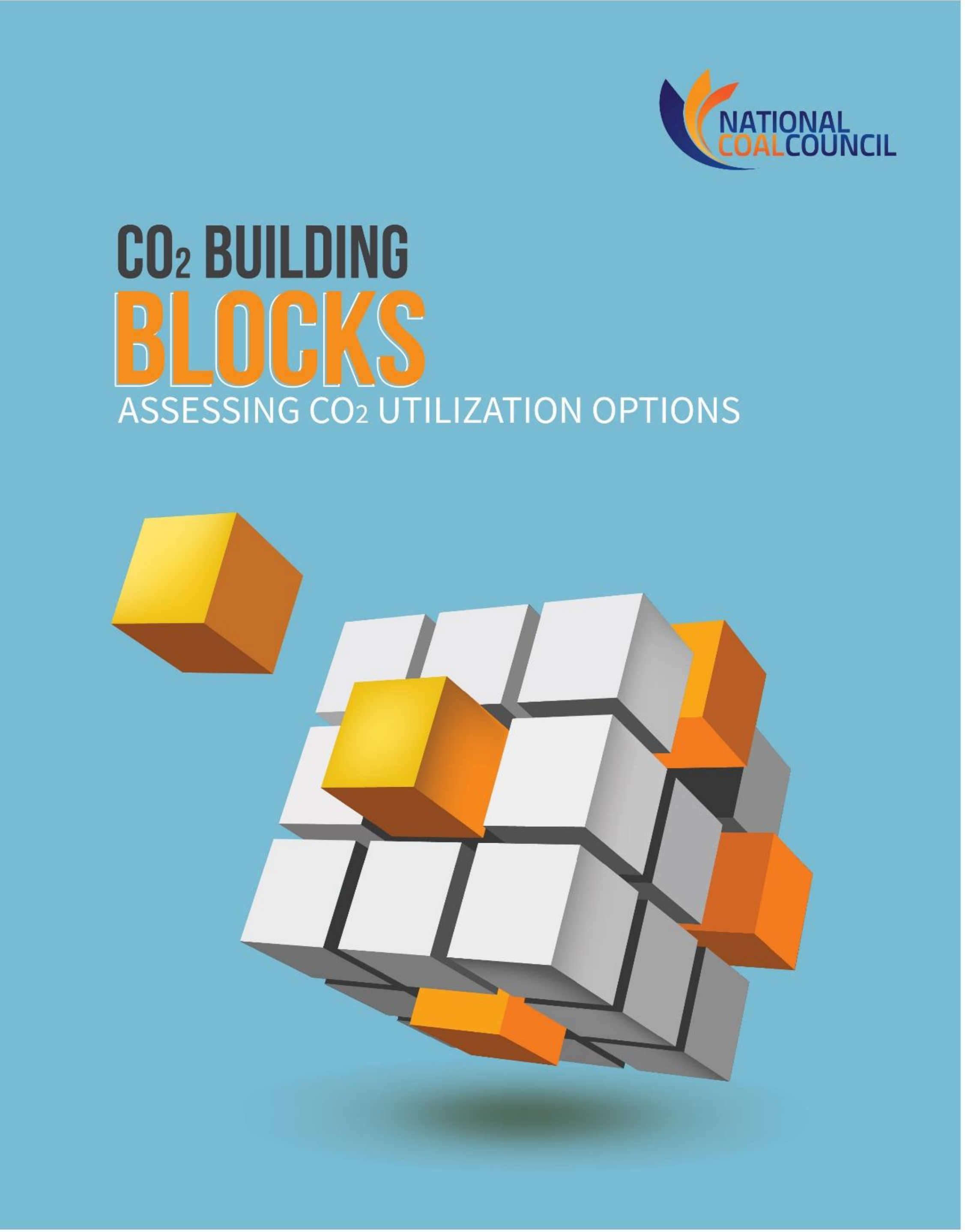


NATIONAL COAL COUNCIL

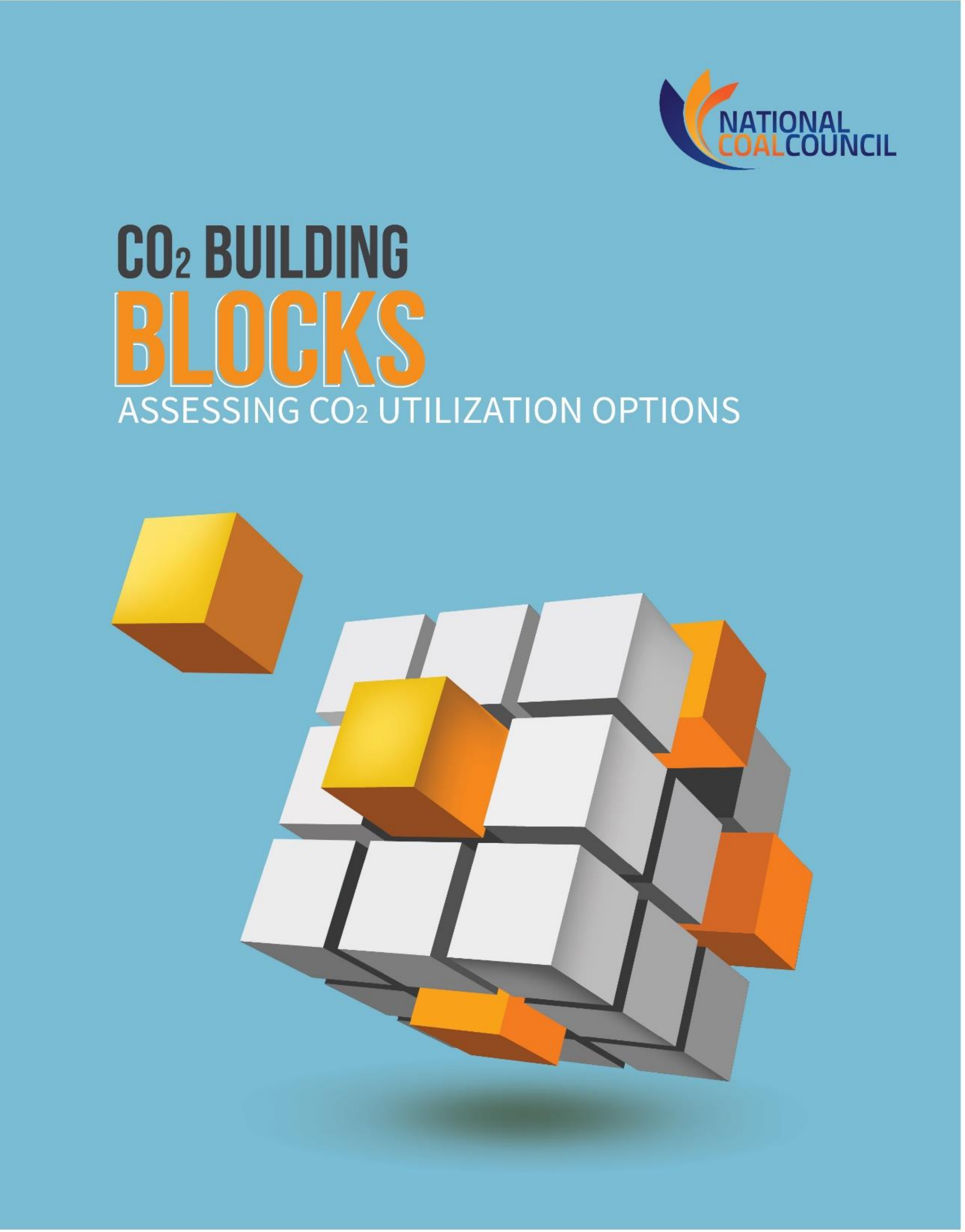
Full Council Meeting

August 30th, 2016 – 2-3 pm Eastern

NCC Webcast Meeting Agenda

- Welcome – NCC Chair, Mike Durham
- Anti-trust Advisory – NCC Legal Counsel, Julia d'Hemecourt
- "CO_2 Building Blocks: Assessing CO_2 Utilization Options"
  - Introduction of Report – NCC CPC Chair, Deck Slone
  - Presentation of Report – NCC Report Chair, Kipp Coddington
- Discussion & Action on NCC Report
- Adjourn

