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CarbonCapture™

Direct Air Capture Team: Final Deliverable

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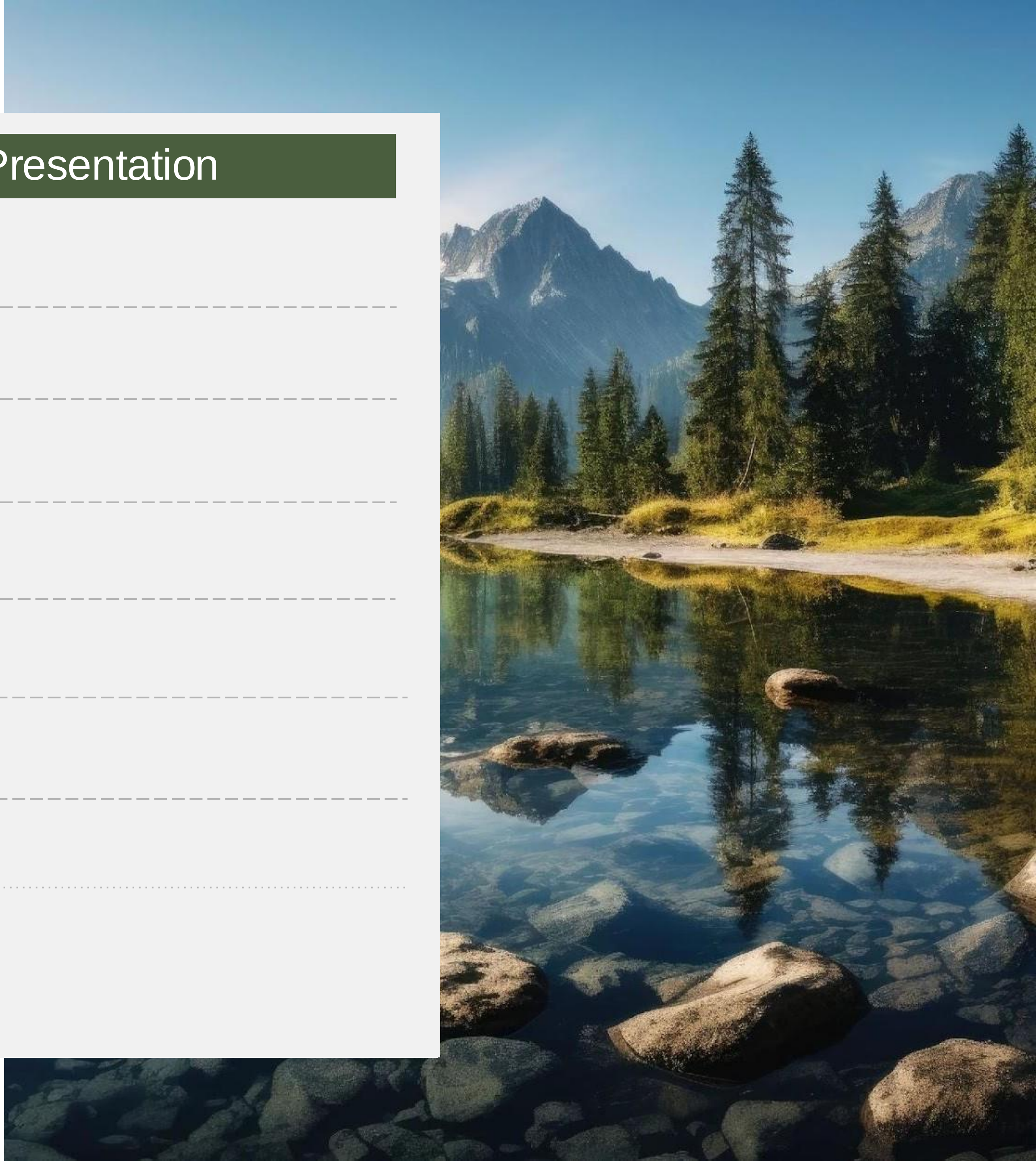
Agenda

NextGen | Student Impact Project Final Presentation

1. Problem Statement
2. Impact of DAC
3. Current State of DAC
4. Scaling Scenarios
5. CarbonCapture and Project Bison
6. Current Policy
7. Actions for CarbonCapture
8. Actions for stakeholders
9. Key Takeaways



