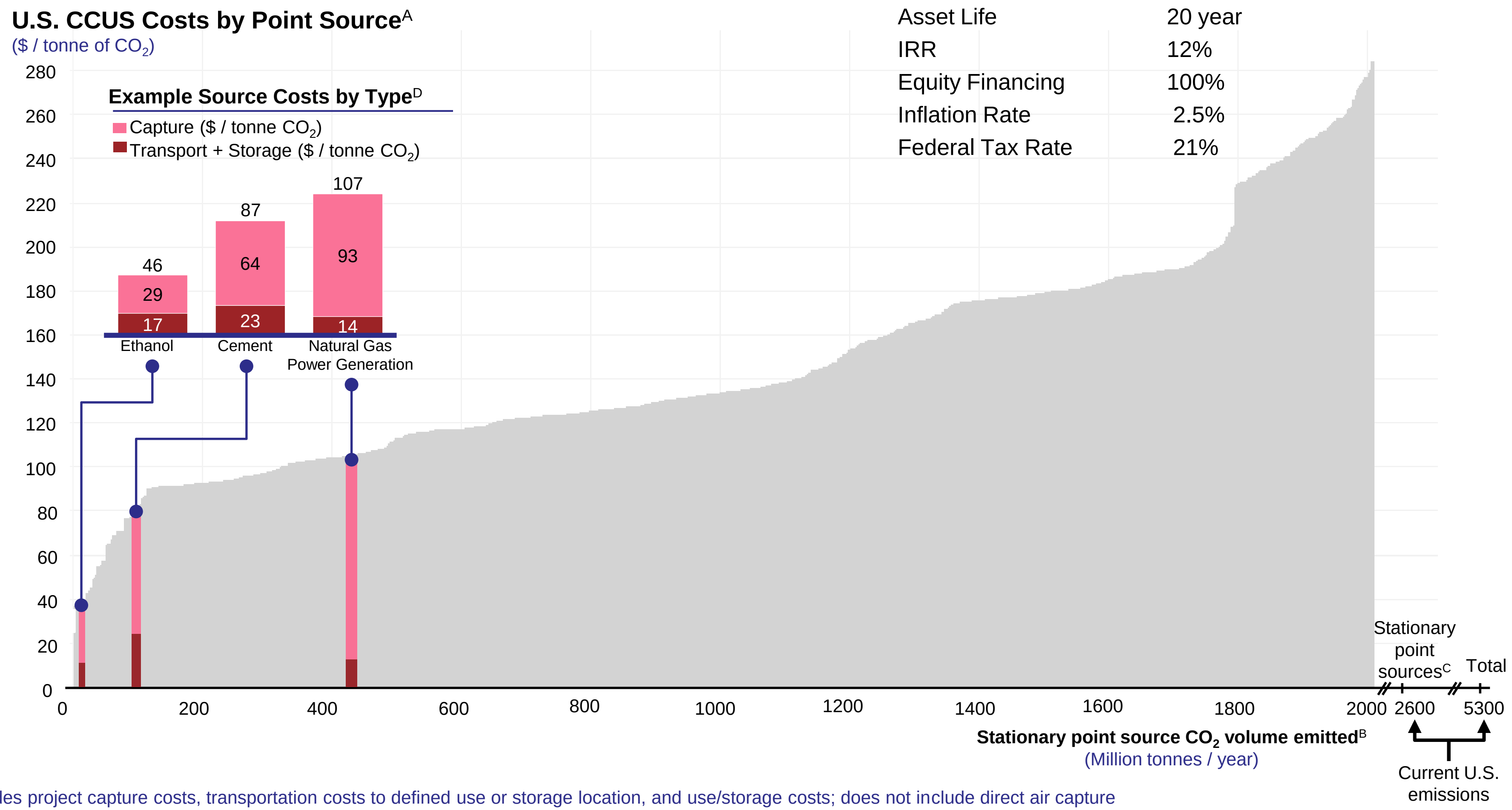
- CCUS refers to the complete supply chain needed to capture, transport and permanently use or store CO_2, eliminating it from the atmosphere.
- All credible future energy scenarios recognize that fossil fuels will remain part of the total energy mix for the next several decades.
- CCUS is essential to addressing the dual challenge of providing affordable, reliable energy to meet the world's growing demand while addressing the risks of climate change.
- The United States is the world leader in CCUS and uniquely positioned to deploy the technologies at scale.
- To achieve CCUS deployment at scale, the U.S. government will need to reduce uncertainty on existing incentives, establish adequate additional financial incentives, and implement a durable regulatory and legal environment that drives industry investment.
- A commitment to CCUS must include a commitment to continued research, development, and demonstration.
- At-scale CCUS deployment will create a new industry, driving job creation and economic growth across the nation.
- Increasing understanding and confidence in CCUS as safe and reliable is essential for public and policy stakeholder support.



Assessed the costs to capture, transport and store 850 point sources of emissions comprising 80% (~2000 Million tonnes) of all U.S. stationary sources:

- Cost to capture, transport, and store one tonne of CO_2 plotted against the volume of CO_2 abatement possible
- Source, industry, and location specific
- Costs and performance based on N^{th} of a kind technology currently available and deployed
- Transparent assumptions, leveraging existing studies combined with industry experience
- Identifies level of value (incentives, revenue, etc.) necessary to enable deployment based on the following financial assumptions:
  - Asset Life 20 years
  - IRR 12%
  - Equity Financing 100%
  - Inflation Rate 2.5%
  - Federal Tax Rate 21%

CCUS cost assessment: methodology



Financial Assumptions

Asset Life	20 year
IRR	12%
Equity Financing	100%
Inflation Rate	2.5%
Federal Tax Rate	21%

A Includes project capture costs, transportation costs to defined use or storage location, and use/storage costs; does not include direct air capture

B This curve is built from bars that each represent an individual point source with a width corresponding to the total CO_2 emitted from that individual source

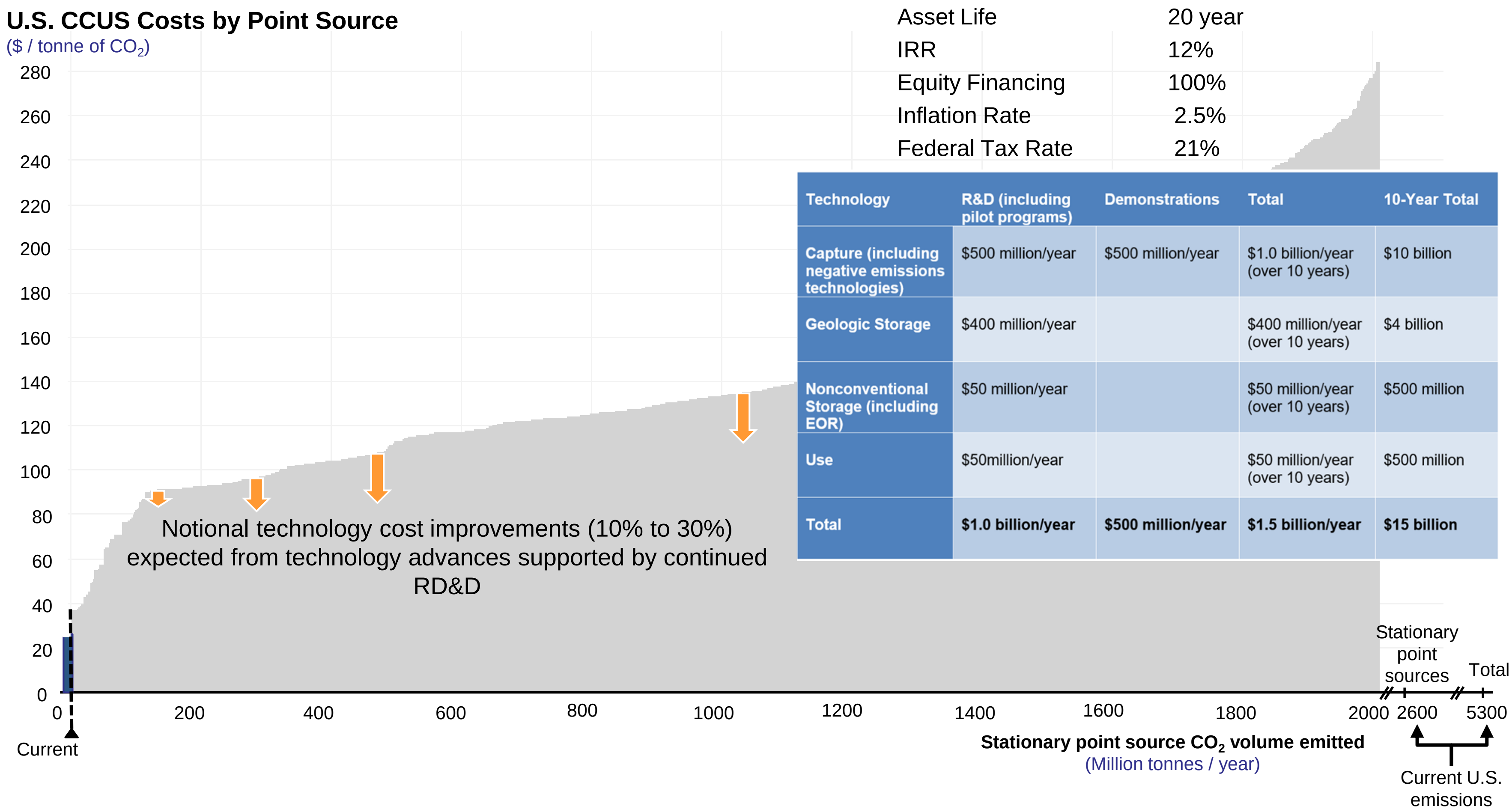
C Total point sources include ~600 MTPA of point sources emissions without characterized CCUS costs

D Widths of bars are illustrative and not indicative of volumes associated with each source

CCUS cost assessment: role of RD&D

Financial Assumptions

Asset Life	20 year
IRR	12%
Equity Financing	100%
Inflation Rate	2.5%
Federal Tax Rate	21%

