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De-Risking Carbon Capture Storage

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- Nonprofit, charitable trust formed in 1925
- Our mission: To translate scientific discovery and technology advances into societal benefits

Gordon Battelle, Founder

Applied Science and Technology

Addressing big challenges

Climate Resilience

Space & Hypersonics

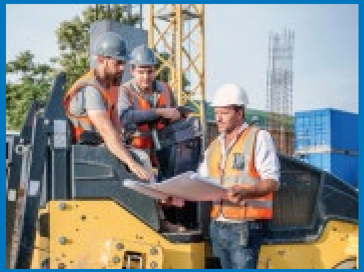
Neurotechnology

PFAS

Research Infrastructure

Microelectronics Trust & Assurance

CCS Deployment



H_2 and DAC Deployment

Enhanced Geothermal

REE / CM

Plastics Upcycling/Recycling

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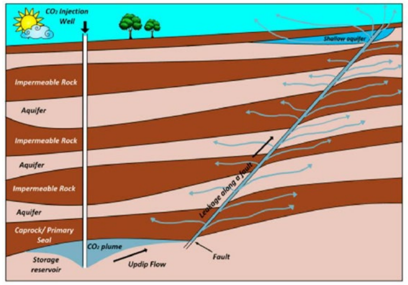
Outline of Presentation

- Introduction
- Literature Review
- Listening Sessions and De-Risking Workshop Summary
- Emerging Technologies
- Summary and Conclusions

Introduction

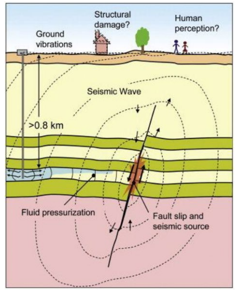
Goal: To better understand issues surrounding de-risking CCS, particularly as they relate to the finance and insurance/ reinsurance and finance industries.

Three different risks are unique for CCS projects and warranted further investigation:



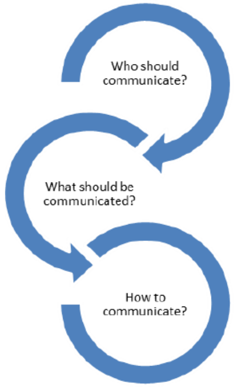
Bachu & Celia, 2013

CO_2 Leakage



Hurtado et al., 2021

Induced Seismicity



Public Acceptance

Introduction

- Approach involved research/literature review
- Applying the perspective of the insurance / reinsurance and finance industries through interviews and workshop
- Focused on all phases of storage (Pre-operations, operations, and post-injection site care [PISC])