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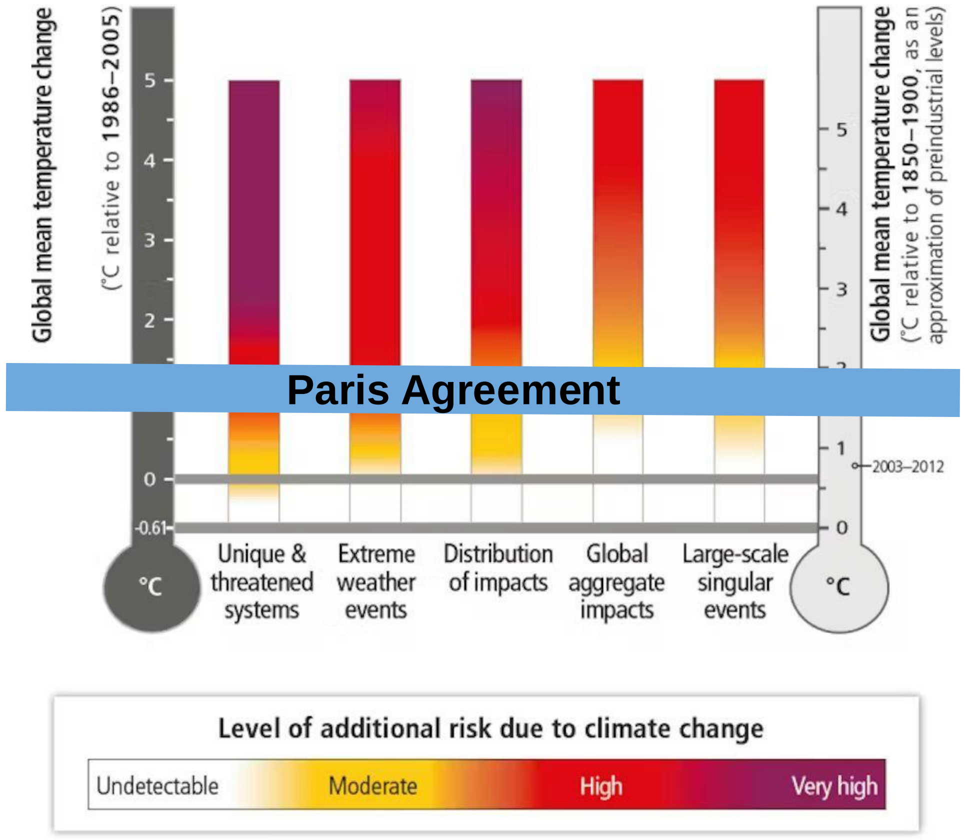
Problem Statement

