National Petroleum Council

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

December 12, 2019
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?
Comprehensive report covering:

**CCUS Energy and Emission Landscape**
- Understanding the dual challenge and the role of CCUS

**Economics**
- Detailed CCUS cost and economic analyses

**Enabling Factors**
- Existing policy and regulatory landscape
- Current barriers and prioritized, actionable recommendations

**Technology**
- Well written technology chapters covering entire supply chain
- Aggressive research and development recommendations

**Roadmap**
- Prioritized based on economics and ease of implementation
- Three phases of deployment
- Detailed plan – who, what, when, and why over 25 years
Study organization

National Petroleum Council (NPC)

NPC Study Committee (NPC Members)

Steering Committee

Coordinating Subcommittee (CSC)

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

• The CSC has membership of 22 individuals representing upstream and downstream oil & gas, LNG, biofuels, power, EPC, NGO, and state and federal governments.

• The overall study team is currently composed of over 300 participants from more than 110 different organizations and includes 17 international members.

• National Coal Council participation is represented through overlap of 21 organizations.
CCUS deployment at scale

Will mean:

- Moving from 25 to **500 Million tonnes per annum** of CCUS capacity
- 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
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 GDP 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.
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.
CCUS as part of a clean energy portfolio

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

Study has assessed the costs to capture, transport and store 850 point sources of emissions comprising 80% (~2Gt) 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 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
- Builds the case for ongoing RD&D across entire CCUS supply chain
- Economic impacts assessment (e.g., jobs, GDP)
CCUS cost assessment: methodology

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 CO₂ 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.

**Example Source Costs by Type**
- Capture ($ / tonne CO₂)
- Transport + Storage ($ / tonne CO₂)

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

**Current U.S. CCUS Costs by Point Source**
- ($ / tonne of CO₂)

- **Capture**
  - Ethanol: $46 / MTCO₂
  - Cement: $87 / MTCO₂
  - Natural Gas: $93 / MTCO₂
- **Transport + Storage**
  - Ethanol: $17 / MTCO₂
  - Cement: $23 / MTCO₂
  - Natural Gas: $14 / MTCO₂

**Notional technology cost improvements**
- from potential technology advances supported by continued R&D.

**Stationary point source CO₂ volume emitted**
- (Million tonnes / year)

**Includes the largest 80% of stationary source emissions**
CCUS cost assessment: phases of deployment

U.S. CCUS Costs by Point Source

- **Current**
  - $0-20/tonne CO$_2$

- **Activation phase** (< $50/teCO$_2$, next 5-7 years)
  - $20-40/tonne CO$_2$

- **Expansion phase** ($50-90/teCO$_2$, next 12-15 years)
  - $40-60/tonne CO$_2$

- **At-scale deployment** ($90-110/teCO$_2$, next 25 years)
  - $60-80/tonne CO$_2$

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

**Includes the largest 80% of stationary source emissions**

**Notional technology cost improvements from potential technology advances supported by continued R&D**

**Stationary point source CO$_2$ volume emitted** (Million tonnes / year)

**Current U.S. emissions**

**Total**

**Stationary point sources**

**2000 2600 5300**
Findings 1 - 4: CCUS landscape and outlooks

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:
   - ~80% of the world’s CCUS capacity (10 of 19 projects) is deployed in the U.S.
   - ~85% of global CO$_2$ pipeline infrastructure is in the U.S.
   - Cutting edge RD&D - $4.5bn DOE investment over last 20 years
   - Supportive policy framework – but insufficient for widescale deployment
Finding 5: activation phase

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.

Recommendations
Agency Action & Rulemaking:

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

*note: 25-40 mtpa 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 phase

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
- Expand access to Section 48 tax credits
- Expand use of MLPs, private activity bonds, and TIFIA eligibility/funding
- Increase funding to support well permitting and timely reviews
- Allow geologic storage in federal waters from all CO₂ sources

**Agencies to:**
- DOE & DOI to implement process for pore space access
- DOE to create CO₂ pipeline working group for development of large scale CO₂ pipeline infrastructure
- DOE to convene stakeholder forum to address geologic storage long-term liabilities
- State policymakers enable access to pore space on private lands

Cumulative annual CCUS Volume:
- ~150 Mtpa
- ~$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 phase

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.
Critical role of RD&D investment

Study describes the evolution of CCUS technologies across the supply chain and builds the case for continued investment in research and development to achieve long-term cost and performance improvements.
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.

<table>
<thead>
<tr>
<th>Technology</th>
<th>R&amp;D (including pilot programs)</th>
<th>Demonstrations</th>
<th>Total</th>
<th>10-Year Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture (including negative emissions technologies)</td>
<td>$500 million/year</td>
<td>$500 million/year</td>
<td>$1.0 billion/year (over 10 years)</td>
<td>$10 billion</td>
</tr>
<tr>
<td>Geologic Storage</td>
<td>$400 million/year</td>
<td></td>
<td>$400 million/year (over 10 years)</td>
<td>$4 billion</td>
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<tr>
<td>Nonconventional Storage (including EOR)</td>
<td>$50 million/year</td>
<td>$50 million/year (over 10 years)</td>
<td>$500 million</td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>$50 million/year</td>
<td>$50 million/year (over 10 years)</td>
<td>$500 million</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$1.0 billion/year</td>
<td>$500 million/year</td>
<td>$1.5 billion/year</td>
<td>$15 billion</td>
</tr>
</tbody>
</table>
9. Increasing understanding and confidence in CCUS as a safe and reliable technology is essential for public and policy stakeholder support.