NATIONAL COALCOUNCIL



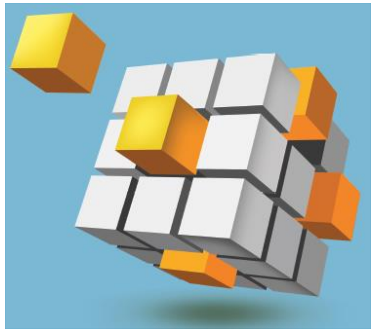
NATIONAL COAL COUNCIL

Report Introduction

Deck Slone, Chair
NCC Coal Policy Committee

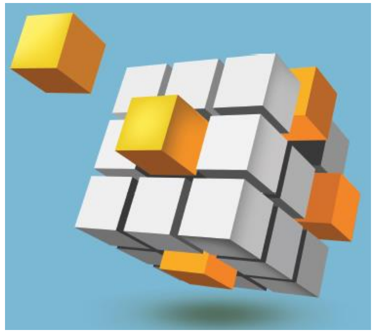
Request from Secretary Moniz

- Develop an expanded white paper assessing opportunities to advance commercial markets for carbon dioxide (CO_2) from coal-based power generation.
- Focus on profit-generating opportunities for CO_2 utilization, both for Enhanced Oil Recovery (EOR) and for non-EOR applications.
- Address the following questions:
  - What is the extent to which commercial EOR and non-EOR CO_2 markets could incentivize deployment of CCS/CCUS technologies?
  - What economic opportunity does deployment of commercial-scale CCS/CCUS technology represent for the U.S.?



Report Leadership

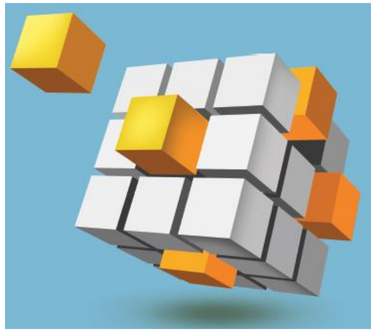
- NCC Chair – Mike Durham, Soap Creek Energy
- NCC Coal Policy Committee Chair – Deck Slone, Arch Coal
- NCC Report Chair – Kipp Coddington
  School of Energy Resources, University of Wyoming
- Report Chapter Leads
  - Kipp Coddington, School of Energy Resources, Univ. of Wyoming
  - Janet Gellici, National Coal Council
  - Sarah Wade, Wade LLC
  - Robert Hilton, Consultant
- Report Contributors +++



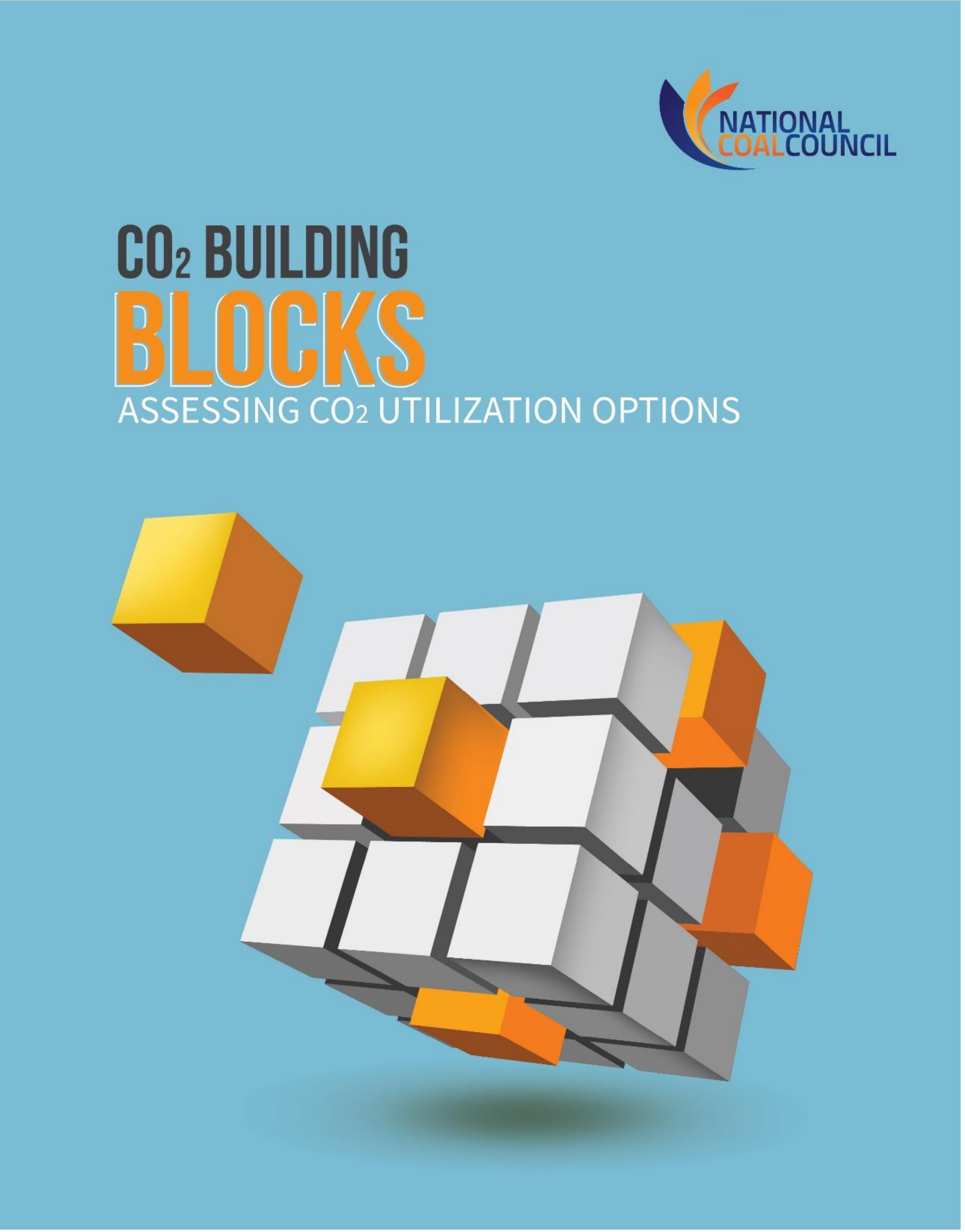
Report Timeline

- February 2016 – Secretary's Request
- March 2016 – NCC Scoping Meeting
- April 2016 – Report Outline Developed/Chapter Leads Secured
- May-July 2016 – Report Drafting
- August 5-22, 2016 – NCC Coal Policy Committee Review
- August 25, 2016 – Report Draft to NCC Members
- August 30, 2016 – Full Council Meeting