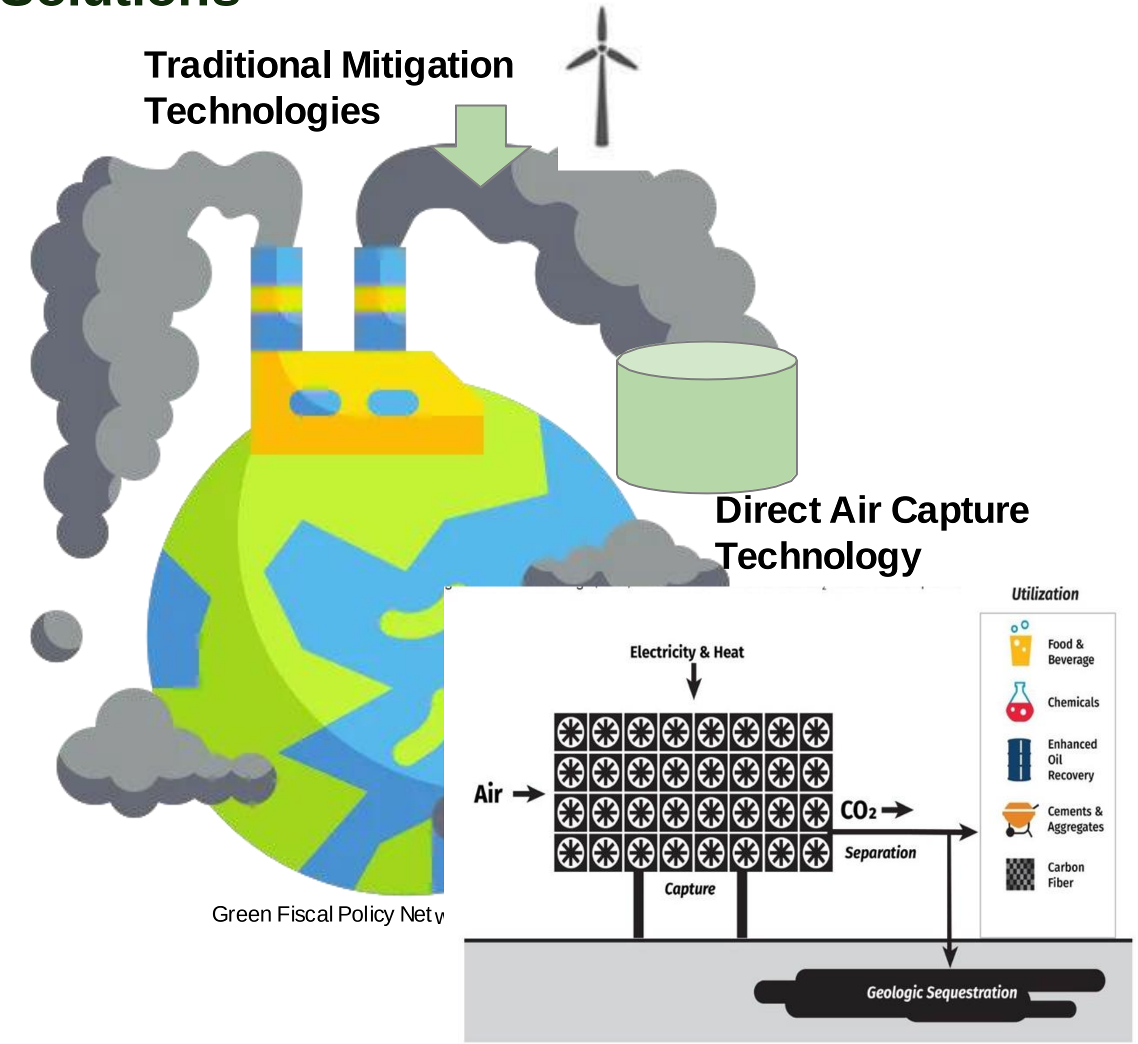
Critical actions and collaborative efforts are needed to overcome technological, financial, and scalability barriers for DAC to transition from potential to impact and position it as a transformative solution for global decarbonization by 203x

Rising risks with increasing temperature



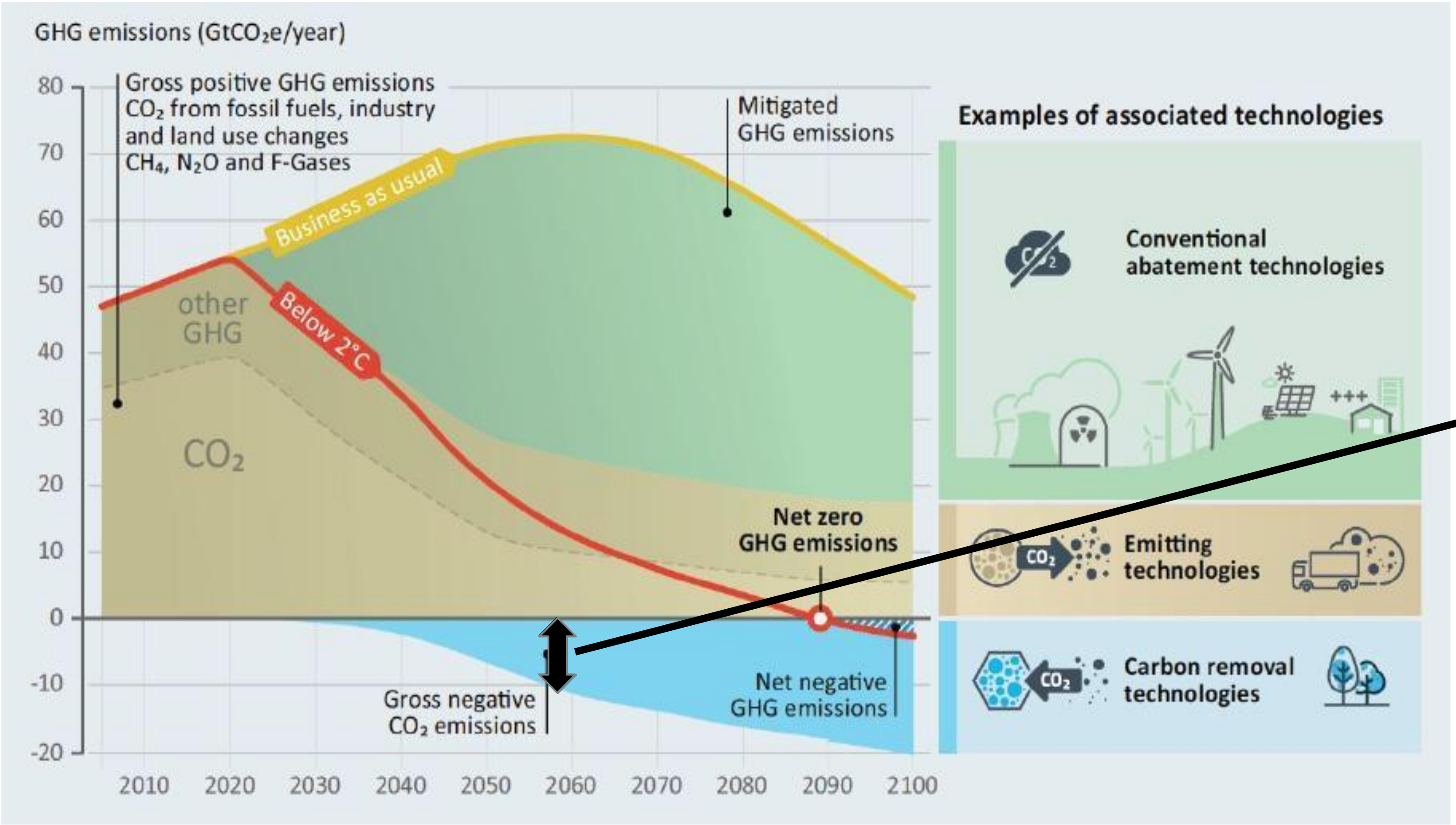
IPCC 2014 Summary for Policymakers., CC BY-NC-ND