Recommendations:
• Simplify terminology and build confidence that CCUS is safe, secure, and critical to managing emissions.
• Oil and natural gas industry remain committed to improving its environmental performance.

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
  – CO₂ pipeline infrastructure needed for EOR and saline storage
  – R&D for advancing CCUS technologies
Key messages

- CCUS refers to the complete supply chain needed to capture, transport and permanently use or store CO₂, eliminating it from the atmosphere.
- 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 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 could 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.
Roadmap and full list of recommendations

Roadmap to At-Scale CCUS Deployment

All Study Recommendations
Executive Summary
• Transmittal letter
• Report outline
• Preface
• Executive Summary, Roadmap and Recommendations

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

CCUS Deployment At-Scale (Volume 1)
• 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
H. Integrated Economic Analysis (ERM Memo)

CCUS Technologies (Volume 2)
• Technology Introduction
• Chapter 5: CO₂ Capture
• Chapter 6: CO₂ Transport
• Chapter 7: CO₂ Geologic Storage
• Chapter 8: Enhanced Oil Recovery
• Chapter 9: CO₂ Use

Appendices
D. Mature CO₂ Capture Technologies
E. Emerging CO₂ Capture Technologies
F. CO₂ EOR Case Studies
G. CO₂ EOR Economic Factors and Considerations

List of Topic Papers
Abbreviations, Units, Glossary

Findings and Recommendations

Full Report
## CCUS deployment at-scale: chapters 1 - 4

<table>
<thead>
<tr>
<th>Title</th>
<th>Lead Authors</th>
<th>Key Sections</th>
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<tbody>
<tr>
<td>The Role of CCUS in a Future Energy Mix</td>
<td>Jason Bordoff, Julio Friedmann</td>
<td>• Global &amp; U.S. energy demand forecasts&lt;br&gt;• Role of CCUS&lt;br&gt;• U.S. CO₂ emissions profile&lt;br&gt;• Benefits of CCUS – environmental, economic, US leadership</td>
</tr>
<tr>
<td>CCUS Supply Chains and Economics</td>
<td>Nigel Jenvey, Guy Powell, Rick Callahan</td>
<td>• Complexity of supply chain&lt;br&gt;• Description of existing projects&lt;br&gt;• Supply chain enablers&lt;br&gt;• Cost to deploy CCUS&lt;br&gt;• Enablers for future projects</td>
</tr>
<tr>
<td>Policy, Regulatory and Legal Enablers</td>
<td>Leslie Savage, Susan Blevins</td>
<td>• Existing policy and regulatory framework&lt;br&gt;• Activation phase actions&lt;br&gt;• Expansion phase actions&lt;br&gt;• At-Scale phase actions&lt;br&gt;• Research and development priorities</td>
</tr>
<tr>
<td>Building Stakeholder Confidence</td>
<td>Sallie Greenberg</td>
<td>• Spheres of public engagement&lt;br&gt;• Public perception of CCUS&lt;br&gt;• Defining and understanding stakeholders&lt;br&gt;• Strategic engagement</td>
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## CCUS technologies: chapters 5 – 9

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<thead>
<tr>
<th>Title</th>
<th>Lead Authors</th>
<th>Key Sections</th>
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| CO₂ Capture                  | John Northington Jennifer Wilcox | • Capture process  
                                  |                                                                 | • Technology types and maturity  
                                  |                                                                 | • Opportunities by sector  
                                  |                                                                 | • Capture cost drivers  
                                  |                                                                 | • Research and development priorities |
| CO₂ Transport                | Dan Cole                          | • Current transport technologies  
                                  |                                                                 | • Existing U.S. CO₂ pipeline network  
                                  |                                                                 | • Role of transport in widespread CCUS deployment |
| CO₂ Geologic Storage        | Richard Esposito Sally Benson     | • Description of CO₂ geologic storage  
                                  |                                                                 | • Commercial scale experience and enablers  
                                  |                                                                 | • Options for CO₂ storage and capacity potential  
                                  |                                                                 | • Research and development priorities |
| CO₂ 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 |
| CO₂ Use                      | Will Morris Alissa Park           | • CO₂ use technologies, pathways and products  
                                  |                                                                 | • Relative experience and maturity  
                                  |                                                                 | • Opportunities and challenges  
                                  |                                                                 | • Research and development priorities |
Forward plans

Digital publications and communications
• Report website will go live this afternoon
• Digital copy of executive summary and related materials
• Council webcast
• Social media friendly
• Other useful links

Printed Report Publication
• Executive Summary volume available mid-January
• Full report available end 1Q 2020

www.npc.org
Communications

• The study will be communicated in 2020 as requested by policymakers, governments, academia, research organizations, trade associations, technical societies and other interested groups.
• To request a presentation, please contact the National Petroleum Council

Protocol for ongoing communications
• Any individual or organization may use the NPC CCUS report in expressing their own views, provided that it is properly cited
• If the request did not originate from the NPC, please inform the NPC staff, and provide the name of the presenter, the audience, and a copy of the presentation or report
• Presenters are to be mindful of the purpose of the Council, and the prohibition against lobbying
Acknowledgements

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- 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.