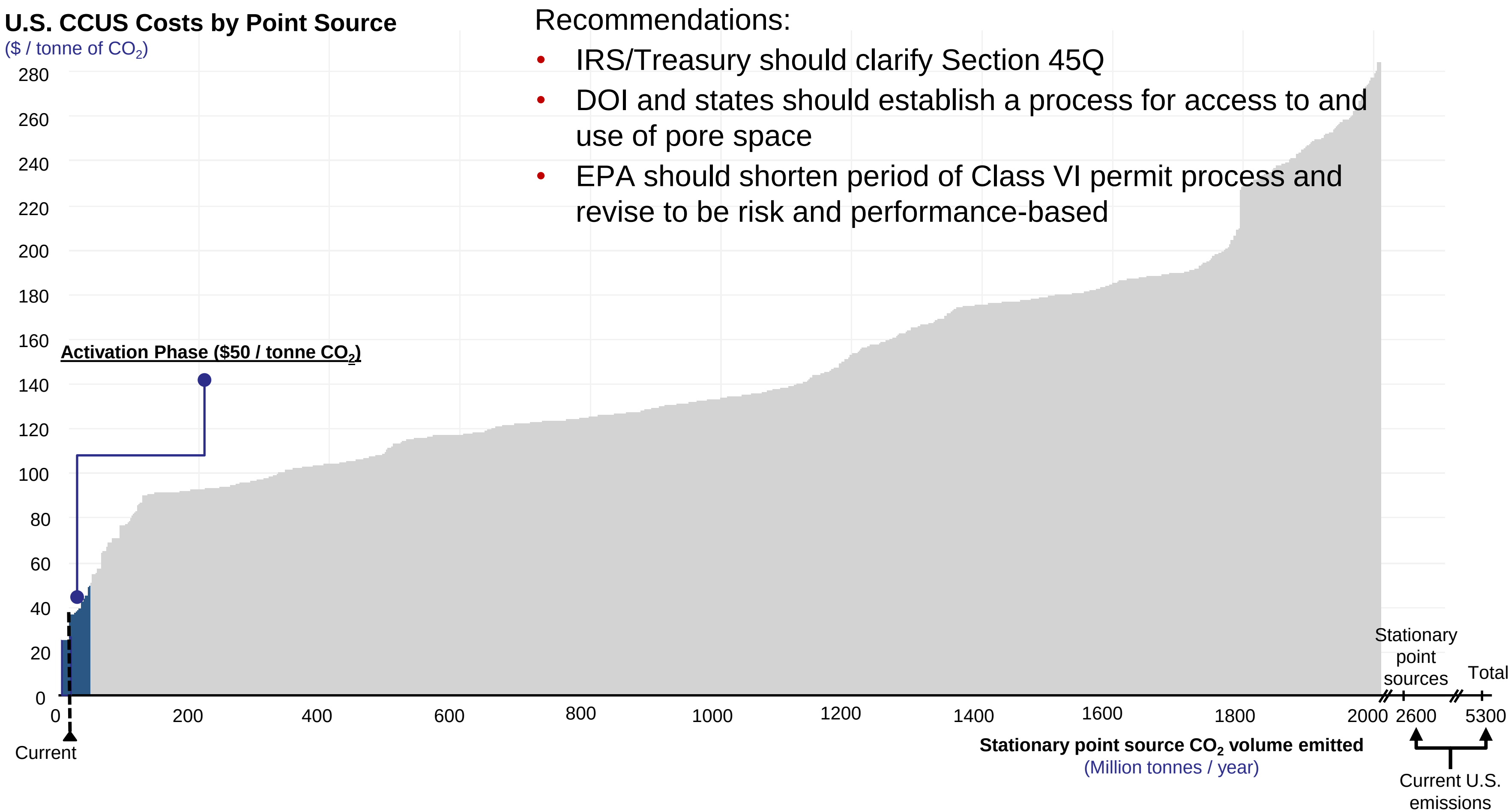


Technology	R&D (including pilot programs)	Demonstrations	Total	10-Year Total
Capture (including negative emissions technologies)	$500 million/year	$500 million/year	$1.0 billion/year (over 10 years)	$10 billion
Geologic Storage	$400 million/year		$400 million/year (over 10 years)	$4 billion
Nonconventional Storage (including EOR)	$50 million/year		$50 million/year (over 10 years)	$500 million
Use	$50million/year		$50 million/year (over 10 years)	$500 million
Total	**$1.0 billion/year**	**$500 million/year**	**$1.5 billion/year**	**$15 billion**

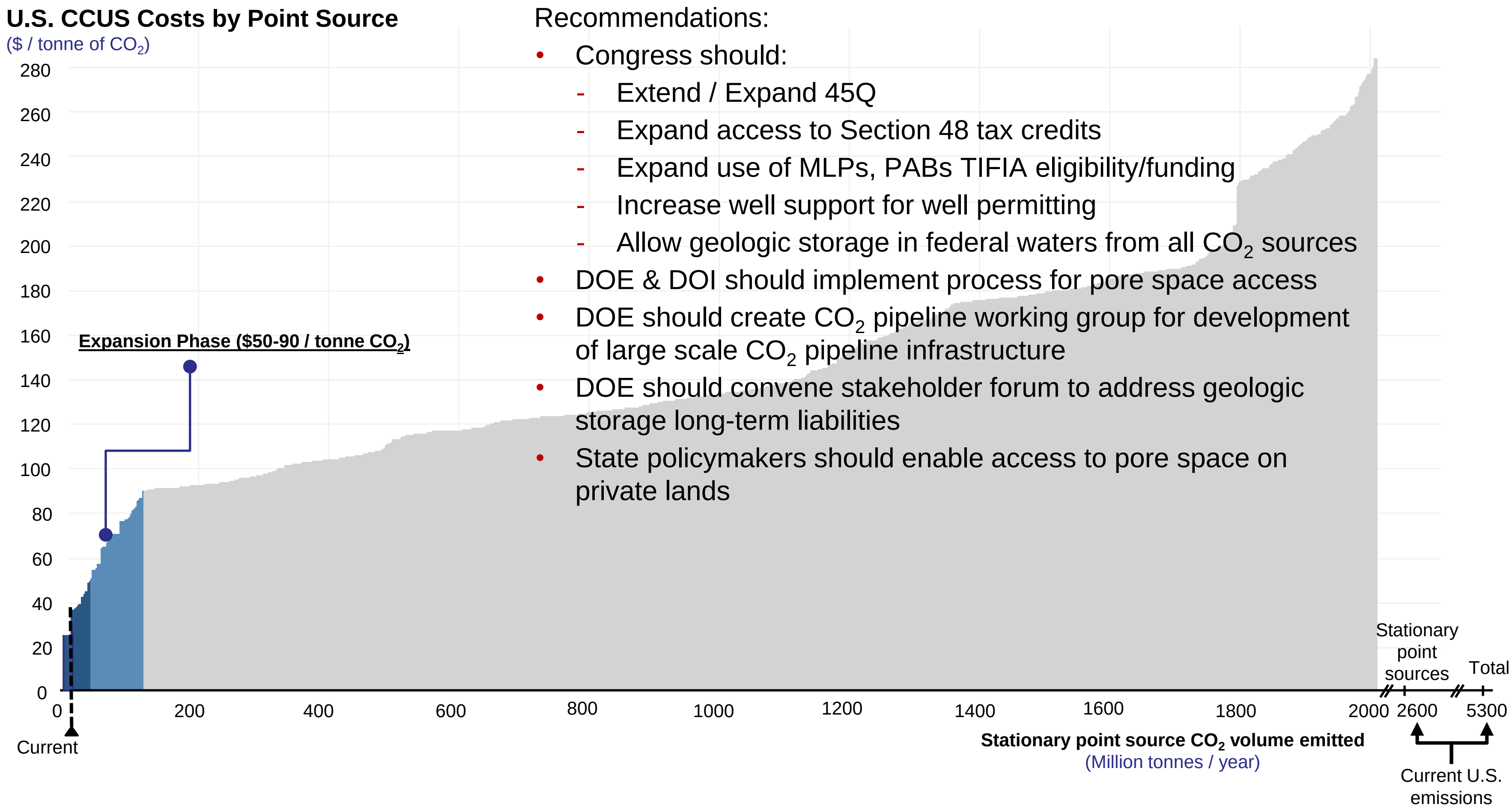
Activation phase

Recommendations:

- IRS/Treasury should clarify Section 45Q
- DOI and states should establish a process for access to and use of pore space
- EPA should shorten period of Class VI permit process and revise to be risk and performance-based



Expansion phase



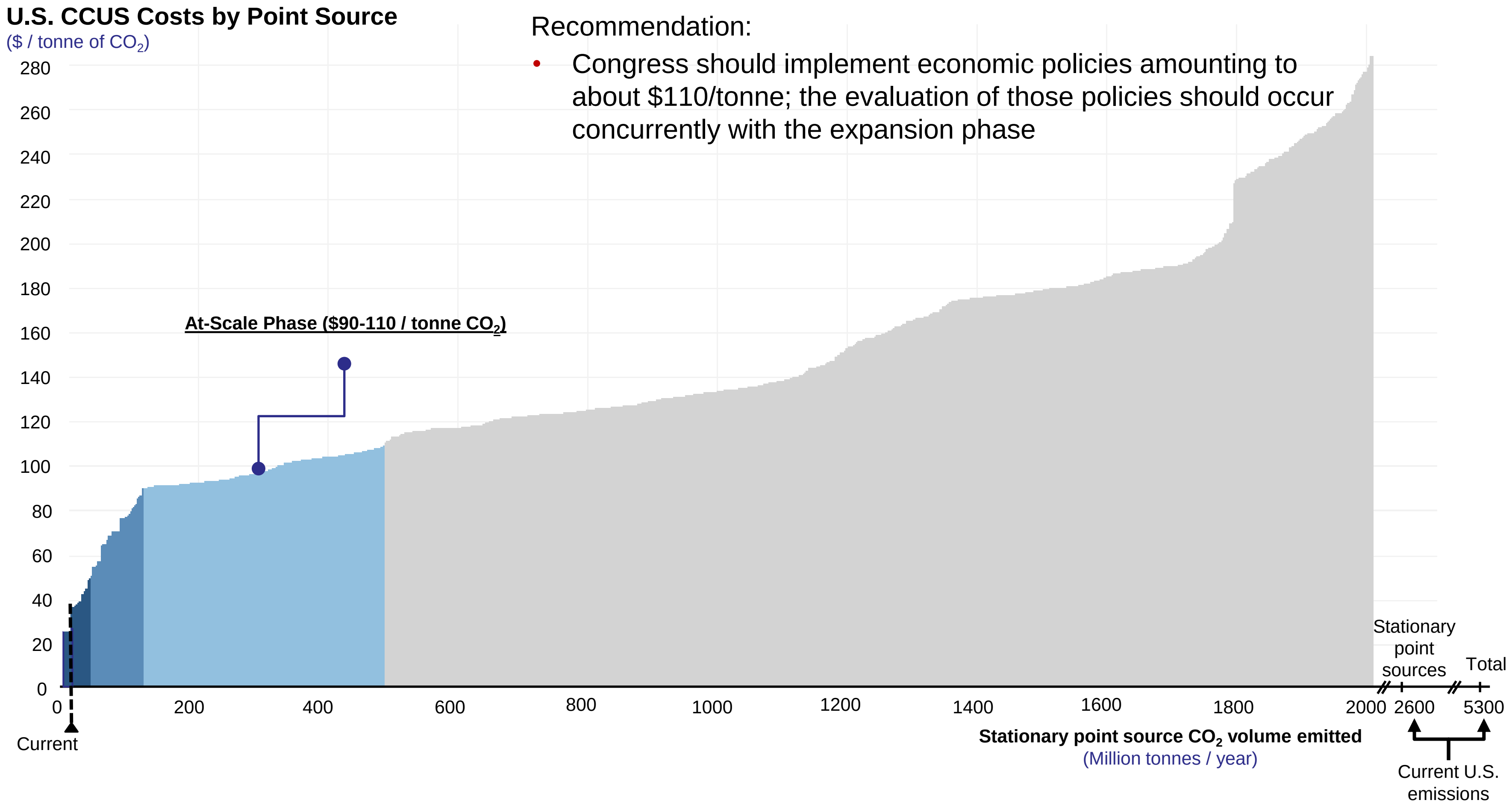
Recommendations:

- Congress should:
  - Extend / Expand 45Q
  - Expand access to Section 48 tax credits
  - Expand use of MLPs, PABs TIFIA eligibility/funding
  - Increase well support for well permitting
  - Allow geologic storage in federal waters from all CO_2 sources
- DOE & DOI should implement process for pore space access
- DOE should create CO_2 pipeline working group for development of large scale CO_2 pipeline infrastructure
- DOE should convene stakeholder forum to address geologic storage long-term liabilities
- State policymakers should enable access to pore space on private lands

At-scale phase

Recommendation:

- Congress should implement economic policies amounting to about \$110/tonne; the evaluation of those policies should occur concurrently with the expansion phase



Acknowledgements

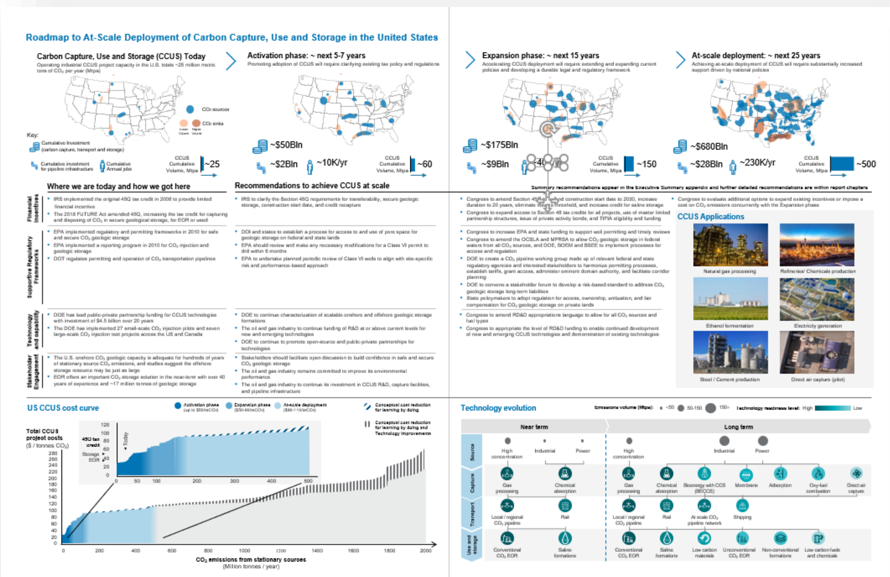
- U.S. Department of Energy
- The National Petroleum Council leadership and staff
- Members of the National Petroleum Council
- The NPC Infrastructure Study leadership and team

… and to the 300+ participants who helped to develop and deliver this comprehensive study on Carbon Capture, Use, and Storage, thank you for your contributions over the last 18 months.

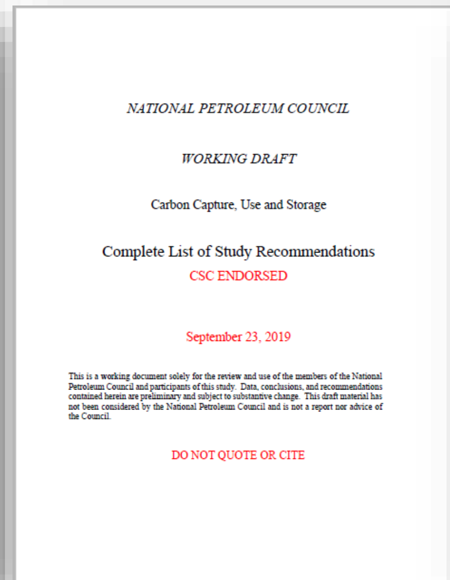
Additional materials

Roadmap and full list of recommendations

Roadmap to At-Scale CCUS Deployment



All Study Recommendations



NATIONAL PETROLEUM COUNCIL

WORKING DRAFT

Carbon Capture, Use and Storage

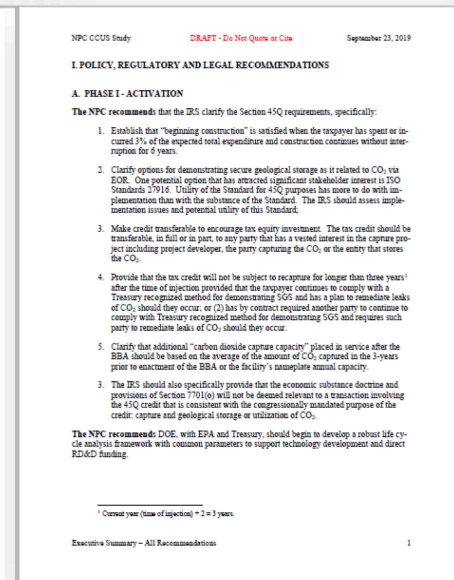
Complete List of Study Recommendations

CSC ENDORSED

September 23, 2019

This is a working document solely for the review and use of the members of the National Petroleum Council and participants of this study. Data, conclusions, and recommendations contained herein are preliminary and subject to substantive change. This draft material has not been considered by the National Petroleum Council and is not a report nor advice of the Council.

DO NOT QUOTE OR CITE



NPC CCUS Study DRAFT - Do Not Quote or Cite September 23, 2019

I. POLICY, REGULATORY AND LEGAL RECOMMENDATIONS

A. PHASE I - ACTIVATION

The NPC recommends that the IRS clarify the Section 45Q requirements, specifically:

1. Establish that "beginning construction" is satisfied when the taxpayer has spent or incurred 3% of the expected total expenditure and construction continues without interruption for 6 years.
2. Clarify options for demonstrating secure geological storage as it related to CO_2 via EOR. One potential option that has attracted significant stakeholder interest is ISO Standards 27916. Utility of the Standard for 45Q purposes has more to do with implementation than with the substance of the Standard. The IRS should assess implementation issues and potential utility of this Standard;
3. Make credit transferable to encourage tax equity investment. The tax credit should be transferable, in full or in part, to any party that has a vested interest in the capture project including project developer, the party capturing the CO_2 or the entity that stores the CO_2.
4. Provide that the tax credit will not be subject to recapture for longer than three years[1] after the time of injection provided that the taxpayer continues to comply with a Treasury recognized method for demonstrating SGS and has a plan to remediate leaks of CO_2 should they occur; or (2) has by contract required another party to continue to comply with Treasury recognized method for demonstrating SGS and requires such party to remediate leaks of CO_2 should they occur.
5. Clarify that additional "carbon dioxide capture capacity" placed in service after the BBA should be based on the average of the amount of CO_2 captured in the 3-years prior to enactment of the BBA or the facility's nameplate annual capacity.
3. The IRS should also specifically provide that the economic substance doctrine and provisions of Section 7701(o) will not be deemed relevant to a transaction involving the 45Q credit that is consistent with the congressionally mandated purpose of the credit: capture and geological storage or utilization of CO_2.

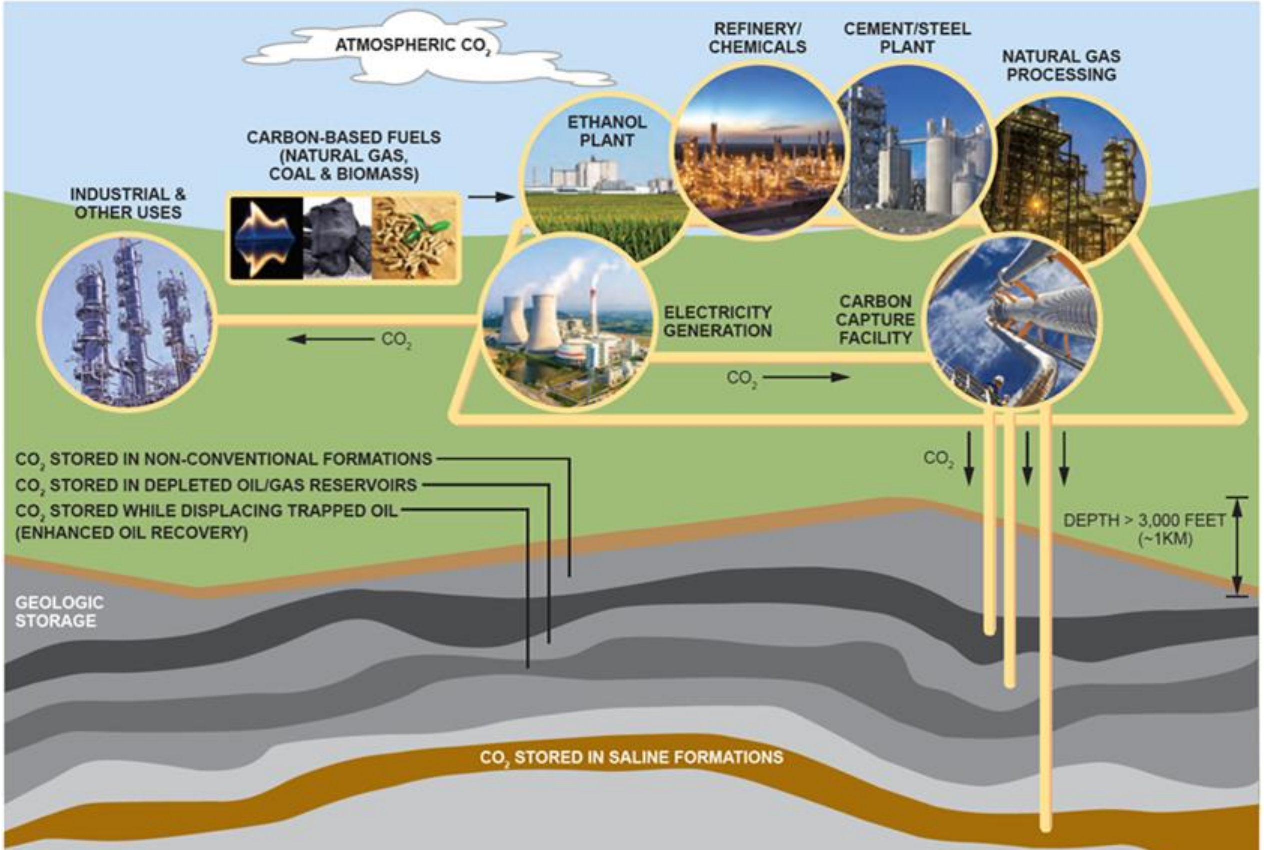
The NPC recommends DOE, with EPA and Treasury, should begin to develop a robust life cycle analysis framework with common parameters to support technology development and direct RD&D funding.