Solutions



Green Fiscal Policy Netw

2 Potential Impact of Direct Air Capture (DAC)



Source: National Academies of Science (2019)

Required Scale

climeworks

Capacity :	4000 tCO_2 / year
Sorbent / Thermal Energy Source:	Solid / Geothermal
1DAC Plant :	
	8600 ft^2 ~ 4 Houses
Number of Plants Required :	2.4 Million
Global Plant Area (Temp. rise under 2 ℃) :	
	1920 km^2 ~ 2.5 Times New York

We are falling behind on emissions reductions targets. According to the IPCC, carbon removal is also now required to meet global temperature targets.

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Current State of DAC

Promise of DAC:

- **Progress in implementation**: Facilities like Climeworks' "Orca" in Iceland are already operational, removing up to 4,000 tons of CO_2 annually using geothermal energy.

Key challenges:

- **Energy demand**: DAC processes are energy-intensive, with energy needs of 7.2–8.8 GJ/t CO_2.
- **Material limitations**: Sorbent challenges (slow CO_2 uptake, high regeneration energy), with research into advanced materials like MOFs underway
- **Scalability and integration**: Few DAC technologies have detailed process designs for large-scale deployment. Integration with energy systems, heat storage, and geological storage is still in the early stages.
- **Infrastructure and logistics**: Deployment requires significant infrastructure, including **CO_2 transport networks** and **geological storage** sites.

Economic outlook:

- **High Costs**: DAC remains expensive, with capture costs ranging from **\$90 to \$600 per ton of CO_2**. Large-scale deployment faces financial challenges due to high capital investment needs and limited economies of scale.

Photo source: Inceptive Mind

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DAC Scaling Scenarios

	Low Adoption	Moderate Adoption	Aggressive Adoption
Scale:	10-30 facilities at a scale of .5-1 million tons captured annually per site.	40-200 facilities at a scale of 1-5 million tons captured annually per site	100-400 facilities at a scale of 5-10 million tons captured annually per site
Cost:	\$300-700 per ton of CO_2	\$200-300 per ton of CO_2	\$100 per ton of CO_2
Investment:	Annual: \$3-\$10 billion Cumulative: \$90-\$300 billion	Annual: \$20-\$60 billion Cumulative: \$600 bn-\$1.8 trillion	Annual: \$50-\$200 billion Cumulative: \$1.5-\$6 trillion
Impact:	2 million tons captured by 2030 On track to capture 10-20 million metric tons by 2050.	20- 50 million tons captured by 2030 On track to capture 200-300 million tons by 2050	100- 200 million tons captured by 2030 Exceeds 500 million tons captured by 2050