NATIONAL COAL COUNCIL



Report Contents



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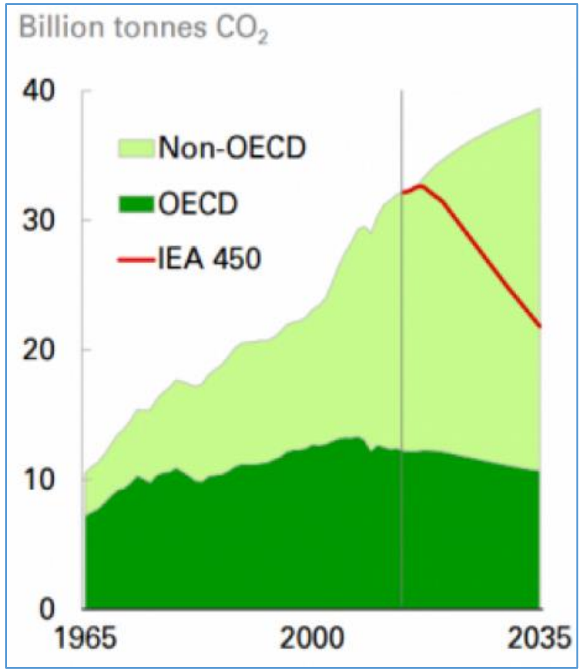
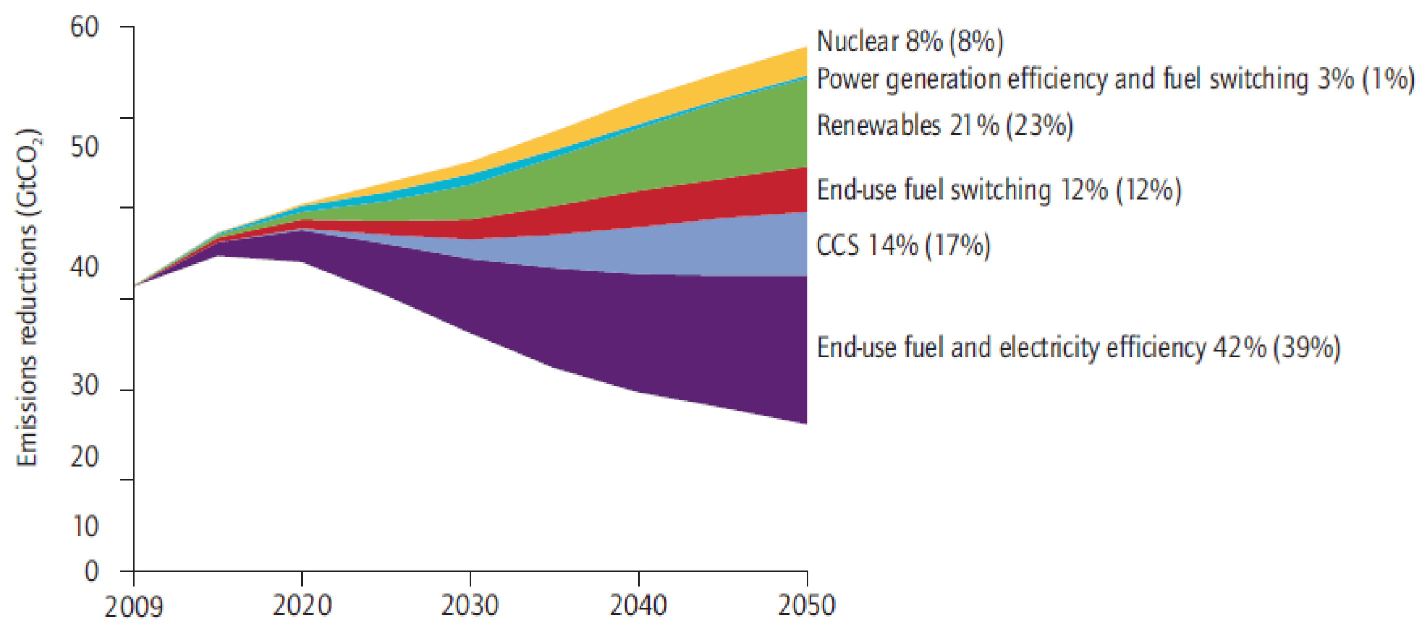
Report Presentation

Kipp Coddington, Chair
NCC CO_2 Building Blocks Report

The Value of Coal



Source: BP Energy Outlook 2016



Note: numbers in brackets are shares in 2050. For example, 14% is the share of CCS in cumulative emission reductions through 2050, and 17% is the share of CCS in emission reductions in 2050, compared with the 6DS.

Source: International Energy Agency 2013

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CO2 Building Blocks

Assessing CO_2 Utilization Options

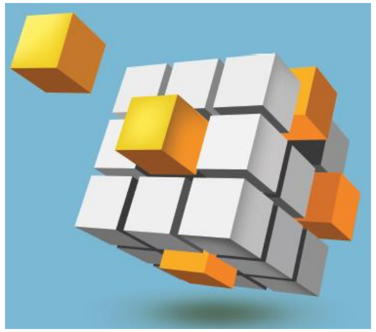
RECOMMENDATIONS

Build on the expanding consensus in support of CCUS deployment.

An expanded coalition of fossil fuel users and producers should collaborate to help develop and commercially deploy CCUS technologies on an accelerated time schedule.

Key Findings

- **Fossil fuels – including coal, natural gas and oil – will remain the dominant global energy source well into the future by virtue of their abundance, supply security and affordability.**
- **There is a growing consensus among industry, the environmental community and governments that future CO_2 emission reduction goals cannot be met by renewable energy sources alone and that CCUS technologies for all fossil fuels will have to be deployed to achieve climate objectives in the U.S. and globally and to ensure a reliable power grid.**
- **CCUS is not exclusively a "clean coal" strategy and will ultimately need to be adopted for all fossil fuels in the power and industrial sectors.**



CO_2 Utilization Imperative

- **Fossil fuels are dependent upon CCUS technologies to comply with U.S. GHG emission reduction requirements.**
  - PSD/Title V Permitting
  - GHG Performance Standards for New Coal-based Power
  - Clean Power Plan
  - International GHG Mitigation Goals

CO2 Building Blocks

Assessing CO_2 Utilization Options

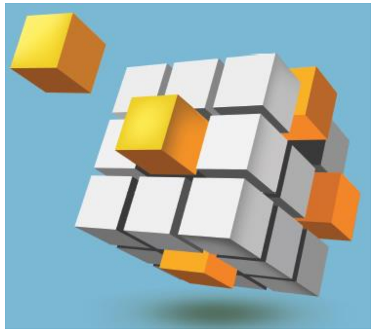
RECOMMENDATIONS

Continue to focus Federal policy on encouraging geologic utilization and storage pathways.

Some non-geologic pathways – such as polymers - hold promise as niche opportunities; additional research should be pursued.

Key Findings

- **CO_2-EOR still represents the most immediate, highest value opportunity to utilize the greatest volumes of anthropogenic CO_2.**
- **Aside from CO_2-EOR and other geologic pathways, research is underway on two general CO_2 utilization pathways – breaking down the CO_2 molecule by cleaving C=O bond(s) and incorporating the entire CO_2 molecule into other chemical structures. The latter pathway holds relatively more promise as it requires less energy and tends to "fix" the CO_2 in a manner akin to geologic storage.**
- **Utilizing CO_2 in non-geologic applications faces hurdles, including yet-to-be resolved issues associated with thermodynamics and kinetics involved in the successful reduction of CO_2 to carbon products.**



CO_2 Utilization Evaluation Criteria

- Global CCS Institute Report (2011)
  - Global demand for CO_2 ~ 80 million tons/year
  - Potential future demand ~ 300 million tons/year
  - CO_2-EOR one of several technologies showing large potential growth
- IEA CO_2-EOR Study (2015)
  - CO_2-EOR could lead to storage of 60,000 MTPY of CO_2
  - CO_2-EOR+ advanced technologies could increase to 240,000-360,000 MTPY
- Evaluation criteria can be used to prioritize R&D and commercial investment in CO_2 utilization technologies

CO2
Building Blocks
Assessing CO_2 Utilization Options

RECOMMENDATIONS

Evaluation criteria should be used to gather info about and compare CO_2 utilization technologies.

A technology ranking system can be used to prioritize candidates for RD&D and product investment.