[1] Current year (time of injection) + 2 = 3 years.

Executive Summary – All Recommendations 1

The CCUS supply chain

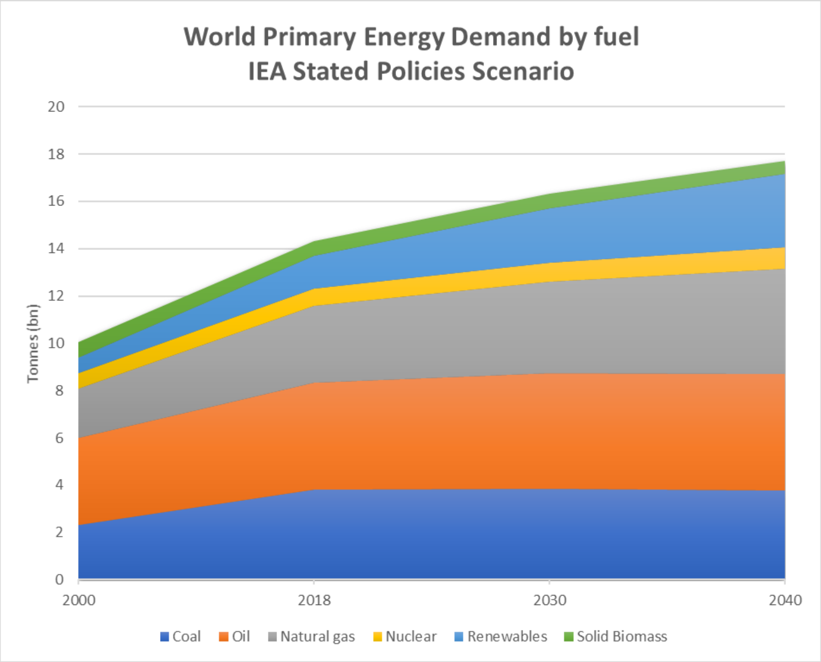
CCUS technologies combine to reduce the level of CO_2 emitted to or remove CO_2 from the atmosphere to be transported to and converted into useful products or injected underground for safe, secure and permanent storage.



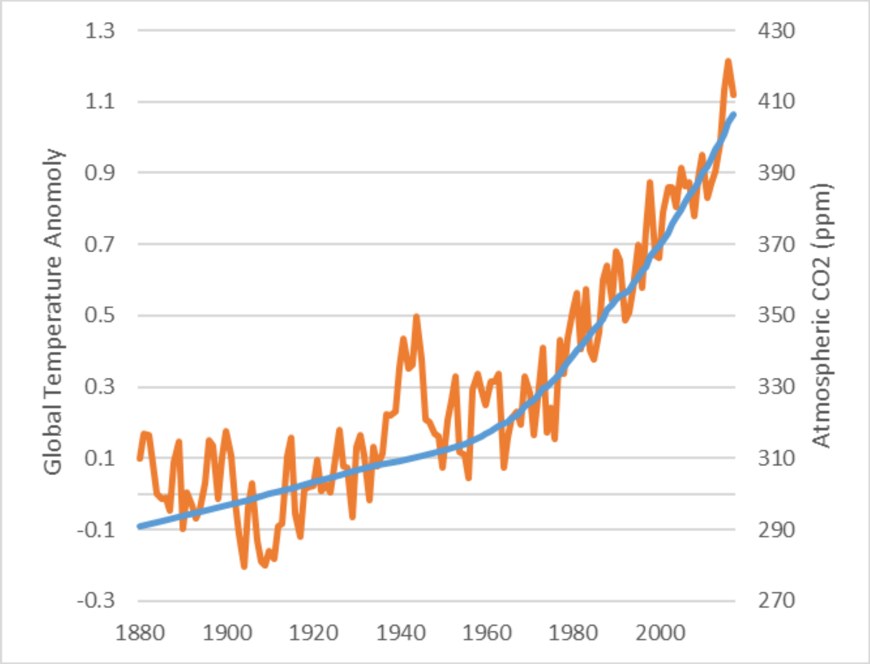
Source: Rocky Mountain Coal Mining Institute, Atlas IV, (2012).

Understanding the dual challenge

The world faces a dual challenge of providing affordable, reliable energy while addressing the risks of climate change.



Over the next two decades, global population and GPD growth will drive continued increase in global energy demand



At the same time, the need to address rising carbon dioxide (CO_2) emissions continues to grow

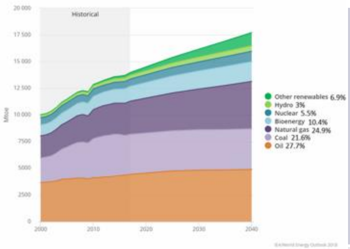
U.S. leads in CCUS deployment

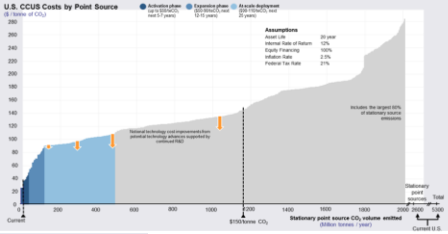
The United States has become the world leader in CCUS with:

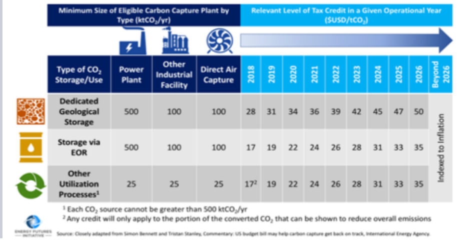
- 40+ years of successful EOR experience
- Ten of 19 industrial scale projects, 80% of the world's capacity
- Over 5,000 miles of CO_2 pipeline
- 20+ years of DOE leadership and support
  - $4.5bn in RD&D programs
  - Over 20 million tonnes CO_2 stored
  - Public-private partnerships
- World-leading policy support (e.g., 45Q)
- Established regulatory framework

CCUS deployment at-scale: chapters 1 - 4

Title	Lead Authors	Key Sections
The Role of CCUS in a Future Energy Mix	Jason Bordoff Julio Friedmann	• Global & U.S. energy demand forecasts • Role of CCUS • U.S. CO_2 emissions profile • Benefits of CCUS – environmental, economic, US leadership
CCUS Supply Chains and Economics	Nigel Jenvey Guy Powell Rick Callahan	• Complexity of supply chain • Description of existing projects • Supply chain enablers • Cost to deploy CCUS • Enablers for future projects
Policy, Regulatory and Legal Enablers	Leslie Savage Susan Blevins	• Existing policy and regulatory framework • Activation phase actions • Expansion phase actions • At-Scale phase actions • Research and development priorities
Building Stakeholder Confidence	Sallie Greenberg	• Spheres of public engagement • Public perception of CCUS • Defining and understanding stakeholders • Strategic engagement



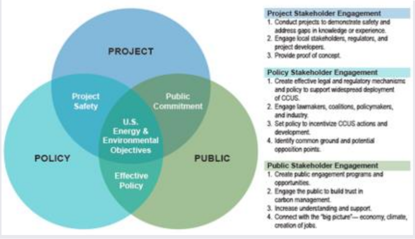




Type of CO_2 Storage/Use	Power Plant	Other Industrial Facility	Direct Air Capture	2018	2019	2020	2021	2022	2023	2024	2025	2026	Beyond 2026
Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	47	50	Indexed to Inflation
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	
Other Utilization Processes[1]	25	25	25	17[2]	19	22	24	26	28	31	33	35	

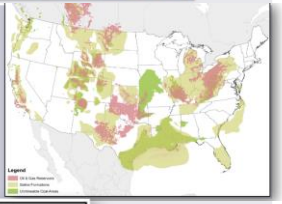
Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2$/yr); Relevant Level of Tax Credit in a Given Operational Year ($USD/$tCO_2$)

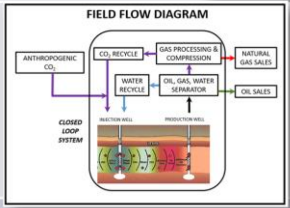
[1] Each CO_2 source cannot be greater than 500 $ktCO_2$/yr
[2] Any credit will only apply to the portion of the converted CO_2 that can be shown to reduce overall emissions

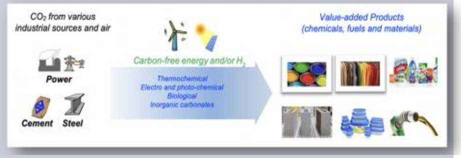


CCUS technologies: chapters 5 – 9

Title	Lead Authors	Key Sections
CO_2 Capture	John Northington Jennifer Wilcox	• Capture process • Technology types and maturity • Opportunities by sector • Capture cost drivers • Research and development priorities
CO_2 Transport	Dan Cole	• Current transport technologies • Existing U.S. CO_2 pipeline network • Role of transport in widespread CCUS deployment
CO_2 Geologic Storage	Richard Esposito Sally Benson	• Description of CO_2 geologic storage • Commercial scale experience and enablers • Options for CO_2 storage and capacity potential • Research and development priorities
CO_2 Enhanced Oil Recovery	William Barrett	• EOR technology experience and maturity • Conventional vs. non-conventional EOR • EOR capacity potential, near- and long-term • Research and development priorities
CO_2 Use	Will Morris Alissa Park	• CO_2 use technologies, pathways and products • Relative experience and maturity • Opportunities and challenges • Research and development priorities