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CarbonCapture Case Study

Project Bison deprioritized

- Energy
  - Competition for energy with data centers & AI
  - Delayed energy supply from utility
- Markets
  - Difficult for small DAC projects to take off & scale without existing dedicated point sourcez
- Infrastructure
  - Lack of available workforce, limited water
- Weather Conditions

Refocus on Louisiana

- Energy
  - Cheaper energy
  - More grid capacity
  - 2050 net zero target
- Infrastructure
  - Plans to build DAC infrastructure in LA (TA3 hub, pipeline, workforce)
- Access to sequestration
  - More Class VI applications in LA than WY

Data source: Young et.al 2023, Ozkkan et al., 2022; Smith et al., 2021

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United States Policy

Inflation Reduction Act

- **$180/ ton of CO_2 geologically sequestered**
- **$130/ ton of CO_2 utilized**
- **$130/ ton of CO_2 sequestered in oil fields**

Permitting

- **National level**
- **Permits needed for new builds and Class VI wells**

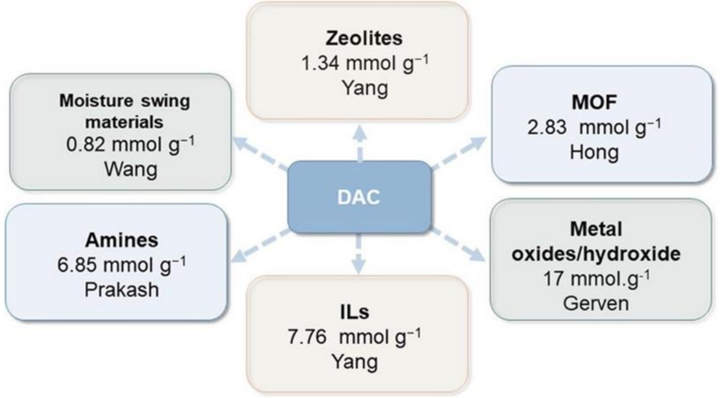
New Administration

- **Pulled out of Paris Agreement**
- **Expected to roll back renewable energy incentives**

Photo source: Viator

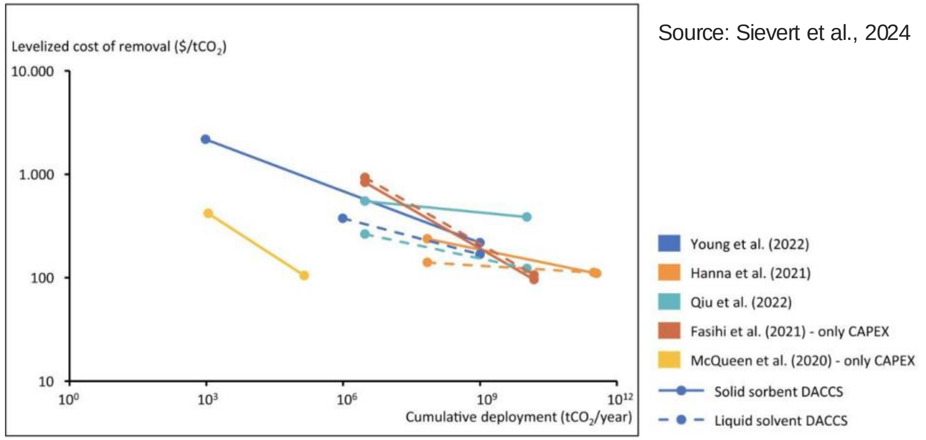
Actions for Carbon Capture Inc.