Intended to provide an initial framework for necessary conversations

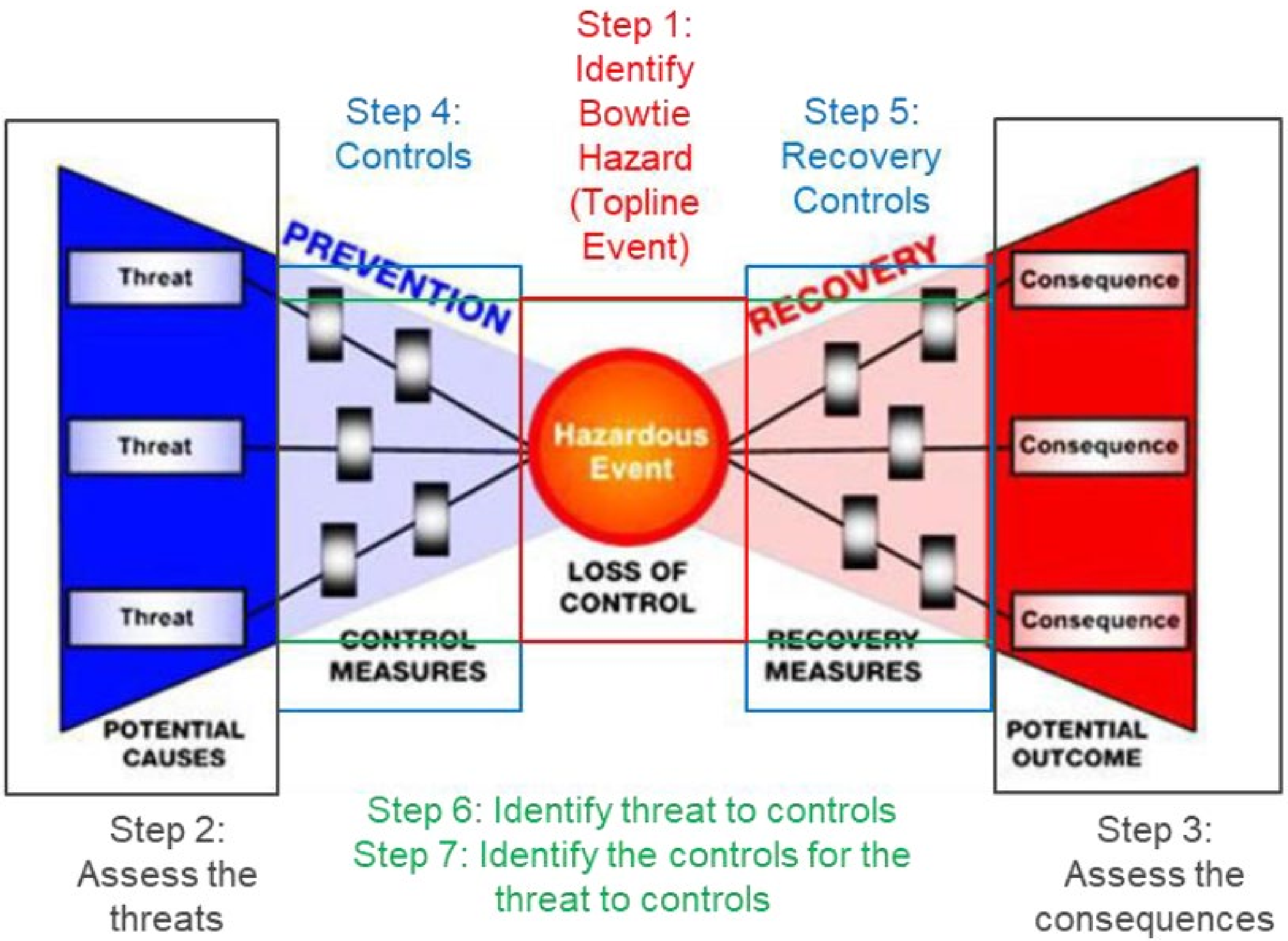
LITERATURE REVIEW

Planning for Risk

1. Provide context for risk management (Project / Location specific)
2. Determine risk assessment methods (Quantitative, Qualitative, or combination)
3. Rank the risks based on the risk assessment
4. Ensure adequate risk mitigation through proactive planning (Risk Mitigation Plan)

DOE/NETL, 2017

Introduction to the Bow-Tie Method

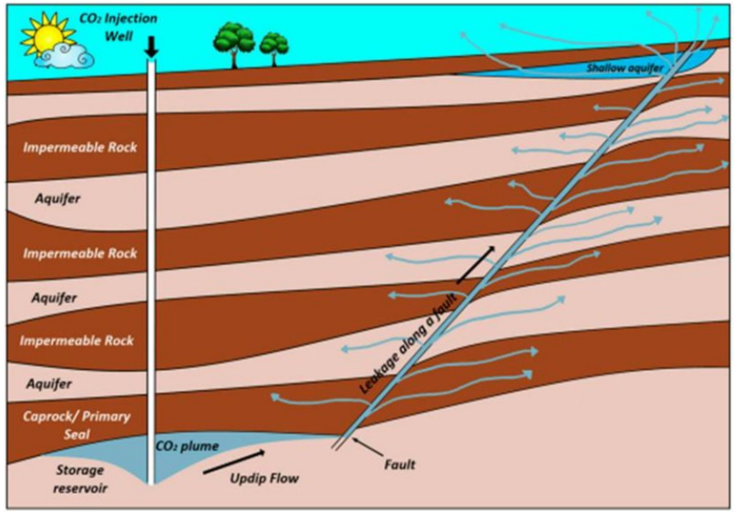


Adapted From: Alizadeh & Moshashaei, 2015

CO_2 Leakage – Process

- Leakage pathways
  - Caprock/Vertical Migration
  - Transmissive Faults (Figure)
  - Artificial Penetrations/Wellbores (Figure)