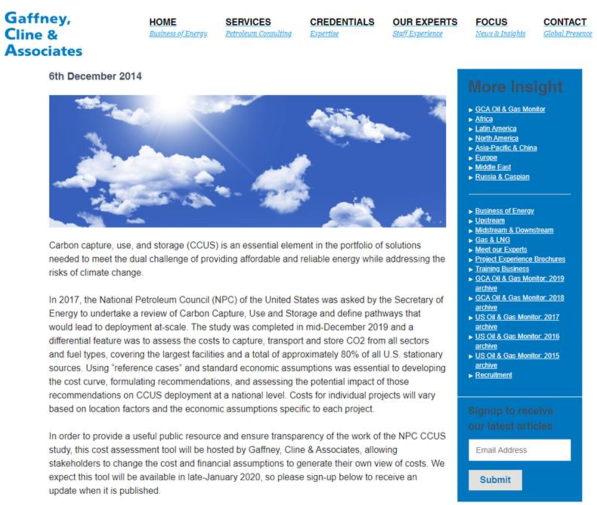


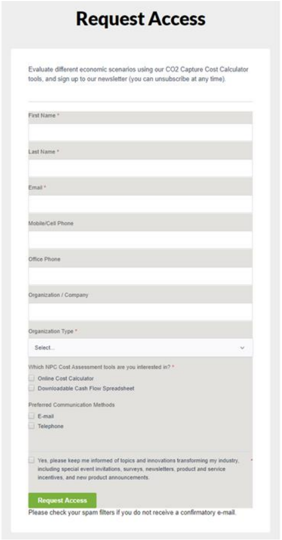


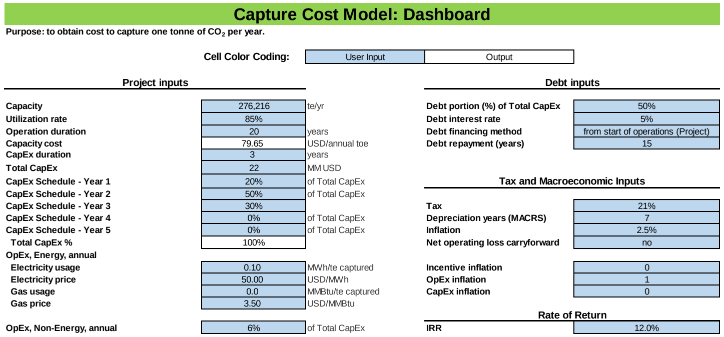
CCUS cost assessment: public online tool

To provide a useful public resource and ensure transparency of the work, a cost assessment tool will be hosted by Gaffney, Cline & Associates and will be available in late January/early February.

- **Registration page www.gaffney-cline-focus.com/npc-ccus-cost-assessment-tool**





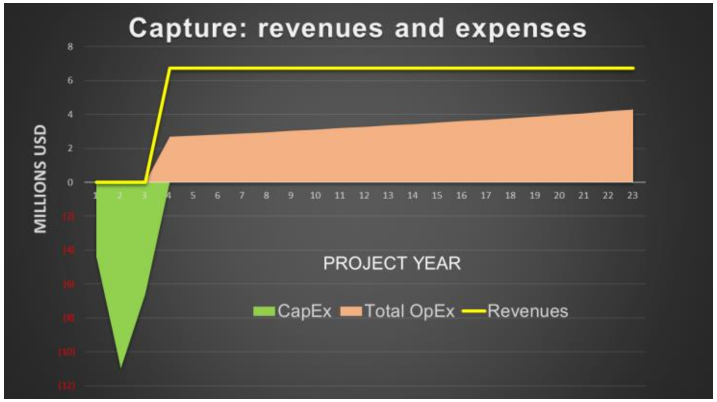


Capture Cost Model: Dashboard

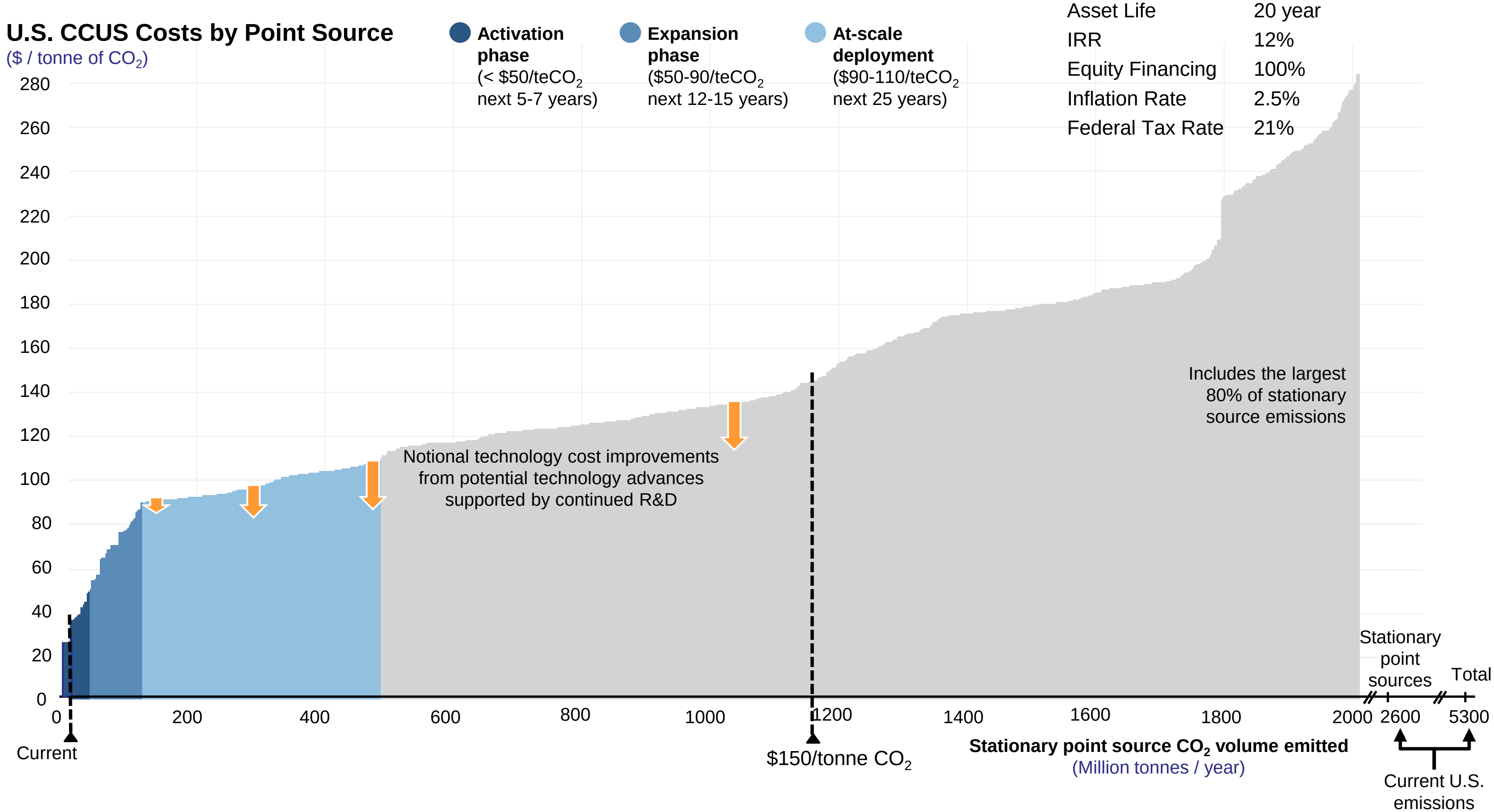
Purpose: to obtain cost to capture one tonne of CO_2 per year.

Cell Color Coding: User Input | Output

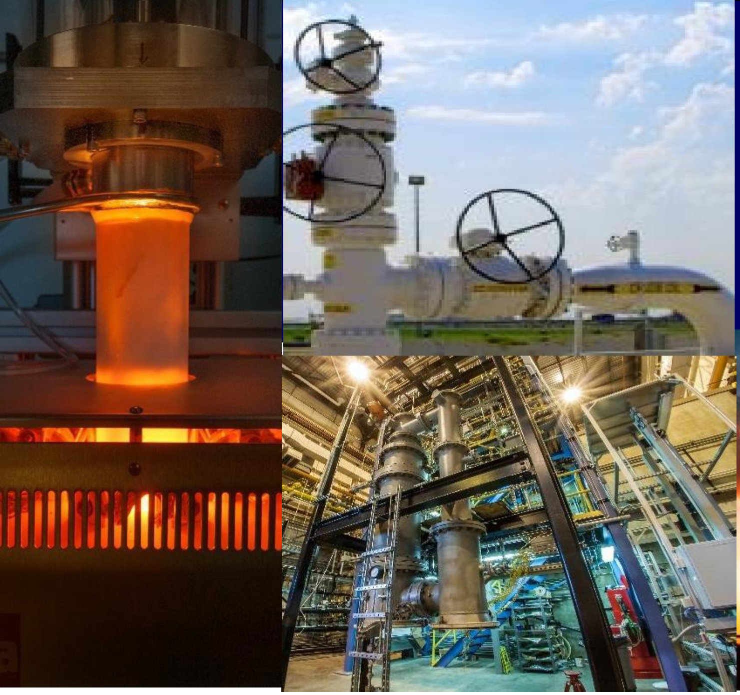
Project inputs			Debt inputs	
Capacity	276,216	te/yr	Debt portion (%) of Total CapEx	50%
Utilization rate	85%		Debt interest rate	5%
Operation duration	20	years	Debt financing method	from start of operations (Project)
Capacity cost	79.65	USD/annual toe	Debt repayment (years)	15
CapEx duration	3	years		
Total CapEx	22	MM USD		
CapEx Schedule - Year 1	20%	of Total CapEx	**Tax and Macroeconomic Inputs**	
CapEx Schedule - Year 2	50%	of Total CapEx		
CapEx Schedule - Year 3	30%		Tax	21%
CapEx Schedule - Year 4	0%	of Total CapEx	Depreciation years (MACRS)	7
CapEx Schedule - Year 5	0%	of Total CapEx	Inflation	2.5%
Total CapEx %	100%		Net operating loss carryforward	no
OpEx, Energy, annual				
Electricity usage	0.10	MWh/te captured	Incentive inflation	0
Electricity price	50.00	USD/MWh	OpEx inflation	1
Gas usage	0.0	MMBtu/te captured	CapEx inflation	0
Gas price	3.50	USD/MMBtu		
			Rate of Return	
OpEx, Non-Energy, annual	6%	of Total CapEx	IRR	12.0%