Key Findings

- **Evaluation criteria fall into three broad categories:**
  1) **environmental considerations**
  2) **technology/product status**
  3) **market considerations**

- **Benefits of applying evaluation criteria include:**
  1) **making relative comparisons among technologies**
  2) **identifying priority technology candidates**
  3) **creating a more comprehensive ranking of the suite of CO_2 utilization technologies**
  4) **enabling revisions to technological assessments as market conditions change**

CO_2 Utilization Markets

Source: National Energy Technology Lab, DOE

CO_2 Markets – Geologic CO_2-EOR/ROZ

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Technically Recoverable Domestic Oil and CO_2 Storage Capacity, State of Art and "Next Generation" CO_2-EOR Technology

Basin/Area	Technically Recoverable Oil (Billion Barrels)		Technical CO2 Demand/Storage (Million Metric Tons)	
	SOA	**"Next Generation"**	**SOA**	**"Next Generation"**
1. Main Pay Zone CO2-EOR				
Lower-48 Onshore	55.6	105.5	22,270	33,050
Alaska	5.8	8.8	3,320	4,110
Offshore GOM	23.5	52.9	12,640	15,060
Sub-Total	**84.9**	**167.2**	**38,230**	**52,220**
2. Residual Oil Zone CO2-EOR				
ROZ Fairways*	n/a	25.7	n/a	17,100
Below Oil Fields	n/a	16.3	n/a	8,200
Sub-Total	**n/a**	**42.0**	**n/a**	**25,300**
Total	**84.9**	**209.2**	**38,230**	**77,520**

*Four County Permian Basin San Andres ROZ fairway.

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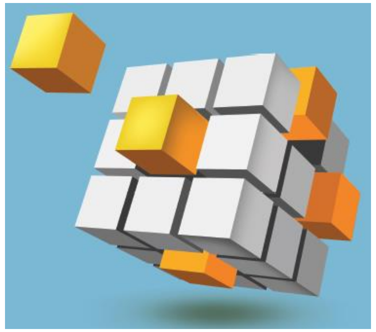

CO_2 Markets – Geologic CO_2-EOR/ROZ

	Recipients of CO_2-EOR Revenues*	Revenues
•	CO_2 Capture and Transporters	$1,210 billion
•	State, Local and Federal Treasuries	$1,130 billion
•	CO_2-EOR Investors (including Return on Capital)	$1,270 billion
•	General Economy/Mineral Owners	$2,060 billion
	Total	$5,670 billion

*Assuming an oil price of $70/B.

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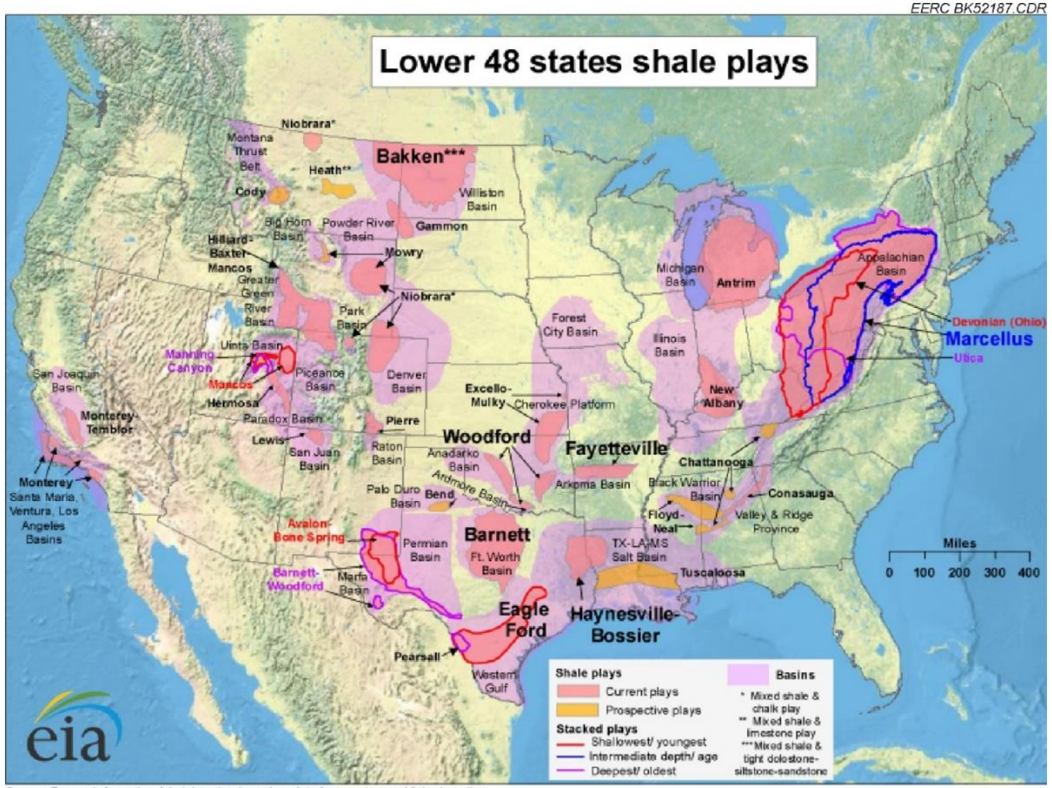
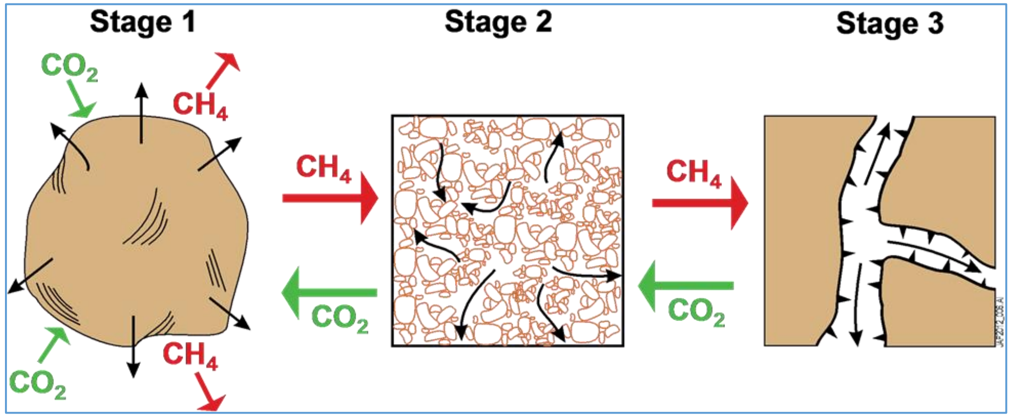
CO_2 Markets – Geologic – Shale & ECBM

U.S. Regions with Potential to Produce Oil and Gas from Shales and Other Unconventionally Tight Rock Formations



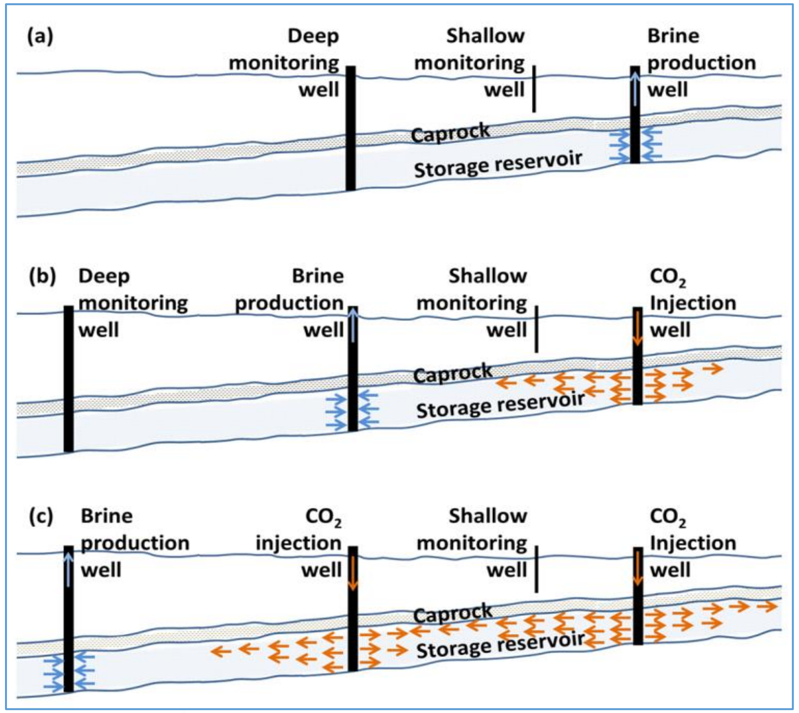
Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Enhanced Coal Bed Methane
Schematic of the Flow Dynamics of CO_2 and CH_4 in Coal Seams