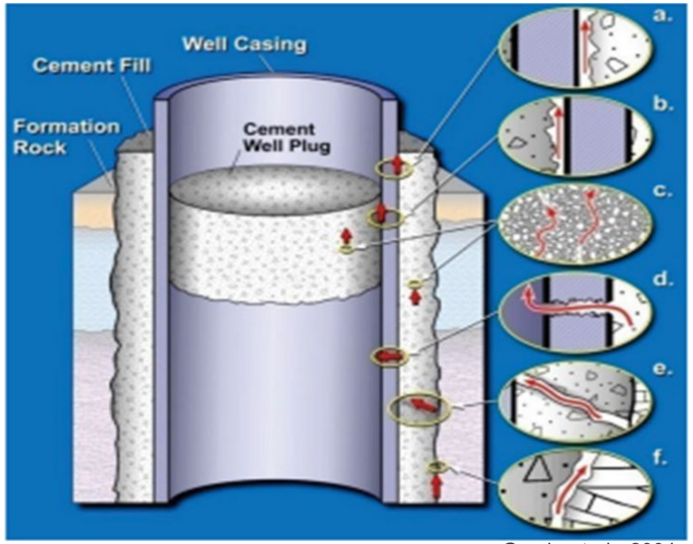
Transmissive Faults



Bachu & Celia, 2013

Possible receptors
Atmosphere
USDW (shallow aquifer)
USDW (deep aquifer)
Caprock / Primary seal

Artificial Penetrations



Gasda et al., 2004.

Leakage pathways
Btw. casing / borehole cement
Btw. casing / cement plug
Through cement
Through casing
Through fractures
Btw. cement / formation

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Bow-Tie Method: CO_2 Leakage

CO_2 Leakage

- Caprock/Vertical Migration
- Transmissive Faults
- Artificial Penetrations/ Wellbores

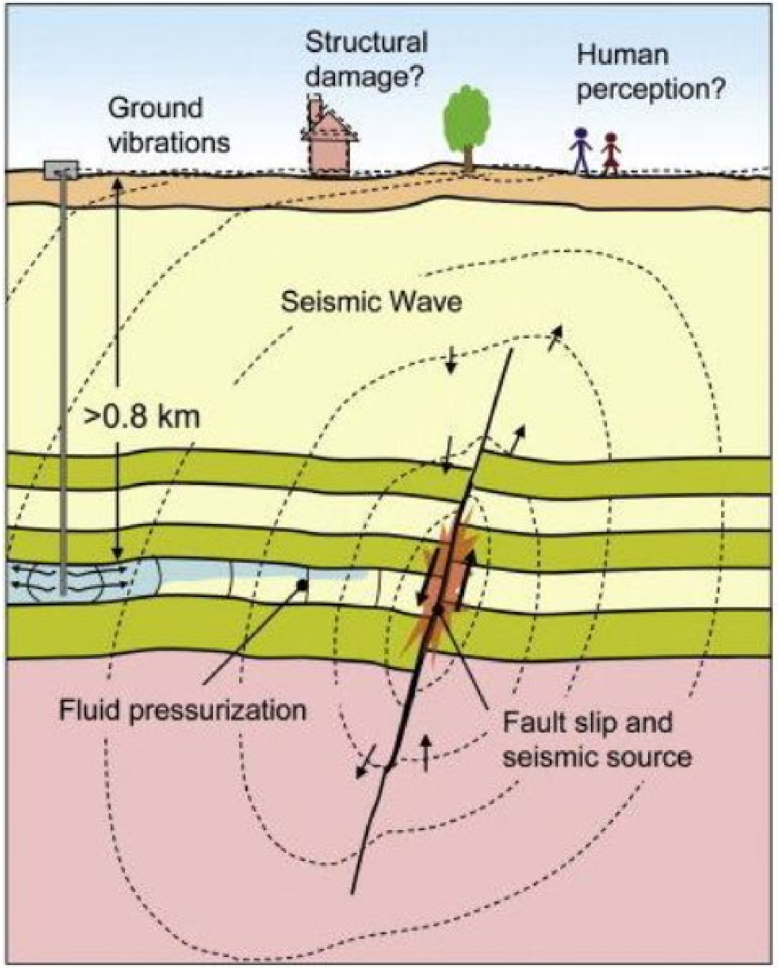
- Impacts to groundwater, surface water, and ecosystems
- Impacts to subsurface
- Impacts to surface land use, mineral extraction
- Asphyxiant (significant accumulations only)
- Costs of responding to leaks (monetary, mission, and trust)

- Site Selection
- Safety inspection / ID wellbores and faults
- Monitoring
- Regulatory oversight
- Well construction / operations
- Natural trapping mechanisms