Develop next-generation sorbent materials



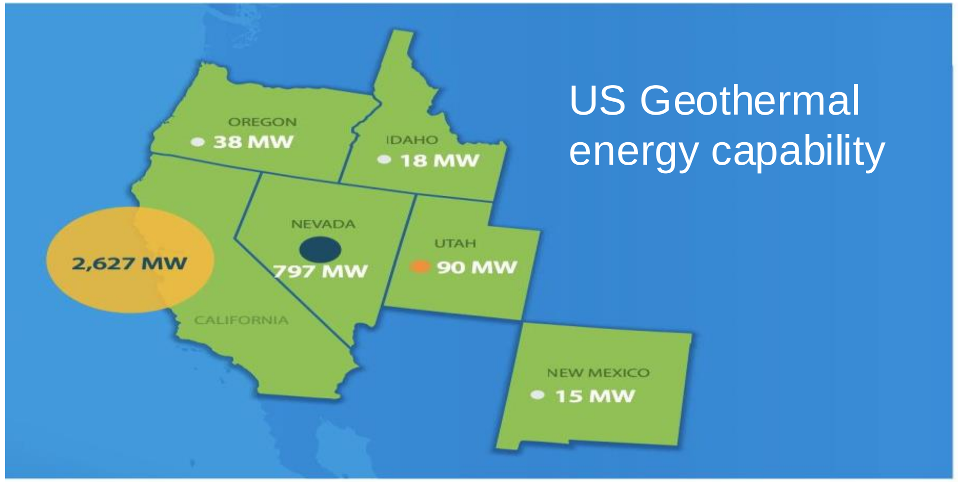
- Higher CO2 absorption rate
- Higher efficiency
- Lower temperature requirements

Scale up DAC facilities



Source: Sievert et al., 2024

Optimize Energy Source



Source: NREL (National Renewable Energy Lab)

Public Relations and Awareness

Actions to take:

- Continuously track policy shifts.
- Develop a series of engaging, easy-to-understand online content for public communication.
- Establish a coalition of industry players who can benefit from carbon credit.

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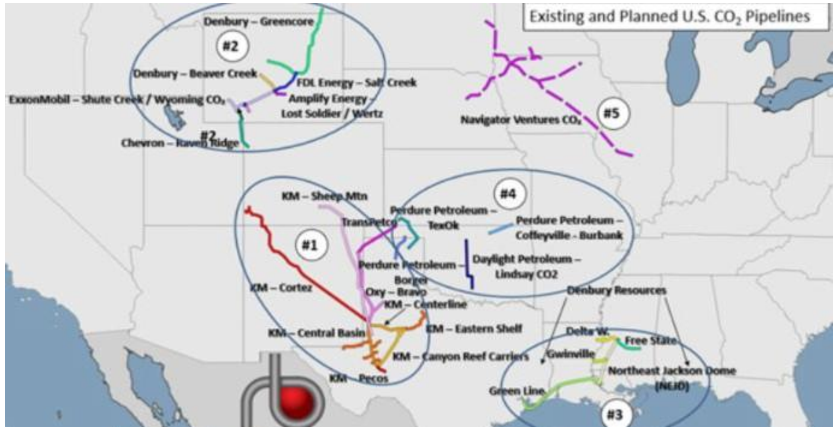
Actions for stakeholders.

Maintain 45Q CO_2 storage tax incentives

45Q

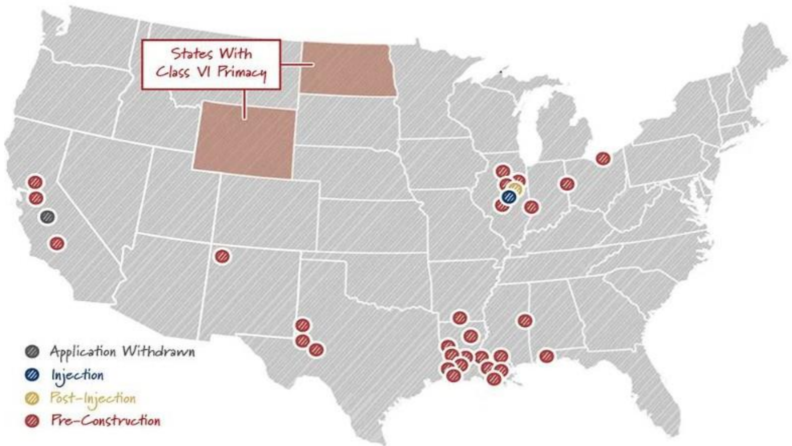
- \$130/ton CO_2 utilized
- \$180/ton CO_2 geologically sequestered
- \$130/ton CO_2 sequestered in oil fields

Investment in CO_2 transport and storage



Source: RBN Energy, LLC

Grant class VI primacy to more states



Source: Clearpath

Increase investment in renewable energy

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Key takeaways

Urgency: Global net-zero targets require capturing/removing 20 Gt of CO_2 per year by 2100 to keep temperature rise under 2°C.[1] Expanding DAC in the next 10 years is essential to this effort

Current challenges:

- **Energy intensity**: High energy demands (7.2–8.8 GJ/t CO_2) limit feasibility at scale
- **Costs**: Current capture costs range from $90–$600 per ton, far exceeding alternative methods
- **Infrastructure bottlenecks**: Deployment hampered by limited access to low-carbon energy, water, and CO_2 storage networks[2]
- **Policy gaps**: Lack of state primacy for Class VI well permitting; challenges with new administration

Potential breakthroughs: Innovations in sorbent materials, streamlined infrastructure, and collaborative stakeholder action can reduce costs and accelerate scaling.