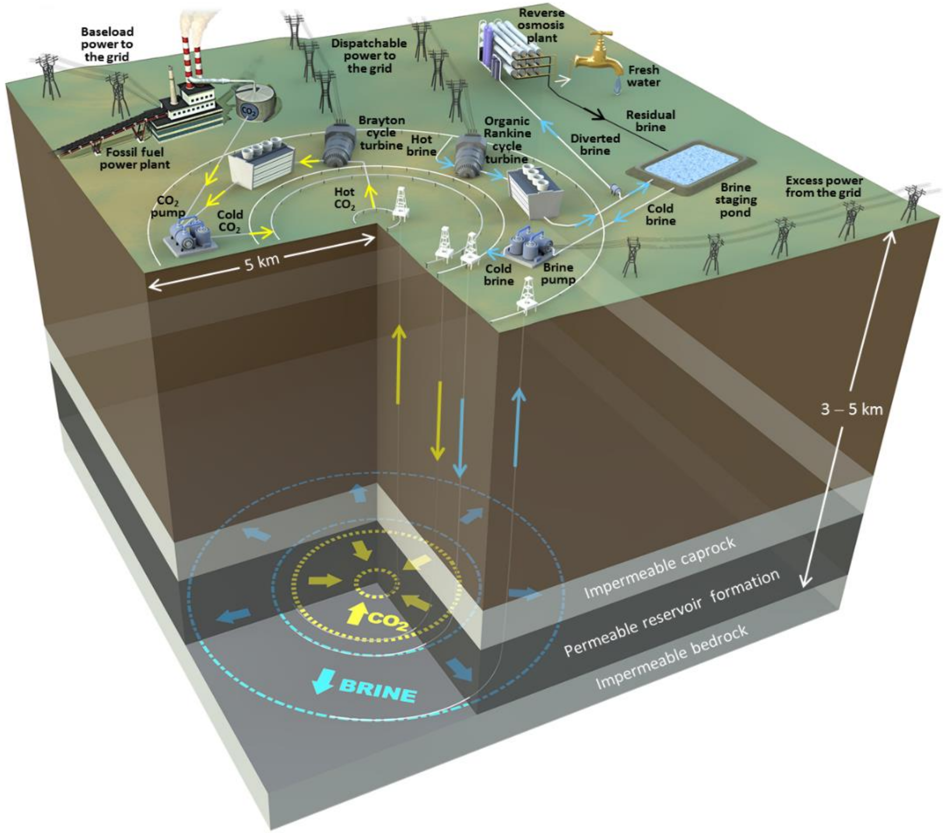


CO_2 Markets – Geologic
Enhanced Water Recovery & Geothermal Storage

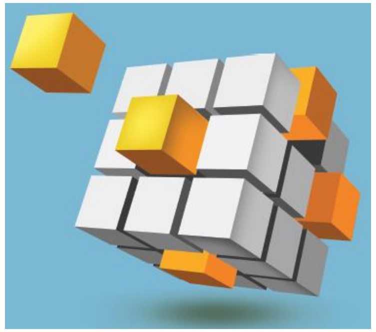
Staged pre-injection brine production



Multi-fluid Geo-energy System with Four Rings of Horizontal Injection and Production Wells



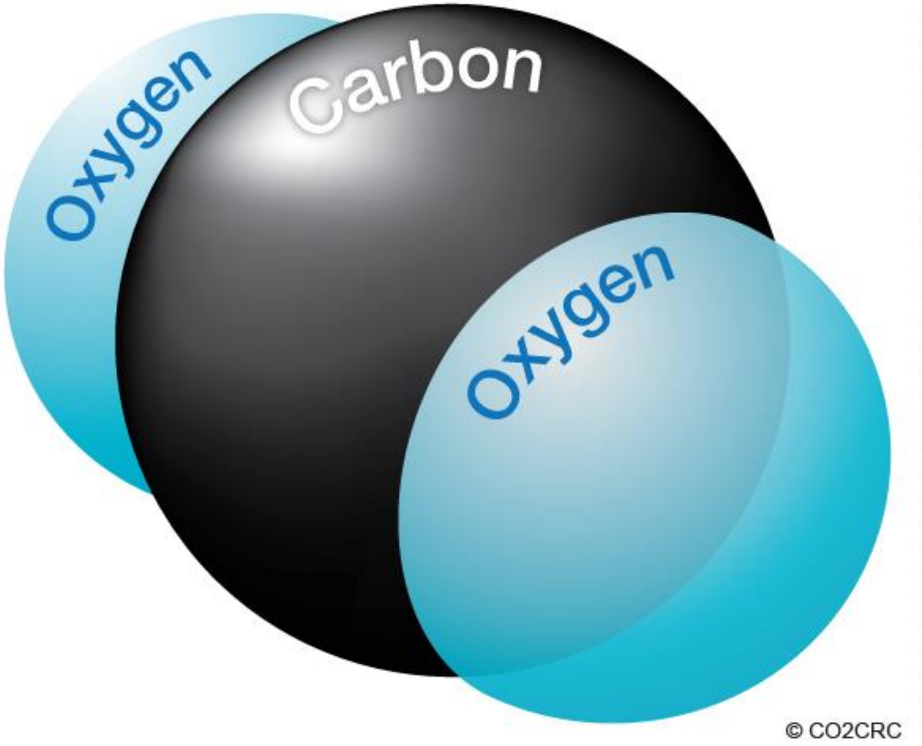
Source: Buscheck et al. 2016a

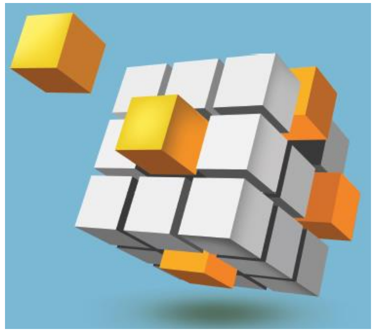


CO_2 Markets – Non-Geologic

Two Pathways to CO_2 Non-Geologic Utilization

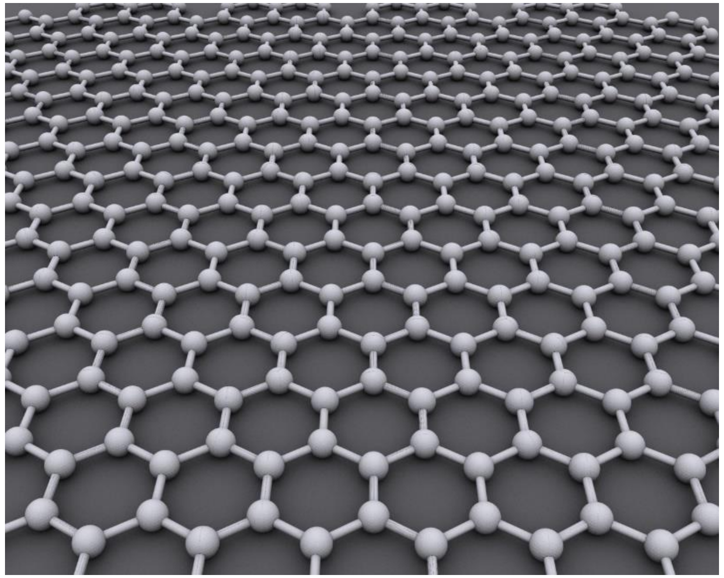
- Cleaving - Breaking down the CO_2 molecule by cleaving C=O bond(s)
- Intact/Fixed – Incorporating the entire CO_2 molecule into other chemical structures