- Reservoir engineering / operational controls
- Correcting loss of well integrity
- Environmental remediation

Induced Seismicity – Process

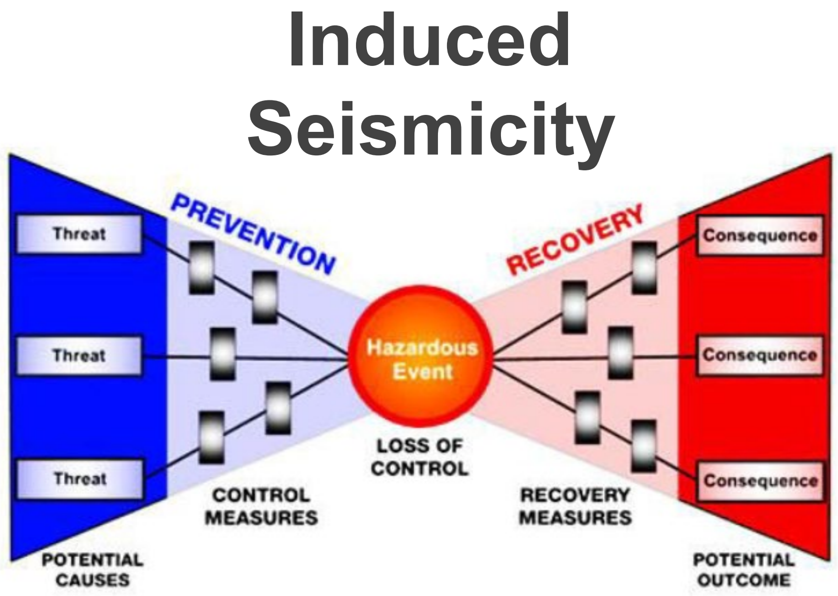
- Injection stresses acting on pre-existing fault (Figure)
- Proxy: Injection of wastewater



Hurtado et al., 2021

Bow-Tie Method: Induced Seismicity

- Injection stresses acting on pre-existing fault



- Felt seismic event:
  - Operational delays
  - Public mistrust
  - Structural damage (significant events only)

- Site Selection
- Safety assessment
- Regulatory oversight
- Operational constraints
- Mitigation plan (traffic light system, checklists/protocols, expert panels)

- Early evaluation/operational updates
- Seismic PISC
- Insurance

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Public Acceptance – Process

- Ineffective public outreach could delay project or make project untenable
- Project communications should start early and be continual throughout the project

WHO?

WHAT?

WHERE?

WHEN?

HOW?

Bow-Tie Method: Public Acceptance

Public Acceptance

- Concerns, real or perceived
- Inaccurate communication
- Appropriate siting

- Project delays
- Project cancellation
- Technology implementation delays

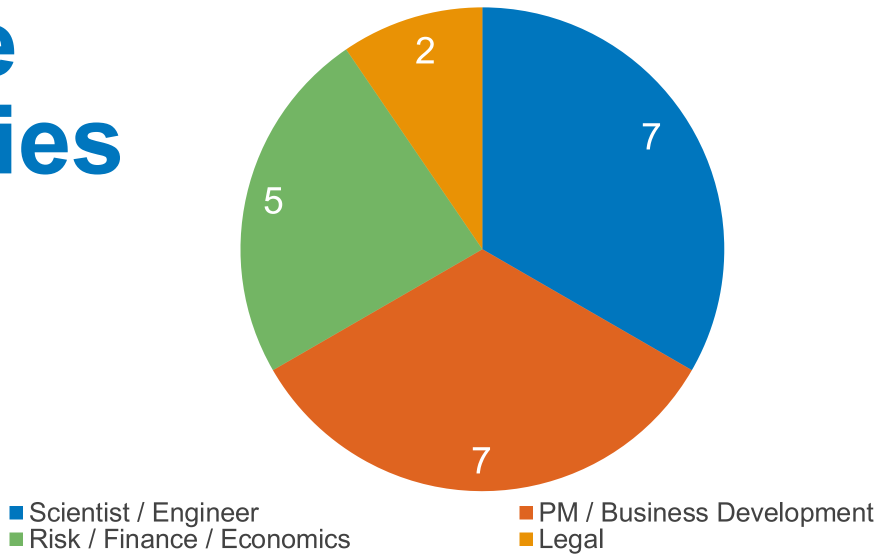
- Effective, proactive project communication
- Introduce major parties to communities
- Include the right people
- Tailor to who you are trying to reach
- Use multiple venues, times, and methods
- Ensure community benefits