Strategic relocation example: CarbonCapture's Project Bison move from Wyoming to Louisiana highlights the importance of energy access, infrastructure, and climate in DAC project siting.

1. National Academies of Sciences, 2018.
2. (*Climeworks, 2024; BCEES, 2023*)

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Solving for the Dual Challenge.

2 Emerging Answer

Hypotheses on Answer

Impact Scenarios

We believe there are three different credible scenarios regarding DAC's impact based off a key set of levers/assumptions and how far they are exercised:c

- Slow adoption
- Moderate adoption
- Aggressive adoption

Methodology

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- Understanding of the correlation between the different assumptions and outcome metrics to map out quantitative impact
- Understanding real-world examples of how the different assumptions/levers are being pulled and what needs to be true in the different scenarios
  - A set of assumptions that guide the impact scenarios:
  - Investment/Cost
  - Clean energy
  - Policy
  - Industry demand
  - Technology
- Projected outcomes for each of the scenarios by 203X:
  - Scale of deployment
  - Cost per ton
  - Market dynamics
  - Environmental impact
- Clear actions for Carbon Capture (DAC companies), policymakers, government, investors etc.

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Emerging Answer Continued

Impact Scenario Assumptions

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Scenario	Investment/Cost	Clean Energy	Policy	Industry Demand	Technology
Slow adoption	• Limited funding ($X) for innovation. • Small government grants and no incentives for DAC tech. • Limited deployment capital.	• Wind, solar and other clean energy grow slowly (30% contribution by 2050). • Fossil generators still play a dominant role in providing energy (more than 65%). • U.S. electricity sector emissions keep increasing, and electricity price increases.	• Minimal regulatory support and low carbon pricing remain the status quo. • Limited or inconsistent tax credits for DAC.	• Low demand from industries for captured CO_2 • Economies of scale are not realized, keeping DAC costs high and demand low.	• Limited funding with no breakthroughs in energy efficiency and cost. • Limited infrastructure prevents large scale growth due to high costs. • Limited partnerships reduces chance of advancements.
Moderate adoption	• Moderate investment ($Y) for R&D and innovation work. • Expansion of tax credits and subsidies. • DAC hubs emerge integrating transportation, capture and sequestration infrastructure.	• Wind, solar and other clean energy grow moderately (50% by 2050) • Fossil fuels contribute more than 50% of electricity generation. • U.S. electricity sector emissions reduces, and electricity price slightly decrease.	• Introduction of a moderate carbon pricing policy, offering medium financial incentives. • Some regulatory support, including tax credits (e.g., 45Q credits) and low-interest loans for DAC facilities.	• Moderate demand for captured CO_2, driven by hard-to-abate sectors. • Economies of scale lower costs, boosting demand from industries as DAC becomes cost-competitive.	• Increased funding leads to new technological advancements. • Medium scale hubs emerge that focus on new materials & systems. • Public and private partnerships drive medium scale DAC projects that increase innovation and investment.
Aggressive adoption	• Generous incentives that promote DAC for long term purposes. • Large scale deployment of DAC plants drives economies of scale significantly. • Significant funding from private sector, government and organizations ($Y).	• Clean energy grow rapidly and contributes more than 70% of the energy generation at 2050. • Fossil generators contributes less than 30% in later years. • U.S. electricity sector emissions rapidly decrease, and electricity price is largely decreasing.	• Comprehensive regulatory framework with high carbon pricing, strong mandates, and direct government investment in DAC infrastructure. • Strong policy incentives for corporations to purchase DAC credits, especially in hard-to-abate sectors.	• Robust carbon market with high demand for captured CO_2 across sectors due to	• Substantial improvement in energy efficiency and cost reduction for DAC systems. • Large scale deployment driven by easy and fast manufacturing of DAC materials and components. • Strong partnerships that lead to rapid tech advancements.