CCUS cost assessment: phases of deployment



Assumptions	
Asset Life	20 year
IRR	12%
Equity Financing	100%
Inflation Rate	2.5%
Federal Tax Rate	21%



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

Overview of DOE's Carbon Capture Program

NARUC Winter Policy Summit

Lynn Brickett
Carbon Capture- Program Manager

Office of Clean Coal and Carbon Management, Office of Fossil Energy

February 9, 2019

MAJOR CCUS DEMONSTRATION PROJECTS

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)
- **Nearly 3.3 million metric tons of CO_2** used for **EOR** in West Ranch Oil Field in Jackson County, Texas since January 2017

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**
- **Over 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

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
- **1.5 million metric tons of CO_2 stored**, since April 2017

CO_2 SOURCE CONCENTRATIONS

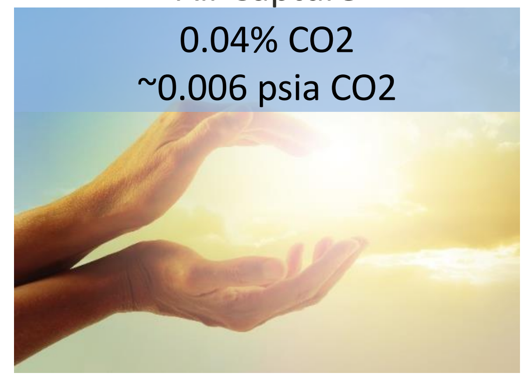
Coal Power Plant

11-14% CO_2
~2 psia CO_2

Gas Power Plant

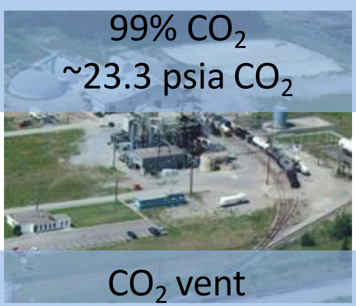
4-6% CO_2
~0.7 psia CO_2

Air Capture



0.04% CO2
~0.006 psia CO2

NG Processing Plant



99% CO_2
~23.3 psia CO_2
CO_2 vent

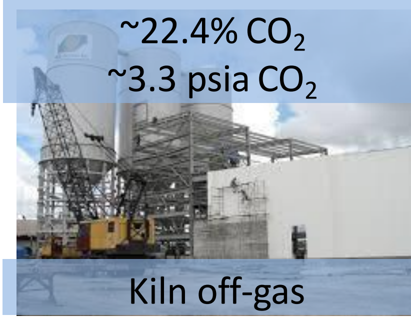
Ammonia Plant

99% CO_2
~22.8 psia CO_2
Stripping vent

Ethanol Plant

100% CO_2
~18.4 psia CO_2
Distillation gas

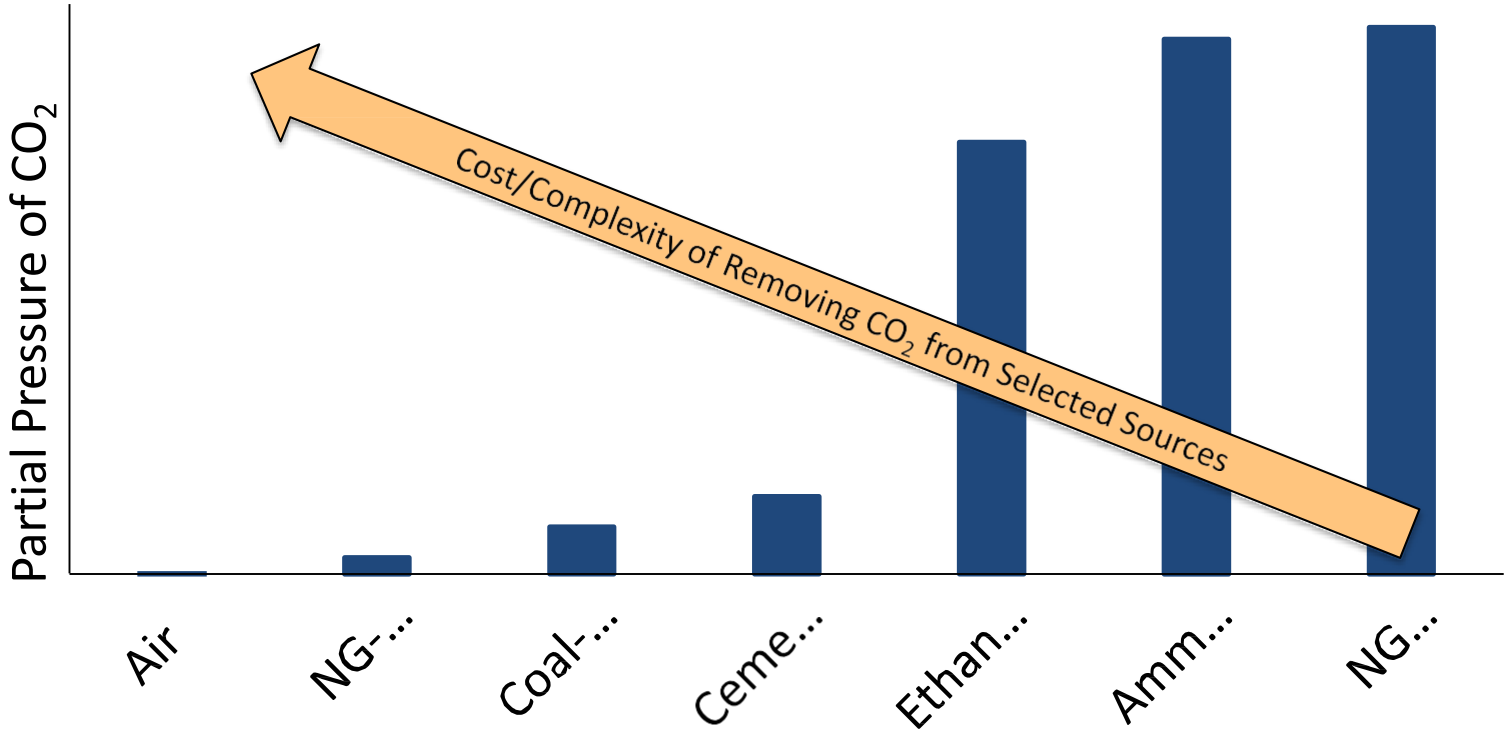
Cement Plant



~22.4% CO_2
~3.3 psia CO_2
Kiln off-gas

Cost of Capturing CO_2 from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602

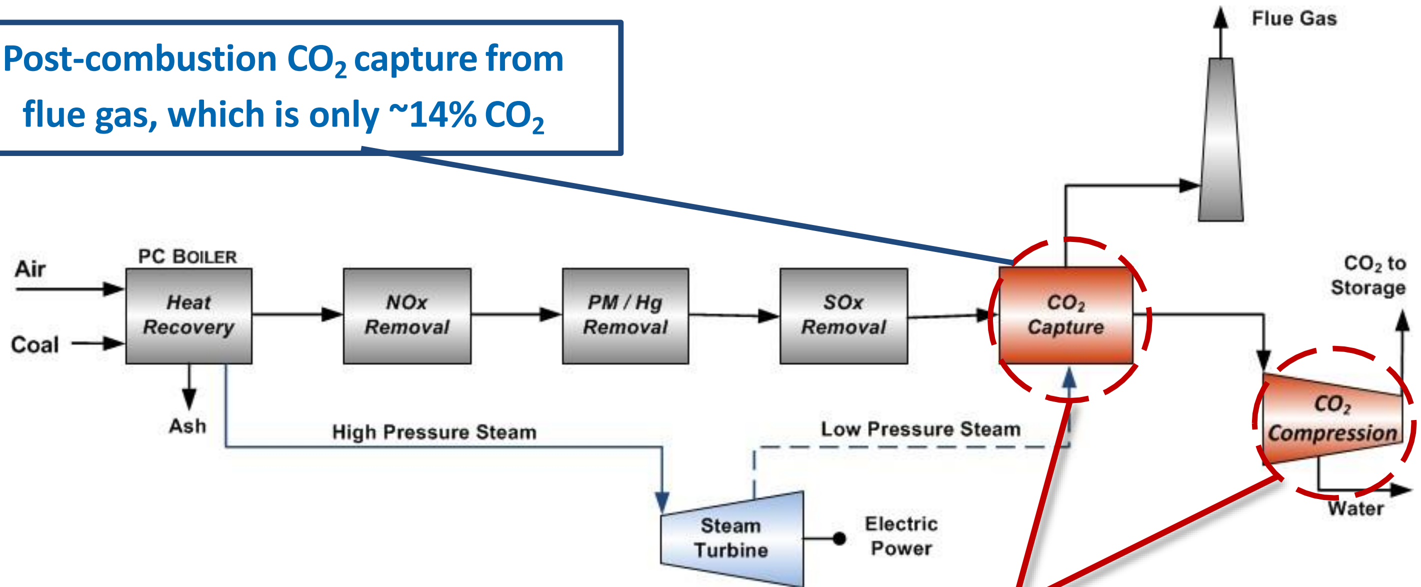
CO_2 PARTIAL PRESSURE AND CAPTURE COST



Cost of Capturing CO_2 from Industrial Sources, January 10, 2014, DOE/NETL-2013/1602