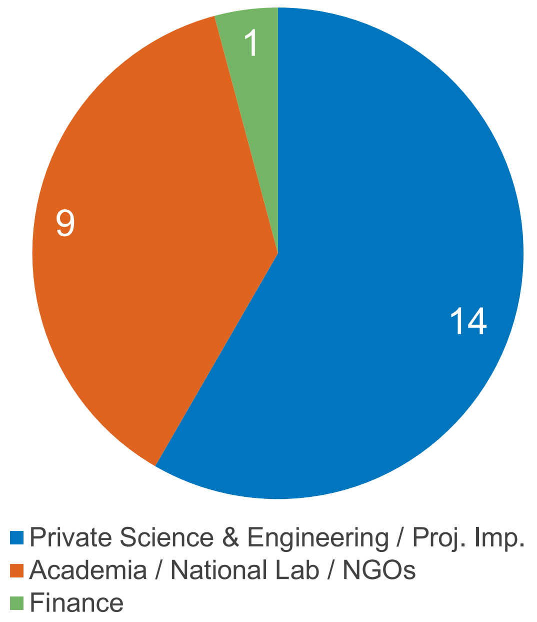
- Crisis Management / Public Relations team
- Outline protocols for crisis response
- Contact emergency response, community leaders, regulators, etc.

LISTENING SESSIONS AND WORKSHOP

Applying the Perspective of the Insurance/Reinsurance Industries

- Several one-on-one and group conversations with relevant experts
- Four questions asked of each person and group:
    1. What are the most important issues to consider when de-risking CCS?
    2. What assurances are needed to ensure the risk is acceptable?
    3. What are the gaps in understanding CCS risks from your point of view?
    4. What has not been asked that is important to consider relative to de-risking CCS projects now and/or in the future?





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What are the most important issues to consider when de-risking CCS?

- Consideration of issues related to the following areas:
  - Storage site selection
  - Permitting and approval process for Class VI wells
  - Long term liability/project close-out uncertainty
- Need for robust site-specific risk management plan / transparency
- Appropriate safety mechanisms and integrity of operations
- Understanding the experience gap and limitations of proxies
- Holistic project management – What happens at project closeout?
- Trust is essential

What assurances are needed to ensure the risk is acceptable?

- Effective enablers in de-risking potential CCUS projects:
  - Implementation efforts by ethanol are great gateway industries.
  - Site must be well-characterized, well-operated, and well-managed.
  - Successful permitting would play a key role for financial insurance.
- Additional quality data / characterization
- Assessing integrity / seals
- Reputation of the technical team
- Land access / pore space availability
- Quantitative Risk Analyses

What Are the Gaps in Understanding CCS Risks from Your Point of View?

- The participants discussed the following key gaps in understanding CCS risks:
  - Legislative clarity, or lack thereof, is a major gap.
  - Public perception relative to technology tied to induced seismicity concerns, which are highly manageable and predictable.
- Long-term risk – Who owns it and how long?
- Long-term business case
- Lack of operational history / experience

What has not been asked that Is important to consider relative to de-risking CCS projects now and/or in the future?

- Key takeaways on additional considerations:
  - Long-term liability issues associated with CCS and how will it be managed?
  - What is in place to keep people from perpetually injecting versus closing the well and initiating a monitoring protocol?
- How are CO2 wells integrated with other disposal wells?
- Miscommunications between agencies / developers
- Public opposition to projects
- Capture costs
- Do not underestimate the importance of relationships and trust