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Emerging Answer Continued

Impact Scenario Projected Outcomes

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Scenario	Scale of deployment	Technology deployment	Market dynamics	Environmental Impact
Slow adoption	• Experimental & niche solution rather than a cornerstone of global CO_2 removal efforts. • Efforts focus on proving feasibility and demonstrating environmental benefits at a small scale. • 10-30 facilities at a scale of .5-1 million tons captured annually per site	• High cost per ton sorbents, catalysts and heat exchangers that aren't efficient remain the standard. • Relying mostly on fossil fuel & grid energy significantly increasing costs and environmental impact. • Cost per ton remains high, around $500-700.	• Niche market driven by voluntary buyers, small-scale projects and EOR initiatives • Few players dominate due to high capital cost • Low economies of scale and limited technological breakthroughs keeping prices above $500	• X million tons captured by 203X on track to capture 10-20 million metric tons by 2050. • Reliance on fossil-based energy, reducing the emissions reduction impact • Insufficient scale means little impact on ecosystem restoration and climate resilience
Moderate adoption	• Strategic U.S. climate strategy, supported by enabling policies, financial and technological investments. • DAC making a substantial impact but not achieving economy-wide integration. • 40-200 facilities at a scale of 1-5 million tons captured annually per site	• Advancements in materials science lead to more efficient sorbents - metal-organic frameworks, improved zeolites and polymer base systems. • Wider integration with renewable energy sources becomes more feasible, reducing capture cost to $200-300 per ton.	• Carbon removal mandates drive growth • New entrants buoyed by cost reductions and an improving business case • Innovation and scaling reduce cost to $200-$300 per ton • Public-private partnerships increasingly fund DAC infrastructure and technology	• Achieves X million tons captured by 203X on track to capture 200-300 million tons by 2050 • Integration with renewable energy achieving net emissions reduction of X% per ton of CO2 captured • Localized land use and biodiversity issues.
Aggressive adoption	• Public and political support for large-scale DAC. • Integration into global carbon markets and industrial supply chains. • Massive cost reductions (<$100/ton) • U.S. committed to aggressive emissions reductions, with DAC • 100-400 facilities at a scale of 5-10 million tons captured annually per site	• Breakthrough innovations lead to ultra-low cost, highly efficient materials specifically tailored for DAC applications. • DAC become fully powered by renewable energy - wind, solar, geothermal, ensuring net negative emissions. • Breakthroughs in technology drive costs down to less than $100 per ton.	• Industries integrate DAC into their operations • Diversified and mature market – modular & centralized systems, CO_2 transport and storage networks • Cost fall below $100 due to advanced R&D, mass production and optimized operations • Massive capital influx – public, private & institutional investors	• Achieves X million tons captured by 203X on track to exceeds 500 million tons captured by 2050 • Full integration with renewables achieving net emissions reduction of Y% per ton of CO_2 captured • Environmental Benefits: Broad ecosystem considerations and achieving national and global net-zero targets

3 Emerging Answer Continued

Takeaways & Next Steps

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Key takeaways

- DAC's effectiveness varies across scenarios, from limited adoption in low-transition pathways to large-scale deployment as a key decarbonization tool under aggressive adoption. Infrastructure development and operational efficiency are critical.
- DAC's environmental impact improves dramatically when powered by renewable energy. Addressing its energy intensity is essential for achieving net-negative emissions.
- Land use, water demand, and ecosystem impacts must be managed carefully, along with transparent community engagement to build local acceptance.
- Multi-stakeholder partnerships and alignment with international climate policies are necessary to address financial, technical, and regulatory challenges.
- The trajectory of DAC depends on the interaction of policy, market readiness, and technological innovation, requiring continuous monitoring and adaptive strategies.

Next steps

No	Action	Action Party	Timeline
1	Implement feedback from OM, sponsor and shepherd	DAC team	12/23/2024
2	Refine and complete the scenario assumptions and projections	DAC team	1/10/2025
3	Create clear actions for different stakeholders for each scenario	DAC team	1/15/2025
4	Consolidate the research and create the final reporting documents	DAC team	1/20/2025

Proposed Run of Show

Assignment	Topic	Time
Isabelle	• Problem Statement & Impact Scenarios Methodology	• 5 mins
Yingxiao	• Impact Scenarios Assumptions & Projected Outcomes	• 5 mins
David	• Key takeaway and next steps	• 5 mins