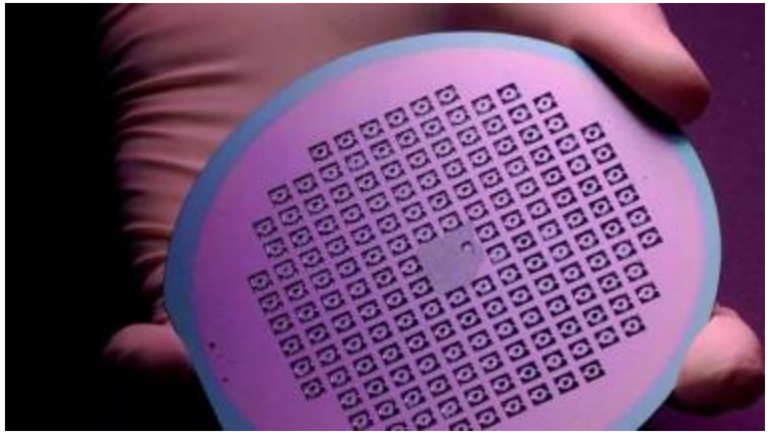




CO_2 Markets – Non-Geologic Inorganic Carbonates & Bicarbonates

- Inorganic Carbonates & Bicarbonates
  - Carbon Products – carbon black, activated carbons, nanofilters, graphene
  - Cement & Aggregate Products
  - Buffers & Other Chemical Products – baking soda, potassium bicarbonate





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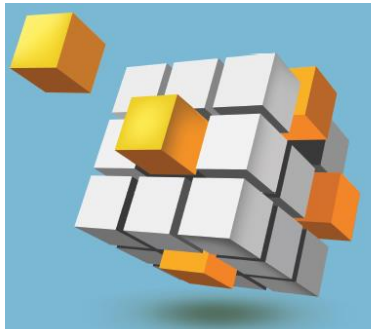

CO_2 Markets – Non-Geologic Plastics & Polymers

- Plastics & Polymers
  - Functional Polymers
  - Synthesized Polymers

ASAHI KASEI PLASTICS
Advanced Material Solutions

BAYER

BASF
The Chemical Company

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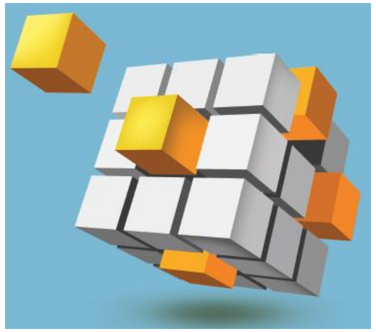
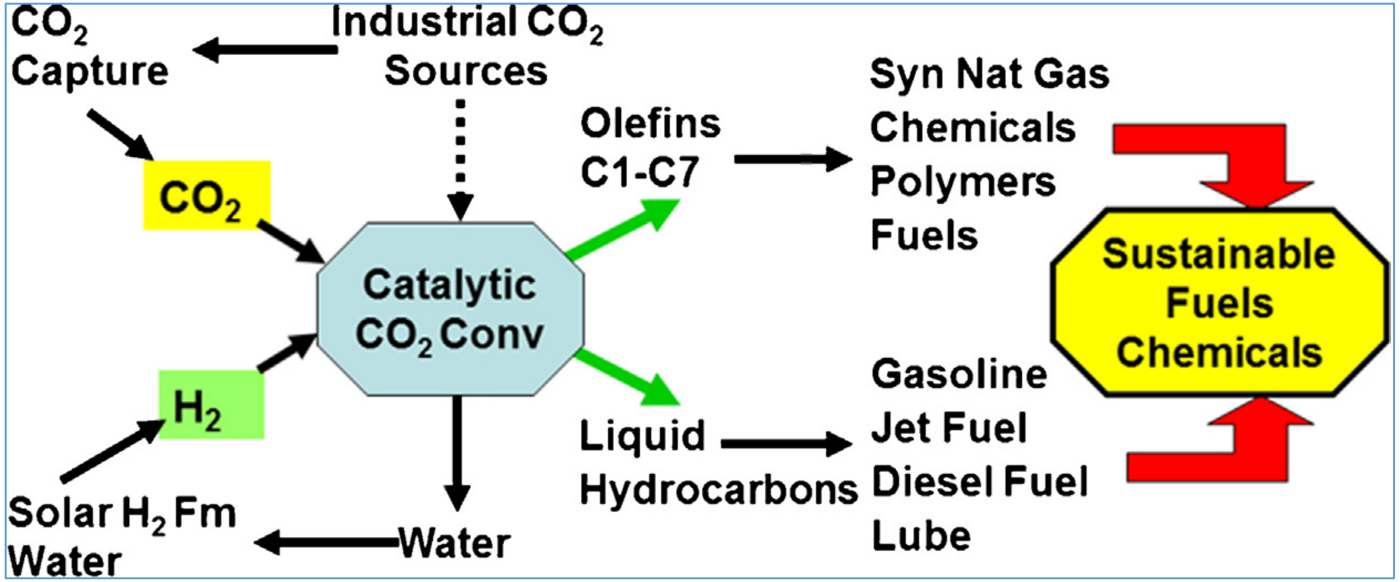
RWE
The energy to lead



CO_2 Markets – Non-Geologic Organic & Specialty Chemicals

- Organic & Specialty Chemicals
  - Urea
  - Ethylene & Propylene
  - DMC – Dimethylcarbonate Synthesis
  - Acrylic Acid
  - Solvents – compressed CO_2 cylinders, liquid CO_2, dry ice

Conceptual system for CO_2-based sustainable chemicals and fuels



Source: Satthawong et al. 2013

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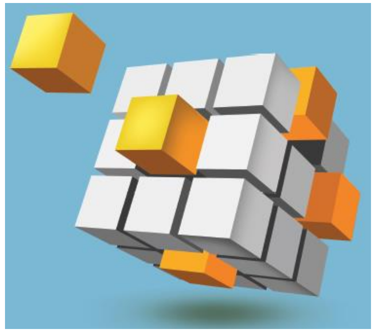

CO_2 Markets – Non-Geologic Agricultural Fertilizers

Estimated Crop Yield Increase with Carbon Addition in Fertilizers

Type of Crop	Estimated Increase in Yield With Carbon Addition
Wheat	3%
Corn	8%
Soy Beans	8%
Potatoes	11%
Almonds	12%
Alfalfa	12%
Sweet Corn	20%
Tomatoes	25%
Grapes	30%
Apples	32%

Source: FB Sciences, Inc. 2015

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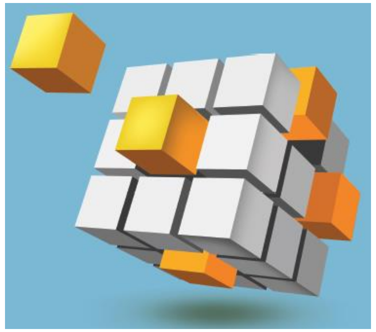

CO_2 Markets – Non-Geologic

- Food & Beverage = 50% of CO2 used globally for commercial applications

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CO_2 Markets – Non-Geologic - Fuels

- Fuels
  - Methanol
  - Hydrocarbon Fuels
  - Biological Processes – algae/microrganisms

Order of Magnitude Estimates for the Worldwide Capacity of CO_2 Utilization

Option of CO_2 Utilization	Worldwide Capacity (Order of Magnitude in Giga Ton Carbon)
Non-chemical Utilization	0.01 – 0.1 GtC per year
Chemicals & Materials	0.1 – 1 GtC per year
Synthetic Liquid Fuels	1 – 10 GtC per year

Source: Song, 2002

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CO2 Building Blocks

Assessing CO_2 Utilization Options

RECOMMENDATIONS

- Policymakers should continue to focus on advancing geological storage options through support for RD&D and adoption of incentives.
- As part of Mission Innovation, DOE should reinvigorate its RD&D program on advanced ("next generation") CO_2-EOR technologies.
- DOE should sponsor a full evaluation of the technically recoverable and economically viable domestic ROZ resource to more completely understand the market for CO_2 from EOR.