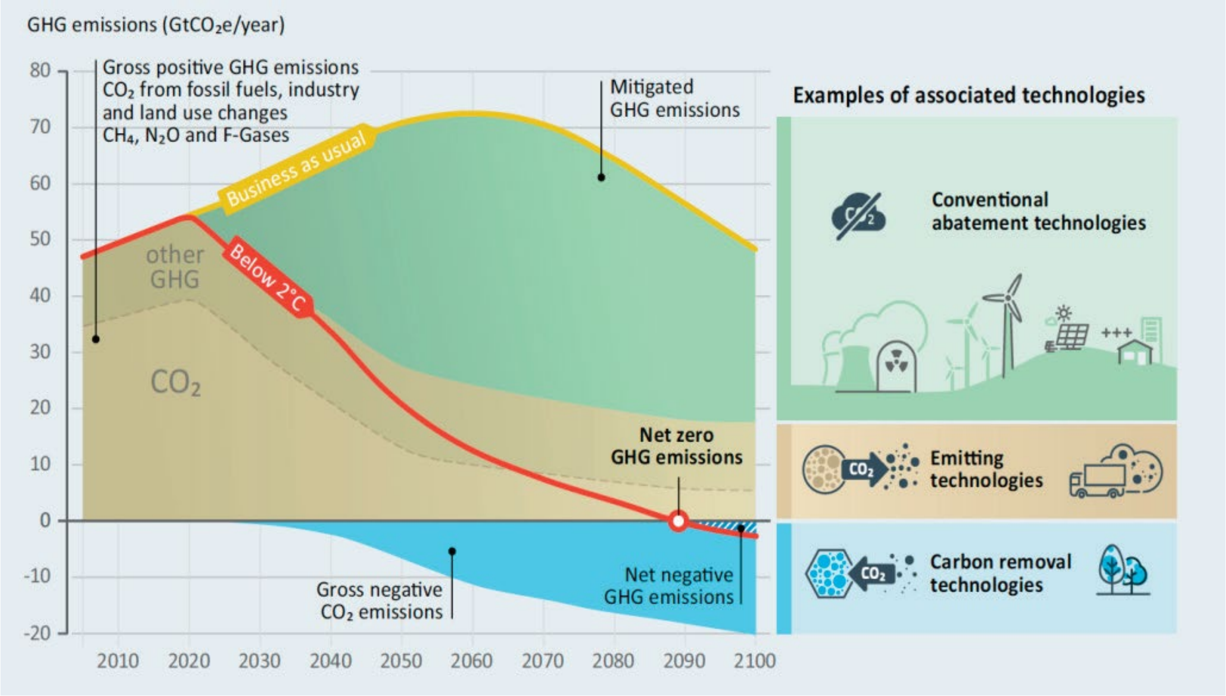
De-Risking CCUS: Paving the way for the Insurance and Finance industries

- Workshop held in September 2022
- Included many of the experts interviewed previously
- Five main topics covered
  - The basics of CCUS
  - DOE Priorities in De-Risking Carbon Capture
  - Risk Mitigation Opportunities
  - Project Implementation
  - The intersection of and de-risking CCUS and Environmental Justice
- Report contains a summary of the workshop

EMERGING TECHNOLOGIES / ISSUES

Emerging Technologies for Carbon Management

- Report focused on five technologies:
  - Direct Air Capture with carbon storage (DACCS)
  - Bioenergy with CCS (BECCS)
  - Reforestation / Afforestation
  - CO_2 Mineralization / Enhanced Weathering
  - Blue / Green Hydrogen
- Potential to support more rapid decarbonization
- Often have a lower Technology Readiness Level (TRL)



NASEM, 2019

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Direct Air Capture

- Capturing CO_2 from ambient air for use or storage
- Currently smaller scale
- DOE-supported DAC Hubs will accelerate development / deployment
- Unique risk characteristics:
  - Siting Balance
  - Must develop lifecycle assessments (LCAs) / strict sustainability criteria
  - Must study impacts on energy systems.