POST-COMBUSTION PROCESS CONFIGURATION

Post-combustion CO_2 capture from flue gas, which is only ~14% CO_2

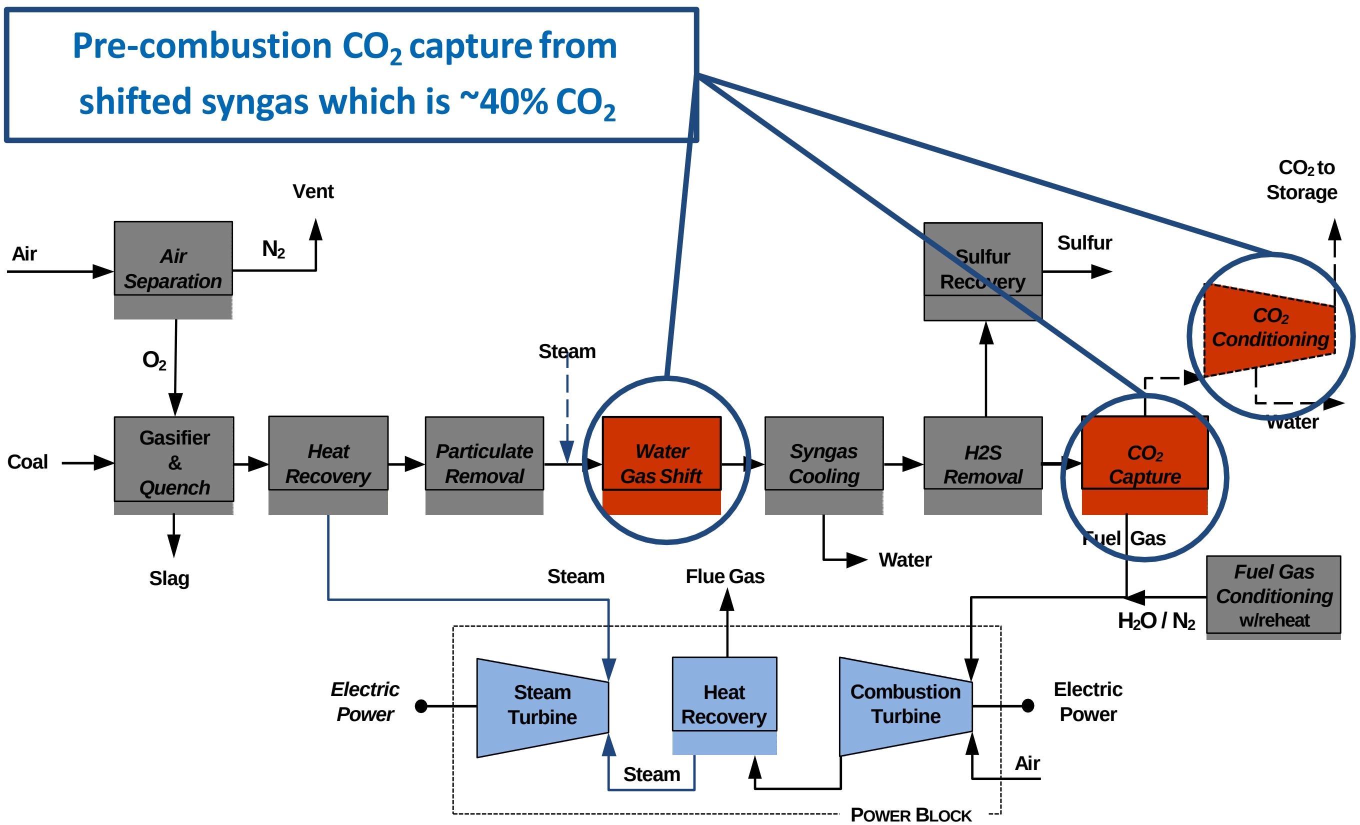


Two-step separation process requiring 5 energy inputs:

Energy = Q (sensible) + Q (reaction) + Q (stripping) + W (process) + W (compression)

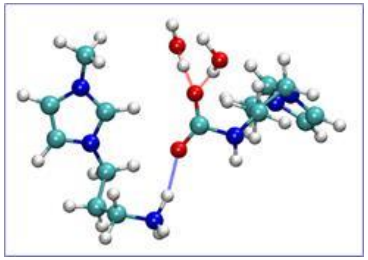
ALL must be reduced in order to significantly reduce Capture COE impact!