Key Findings

- **Geological CO_2 utilization options have the greatest potential to advance CCUS by creating market demand for anthropogenic CO_2. Non-geological CO_2 utilization options are unlikely to significantly incentivize CCUS in the near- to intermediate-term because of technical, GHG LCA considerations, challenges regarding scalability and related reasons.**
- **CO_2-EOR – including production and storage activities in residual oil zones (ROZ) – remains the CO_2 utilization technology with the greatest potential to incentivize CCUS.**

CO_2 Building Blocks

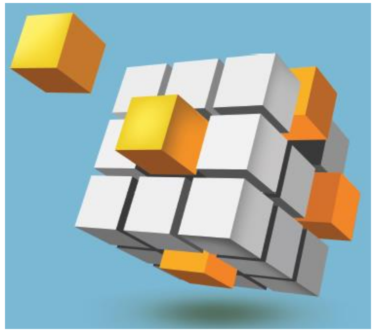
Assessing CO_2 Utilization Options

RECOMMENDATIONS

- Additional technical and economic research should be directed towards the following non-geologic utilization products and pathways: (1) inorganic carbonates and bicarbonates; (2) plastics and polymers; (3) organic and specialty chemicals; and (4) agricultural fertilizers.
- GHG LCA of all CO_2 utilization options should be undertaken.

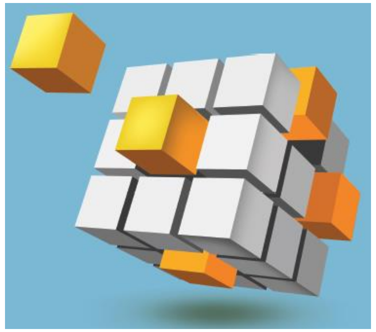
Key Findings

- Some non-geologic utilization opportunities are promising incentives for CCUS in that they tend to "fix" CO2 so have the advantage of potentially serving as preferred carbon management solutions. These include (1) inorganic carbonates and bicarbonates; (2) plastics and polymers; (3) organic and specialty chemicals; and (4) agricultural fertilizers.
- CO_2 may also be utilized through chemical and biological processes to produce transportation fuels, which is a very large market. This pathway is unlikely to incentivize CCUS in the immediate future because 1) these fuels are ultimately combusted and thus release CO_2 to the atmosphere and 2) current U.S. policy favors geologic-based utilization pathways for CAA compliance. And while the case could be made that some CO_2-derived transportation fuels have lower GHG emissions than fossil-based fuels on a GHG LCA basis, non-fossil-based transportation fuels still face significant market competition and displacement hurdles.



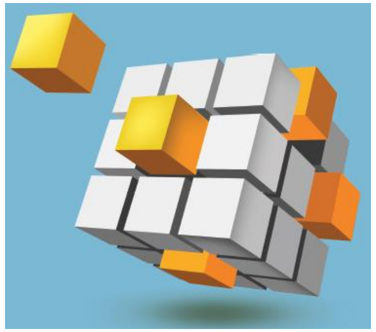
CO_2 Markets as Incentives for CCUS

- Monetary, regulatory and policy investments in the following CO_2 utilization and storage technologies, in descending order, are most likely to incentivize the deployment of CCUS technologies:
  - Current CO_2–EOR Technology
  - State-of-the-Art CO_2–EOR Technologies
  - Other geologic storage technologies that provide economic return
  - Saline Storage
  - Non-geologic storage technologies that provide economic return and that are as effective as geologic storage
  - Non-geologic storage technologies that provide economic return yet are not as effective as geologic storage if appropriate EPA research waivers may be obtained



CO_2 Markets as Incentives for CCUS

- U.S. law recognizes CO_2–EOR and other geologic storage technologies for compliance purposes.
- Non-geologic storage technologies may be used only if EPA determines they are as effective as geologic storage.
- U.S. climate goals and non-binding international climate goals require CCUS technology deployment at scale in the near future.



CO_2 Markets as Incentives for CCUS

- CO_2 utilization in non-geologic contexts face the following hurdles:
  - Cost of capture
  - Insufficient scope of market/supply
  - Nearly all non-geologic CO_2 utilization technologies are not yet commercialized
  - Geographic/infrastructure considerations
  - Legal and regulatory considerations

NATIONAL COAL COUNCIL

CO2 Building Blocks

Assessing CO_2 Utilization Options

RECOMMENDATIONS

- A regulatory based, incentive and tax compliant framework that provides a well-defined no-regrets economic calculus that limits the loss-of-capital to the investment community in FOAK (first-of-a-kind) CCUS projects should be developed.
- Monetary, regulatory and policy investments in CO_2 utilization technologies should be roughly prioritized from geologic to non-geologic, with exceptions made if non-geologic technologies are found to be as effective as geologic storage.
- Assessments should include in all CO_2-dependent products a full life-cycle CO_2 accounting of the displacement of current fossil sources of captured CO_2 by those that utilize CO_2 capture from fossil resources.

Key Findings

- **U.S. law currently favors geologic storage/utilization technologies; laws mandate that non-geologic CO_2 uses demonstrate that they are as effective as geologic storage.**
- **Timing of U.S. and international climate goals point towards the use of CO_2 utilization technologies that are either already commercialized or near commercialization.**
- **There is a misalignment of needs between industries who would utilize CO_2 and the power sector.**
- **CCUS technology deployments face a host of unresolved impediments that are unlikely to be mitigated by market demand for CO_2 alone in any near- to intermediate-term scenario.**
- **With the exception of geological utilization under appropriate circumstances, CO_2 utilization is unlikely by itself to incentivize CCUS technologies.**

CO2 Building Blocks

Assessing CO_2 Utilization Options

RECOMMENDATIONS

- More economic and technical research and analysis need to be conducted on CO_2 utilization in non-geologic options, including chemicals and fuels.
- The focus of this additional research and analysis should take into account the criteria for review of CO_2 utilization technologies detailed in this report.
- Additional research should be supported regarding advancing the following technologies toward commercialization: 1) inorganic carbonates and bicarbonates; 2) plastics and polymers; 3) organic and specialty chemicals; and 4) agricultural fertilizers.

Key Findings
Economic Opportunities

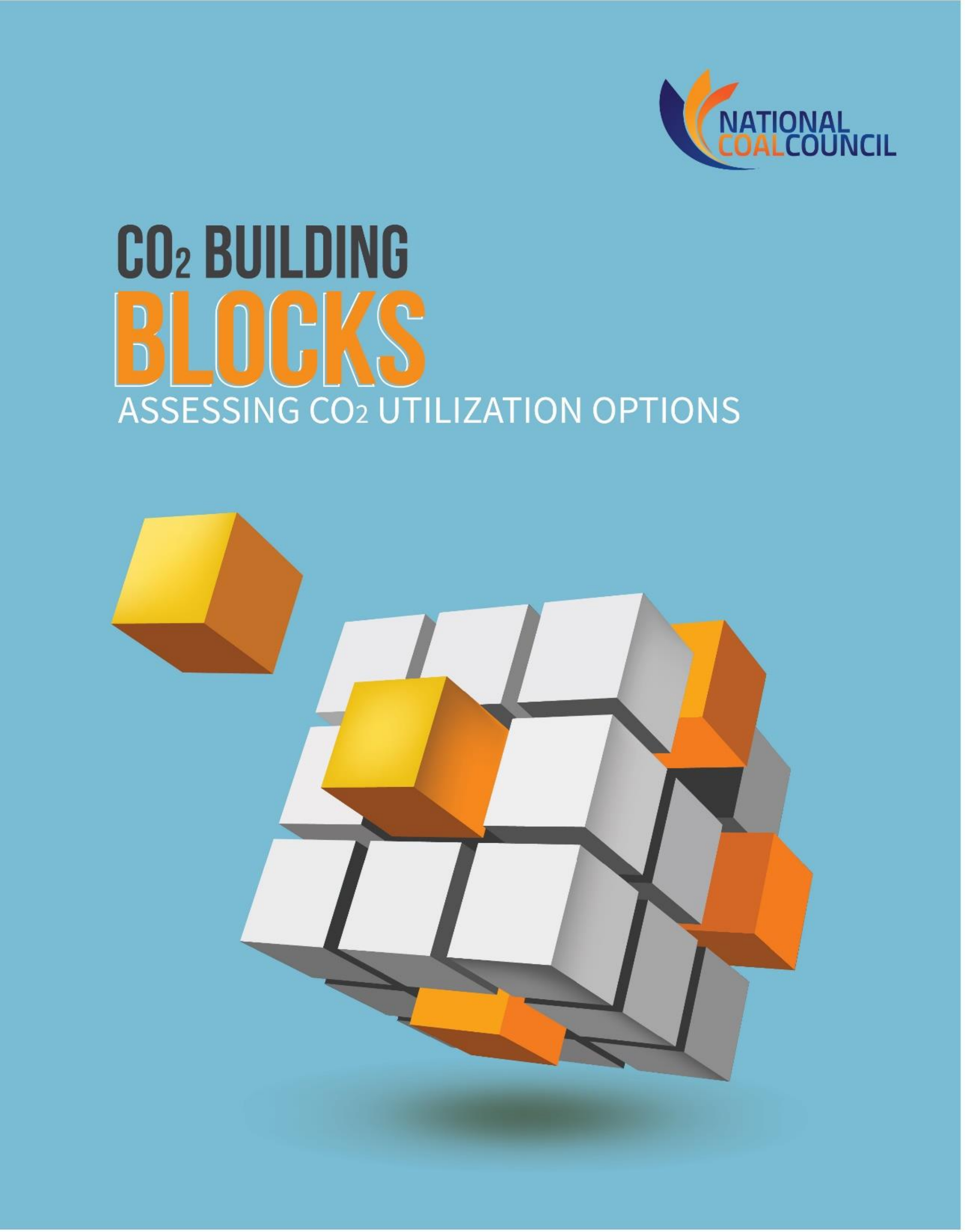
- **Applying various evaluation criteria, the primary economic opportunity for the United States associated with commercial-scale CCUS deployment remains geologic storage associated with energy production. These include: 1) CO_2-EOR; 2) ROZ; 3) organically-rich shales; and 4) ECBM.**
- **The economic incentive potential of all other pathways (to include all non-geologic options) is largely unquantifiable based on publicly available data. Moreover, such options face a host of known technical, economic and policy hurdles.**