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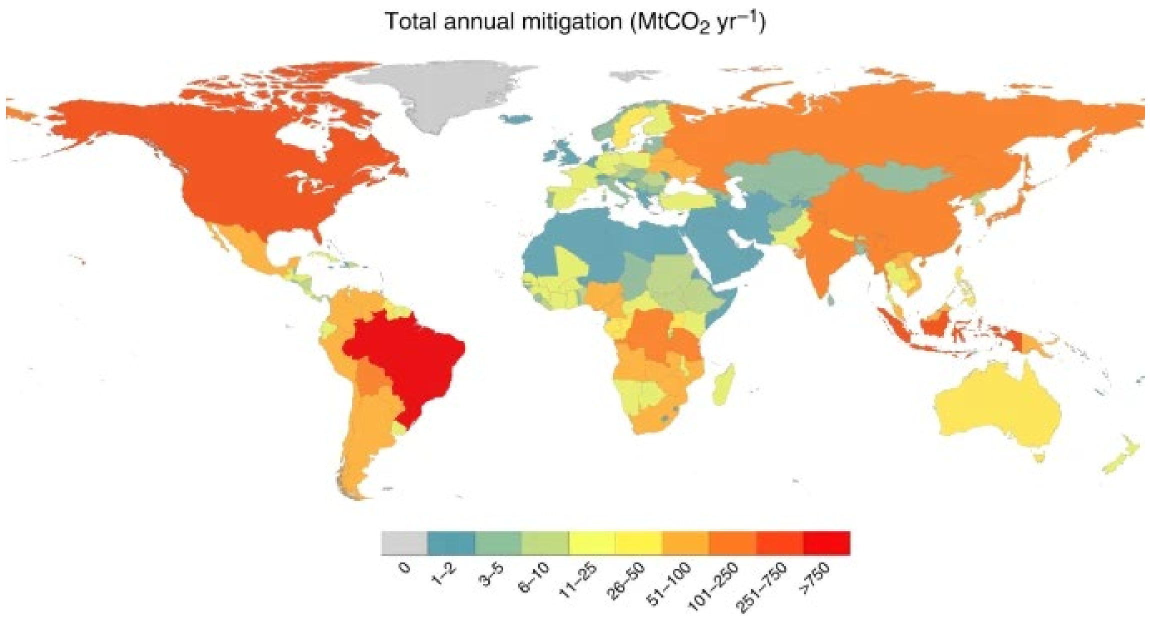
Bioenergy with CCS (BECCS)

- Biomass to generate electricity. Carbon is captured and stored.
- Supportive policy in U.S. enables BECCS
- Potential and impact is dependent on project details
- Unique risk characteristics:
  - Land intensive
  - Sustainability
  - Economic viability / affordability of power

Reforestation / Afforestation

- Replanting (reforestation) or establishment (afforestation) of forests
- High mitigation potential in North America, Brazil, Indonesia – highly dependent on land availability
- Already practiced
- Unique risk characteristics:
  - Permanence / Reversal
  - Disturbance events (fires, clearing, etc.)
  - Balancing land management



Austin et al. (2020)

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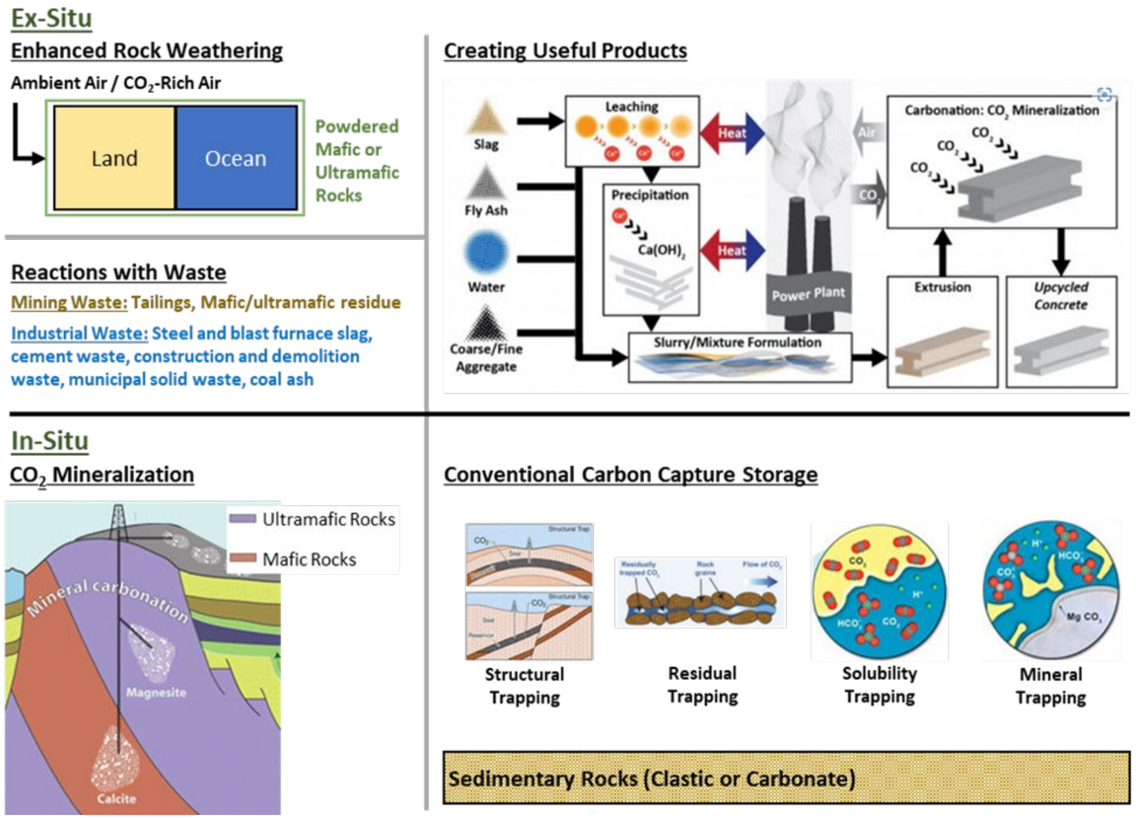
Enhanced Weathering / CO_2 Mineralization