IGCC PROCESS CONFIGURATION



CAPTURE = Materials + Process

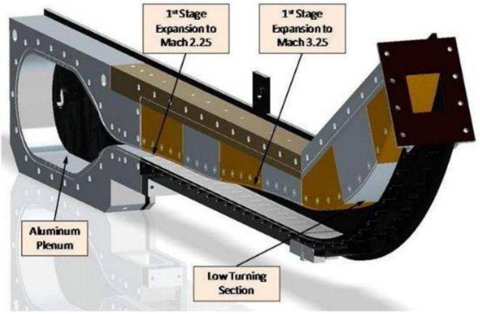
Solvents



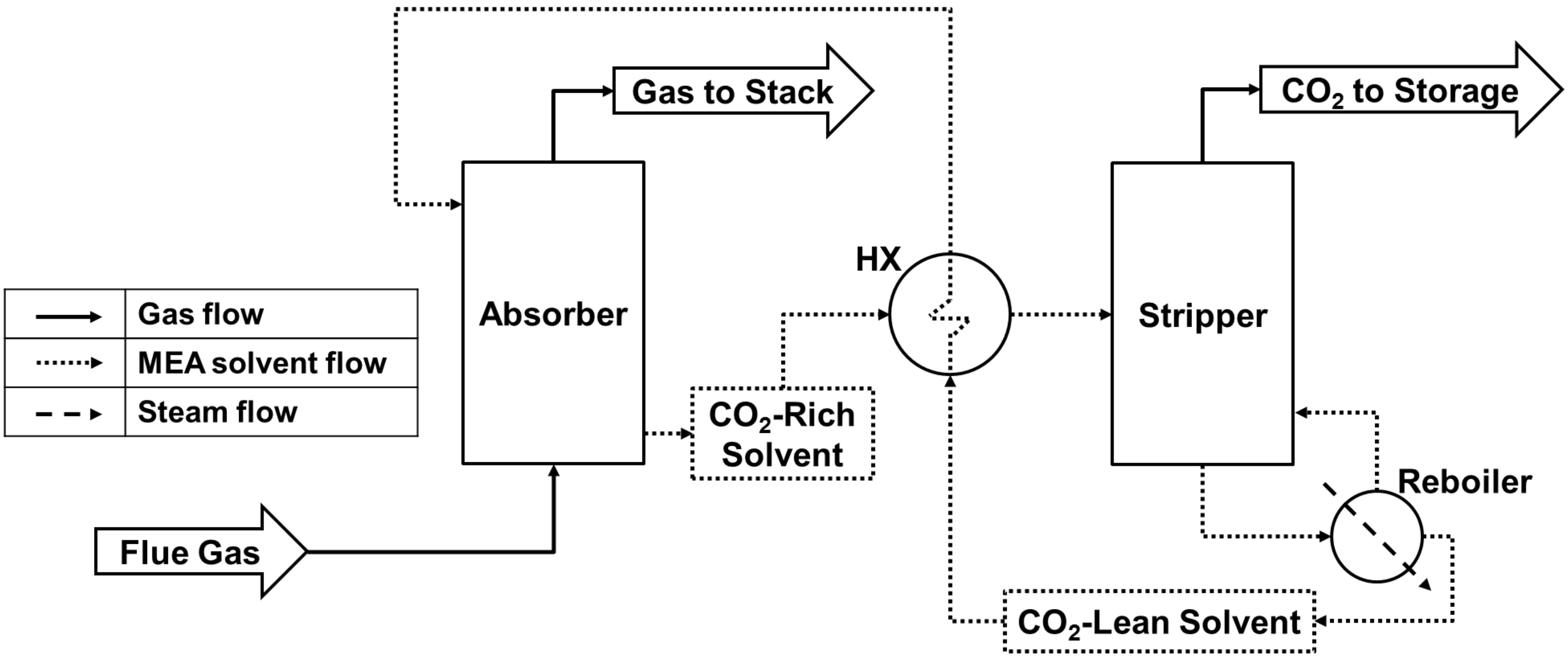
Sorbents

Membranes

Novel Concepts

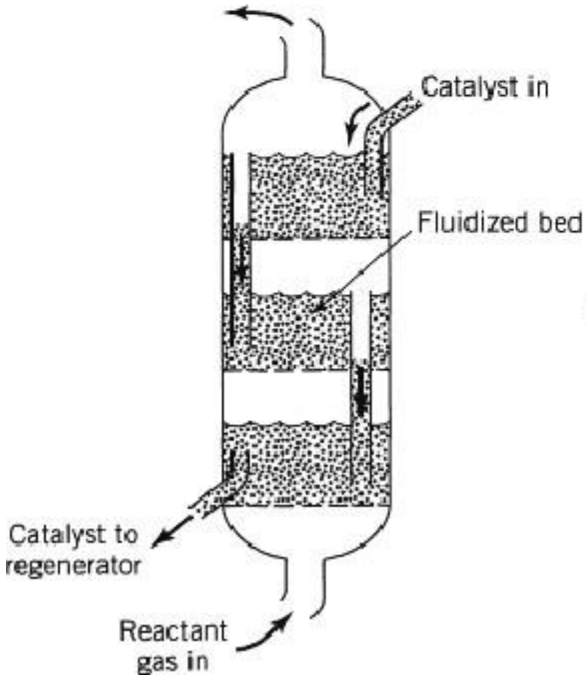


SOLVENT CAPTURE PROCESS

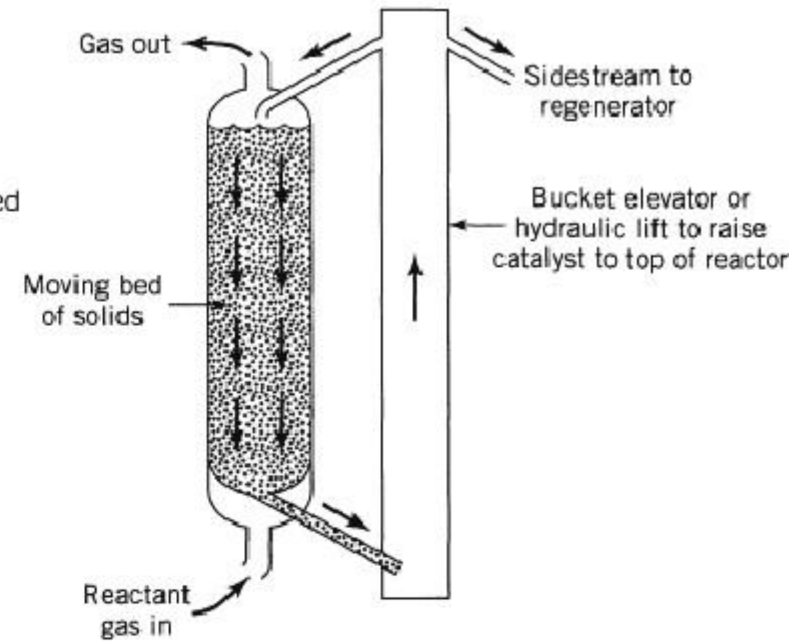


SORBENT CAPTURE PROCESS

Fluidized Bed



Moving Bed



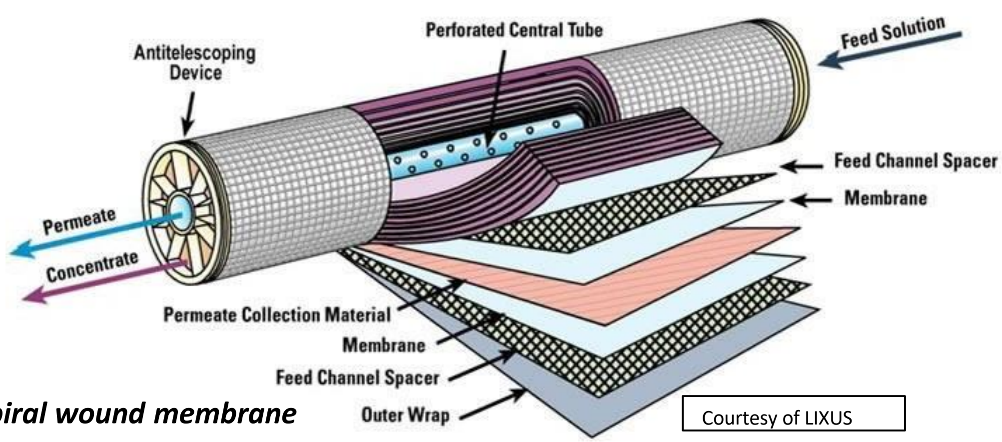
- ***Processes***
  - Fluidized, moving, fixed bed
  - & bubbling
    - Temperature Swing Adsorption
    - Vacuum Swing Adsorption
    - Pressure Swing Adsorption

MEMBRANE CAPTURE PROCESS

Membrane process is specific to the membrane type:

Hollow fiber membrane

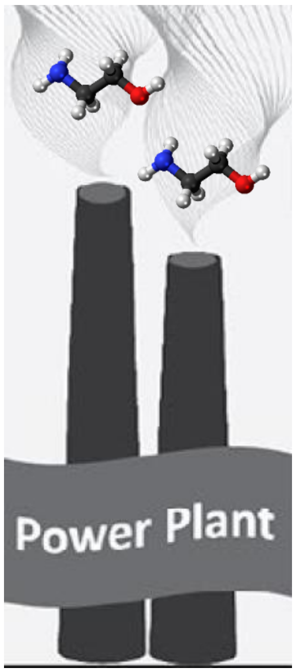
Flat Sheet Membrane



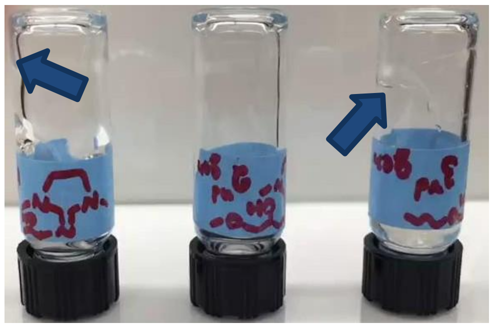
Spiral wound membrane

Carbon Capture Program Specific Challenges

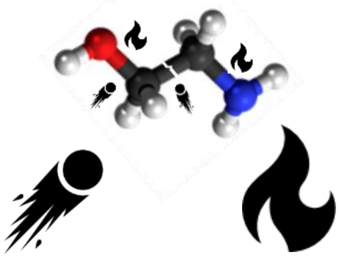
Aerosols



Viscosity



Degradation



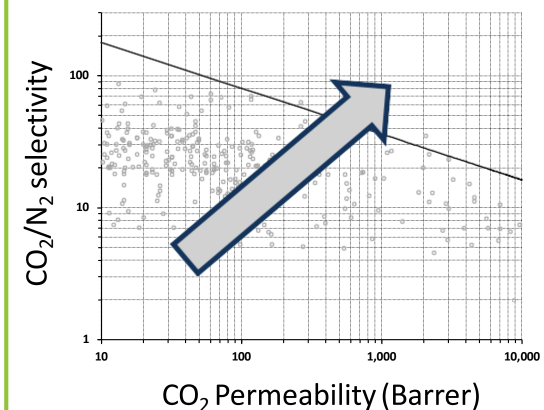
Oxidative **Thermal**

Attrition

Corrosion

Disposal & Loss

Selectivity and Flux



Lloyd M.Robeson, Journal of Membrane Science, 320, 2008, 390-400

CARBON CAPTURE PROGRAM
ADDRESSING LARGER-SCALE CHALLENGES

- $>$400M
- Almost 40 technologies
- 6 countries

NATIONAL CARBON CAPTURE CENTER

SMALL PILOTS

LARGE PILOTS

CCUS FEED STUDIES SELECTIONS

Front-End Engineering Design (FEED) Studies for Carbon Capture Systems on Coal and Natural Gas Power Plants (DE-FOA-0002058)

Projects will support FEED studies for commercial-scale carbon capture systems

- $55.4 million in Federal funding awarded
- Nine projects selected
- Eight solvent & 1 membrane

Awardee	Project
Bechtel National	FEED Study for Retrofitting a 2x2x1 Natural Gas-Fired Gas Turbine Combined Cycle Power Plant for Carbon Capture Storage/Utilization – *MEA Solvent*
The Board of Trustees of the University of Illinois	Full-Scale FEED Study for Retrofitting the a coal plant with an **816 MWe** Capture Plant Using Mitsubishi Heavy Industries of America Post-Combustion CO_2 Capture Technology – *MHI advanced solvent*
Electric Power Research Institute	Front End Engineering Design Study for Retrofit Post-Combustion Carbon Capture on a Natural Gas Combined Cycle Power Plant – Fluor's amine-based *Econamine FG Plus*
Enchant Energy	Large-Scale Commercial Carbon Capture Retrofit of the San Juan Generating Station – *MHI solvent*
Ion Engineering	Commercial Carbon Capture Design & Costing: Part Two – *Ion Engineering Non- aqueous Solvent*
Membrane Technology and Research Inc.	Commercial-Scale Front-End Engineering Study for MTR's Membrane CO_2 Capture Process – *MTR, Inc Polymeric Membrane*
Minnkota Power Cooperative Inc.	Front-End Engineering & Design: Project Tundra Carbon Capture System – Fluor's amine-based *Econamine FG Plus*
Southern Company Services	Front End Engineering Design of Linde-BASF Advanced Post-Combustion CO2 Capture Technology at a Southern Company Natural Gas-Fired Power Plant – *Linde BASF amine Solvent*
The University of Texas at Austin	Piperazine Solvent/Advanced Stripper Front-End Engineering Design *PZAS*

CARBON CAPTURE FRONT-END ENGINEERING DESIGN (FEED) STUDIES

Membrane Technology and Research, Inc. (12854825) Newark, CA
Basin Electric Dry Fork Station, WY

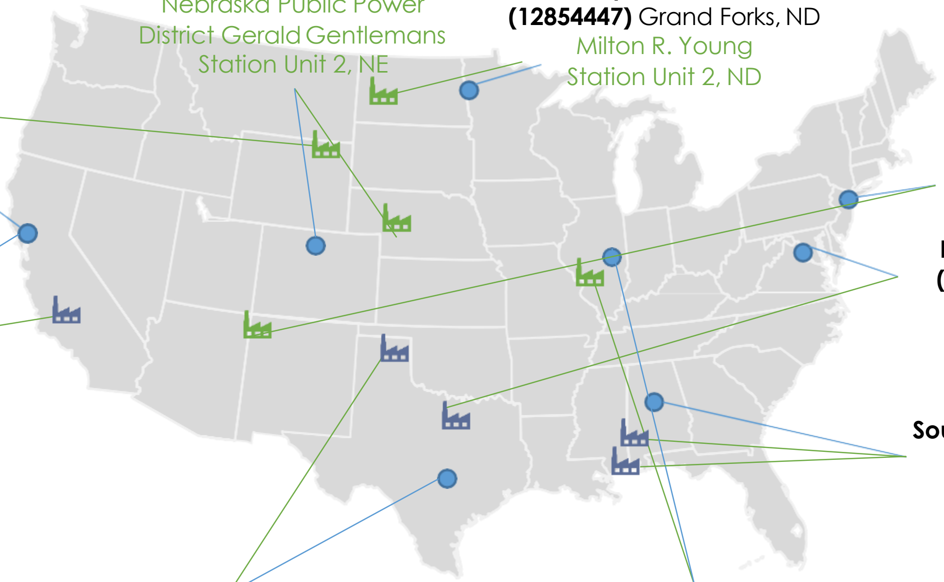
Ion Engineering LLC (12854929) Boulder, CO
Nebraska Public Power District Gerald Gentlemans Station Unit 2, NE

Minnkota Power Cooperative, Inc. (12854447) Grand Forks, ND
Milton R. Young Station Unit 2, ND

Enchant Energy LLC (12854294) New York, NY
San Juan Generating Station, NM

Bechtel National, Inc. (12855067) Reston, VA
Panda Power Funds, TX

Electric Power Research Institute, Inc. (12854657) Palo Alto, CA
Elk Hills Power Plant, CA



Southern Company Services, Inc. (12854859) Birmingham, AL
Plant Barry 6 &7 AL or Plant Daniels 3&4. MS

The University of Texas at Austin (12855053) Austin, TX
Golden Spread Electric Cooperative Mustang, TX

Board of Trustees of the University of Illinois (12854268) Champaign, IL
Prairie State Generating Company's Energy, IL

Natural Gas
Coal

Applicant Locations and Host Sites

FUTURE COMMERCIAL-SCALE DEPLOYMENT

Integrated R&D Approach

2017
Large Capture Pilots Initiated

2020
R&D Completed for Carbon Capture 2nd Generation Technologies

2017
Initiate Storage Feasibility for Integrated CCS

2022
Commercial-scale Storage Complexes Characterized

2025
Integrated CCS Projects Deployed

Deployments

2035
Transformational Technologies Available for Deployment


Thank You
Questions?
Lynn.Brickett@hq.doe.gov