Summary Primary Recommendations

- Geological CO_2 utilization options have the greatest potential to advance CCUS by creating market demand for anthropogenic CO_2. Policymakers should continue to focus on advancing geological storage options through support for RD&D and adoption of incentives. As part of Mission Innovation, DOE should reinvigorate its RD&D program on advanced ("next generation") CO_2-EOR technologies.
- Non-geological CO_2 utilization options are unlikely to significantly incentivize CCUS in the near- to intermediate-term because of technical, GHG LCA considerations, lack of scalability and related reasons. Those technologies that can "fix" CO2 molecules intact, akin to geologic storage, hold the most promise and are worthy of continuing evaluation, including inorganic carbonates/bicarbonates, plastics/polymers, organic/specialty chemicals and agricultural fertilizers.
- There is a benefit to establishing a technology review process that is as objective as possible to assess the benefits and challenges of different CO2 utilization technologies and products. Technologies should be evaluated on the basis of: 1) environmental considerations, 2) technology/product status and 3) market considerations.

Summary Primary Recommendations

- U.S. law recognizes CO_2-EOR and other geologic storage technologies as compliance options; non-geologic technologies may be used only if EPA determines they are as effective as geologic storage. Aligning CO_2 production and utilization markets may require relaxing terms of compliance for CO_2 emitting utilities and industrial facilities, as well as providing for establishment of an inventory of unused CO_2 in geologic storage. Appropriate policy and regulatory relief for higher-risk CCUS projects may also incentivize investment from the venture capital community.
- U.S. and international GHG reduction objectives and timeframes dictate the need to employ CO_2 utilization technologies that can be quickly commercialized at significant scale. Monetary, regulatory and policy investments in CO_2 utilization technologies should be roughly prioritized from geologic to non-geologic, with exceptions made for any non-geologic technologies that are found to be as effective as geologic storage. To identify the most expeditious and impactful technology options, NCC suggests applying a reasonable market potential threshold of 35 MTPY, which is roughly equivalent to the annual CO_2 emissions from about 6 GWe or a dozen 500 MWe coal-based power plants.



Questions?

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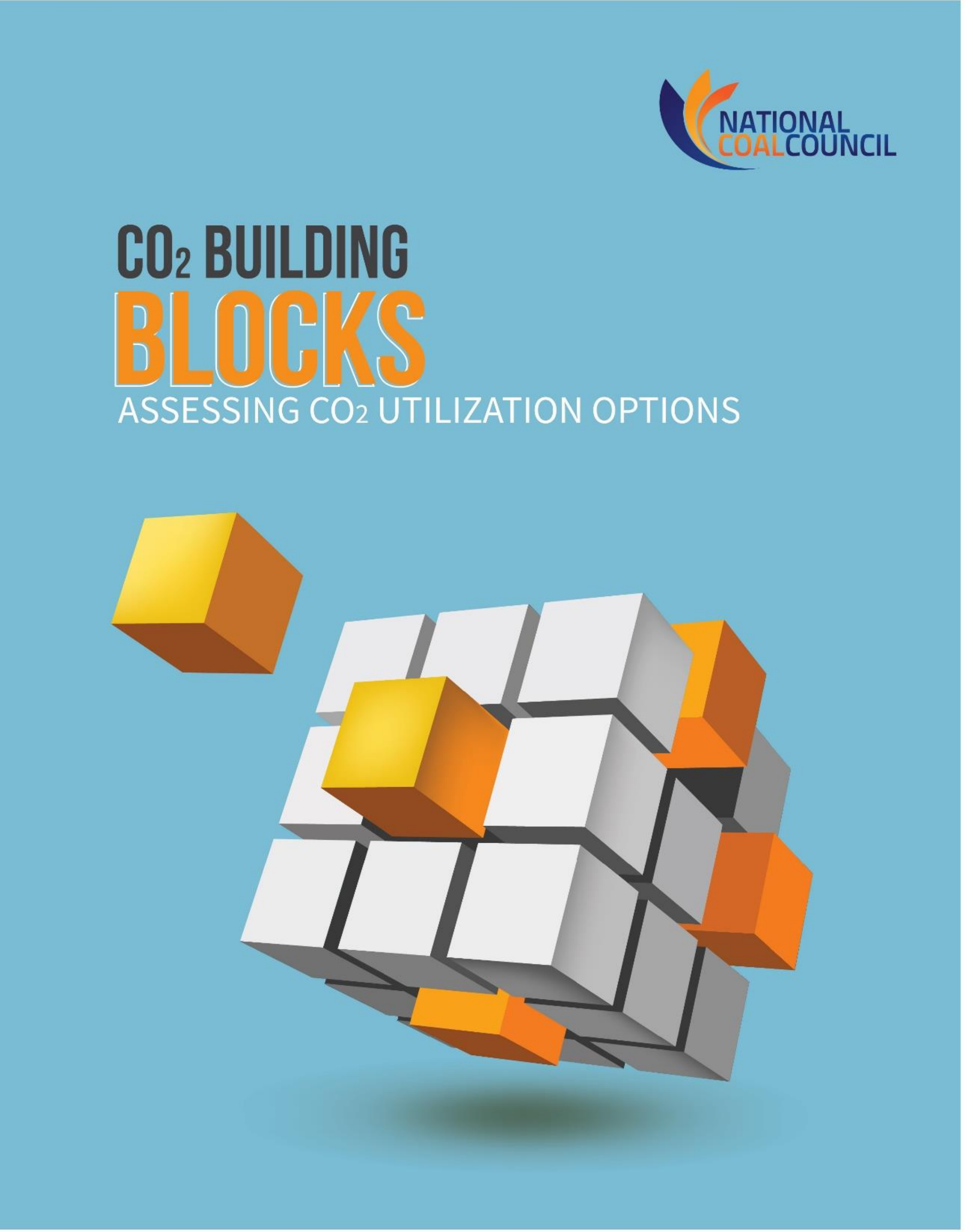

NCC Members' Supplemental Comments

Due Friday September 2, 2016

3-page limit

Submit to jgellici@NCC1.org

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