- Reactions with CO_2 and mafic or ultramafic minerals- / wastes
- In-Situ / Ex-Situ methods
- Unique risk characteristics:
  - Low TRL / Requires Validation
  - Reaction kinetics
  - Land use considerations
  - Economics of useful products



Sandalow et al. (2021); Garcia del Real and Vidal, (2016); DOE (nd)

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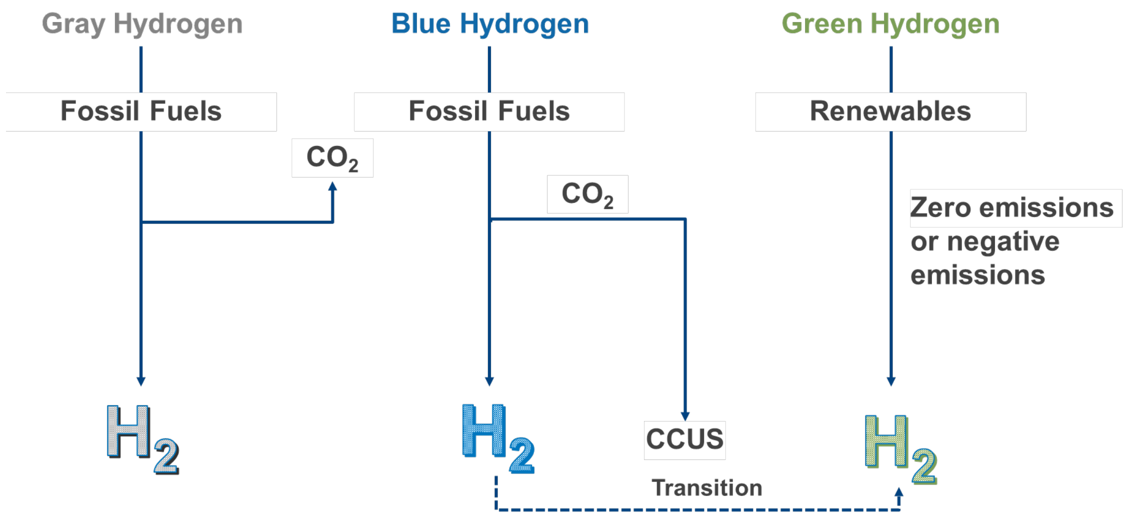
Blue / Green Hydrogen

- Steam methane reformation (SMR) with CCS (blue)
- Electrolysis with renewables (green)
- Blue hydrogen is bridge technology
- Emissions from multiple sectors dealt with
- Unique risk characteristics:
  - Additional research needed
  - Economics / Future demand



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Summary and conclusions

- CCS risk assessments must be site-specific, ongoing, and iterative
- Assessments require a broad set of capabilities
- Engagement conducted under this study are intended to translate technical information so wider audience / non-technical stakeholders can understand risks posed by CCS projects.
- Additional communication with project financers and insurers must continue. The project and report provides a framework for these discussions.

Conclusion from Expert Interviews

- The conversations were open, two-way, and appreciated!
- Several issues were raised:
  - CCS can be safe and effective with planning–this must be communicated
  - Trust and credibility are going to be crucial
  - Site and land accessibility / ownership remain a question in some jurisdictions
  - Lack of existing projects / uncertainty compounds the hesitation but can be overcome with the right communication and investigation
  - Effective site characterization can be this mitigating factor
  - Must communicate risk profiles as well as the technical aspects of CCS
  - Reputation of the companies involved with help provide credibility
  - The industry is well-regulated / Class VI is protective
  - Legislative clarity / public perception must be addressed

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