



*National Association of  
State Energy Officials*

# NASEO Webinar: Moving the Market for Direct Air Capture Forward

August 15, 2024

Thank you to the U.S. Department of Energy Office of Fossil Energy and Carbon Management for their support of this event.



# Welcome and Logistics

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Kelsey Jones, Program Director, NASEO



# Speakers



- Grant Faber, Direct Air Capture Hubs Program Manager, Office of Fossil Energy and Carbon Management, U.S. Department of Energy
- Andrew Fishbein, Lead Government Affairs North America, Climeworks





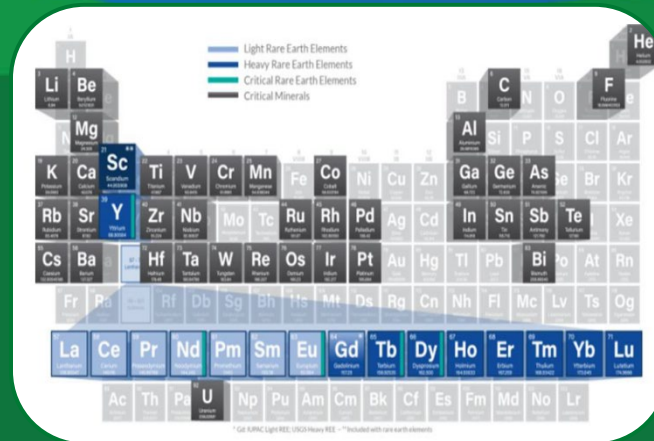
U.S. DEPARTMENT OF  
**ENERGY**

Fossil Energy and  
Carbon Management

# Overview of Direct Air Capture Activities at DOE FECM

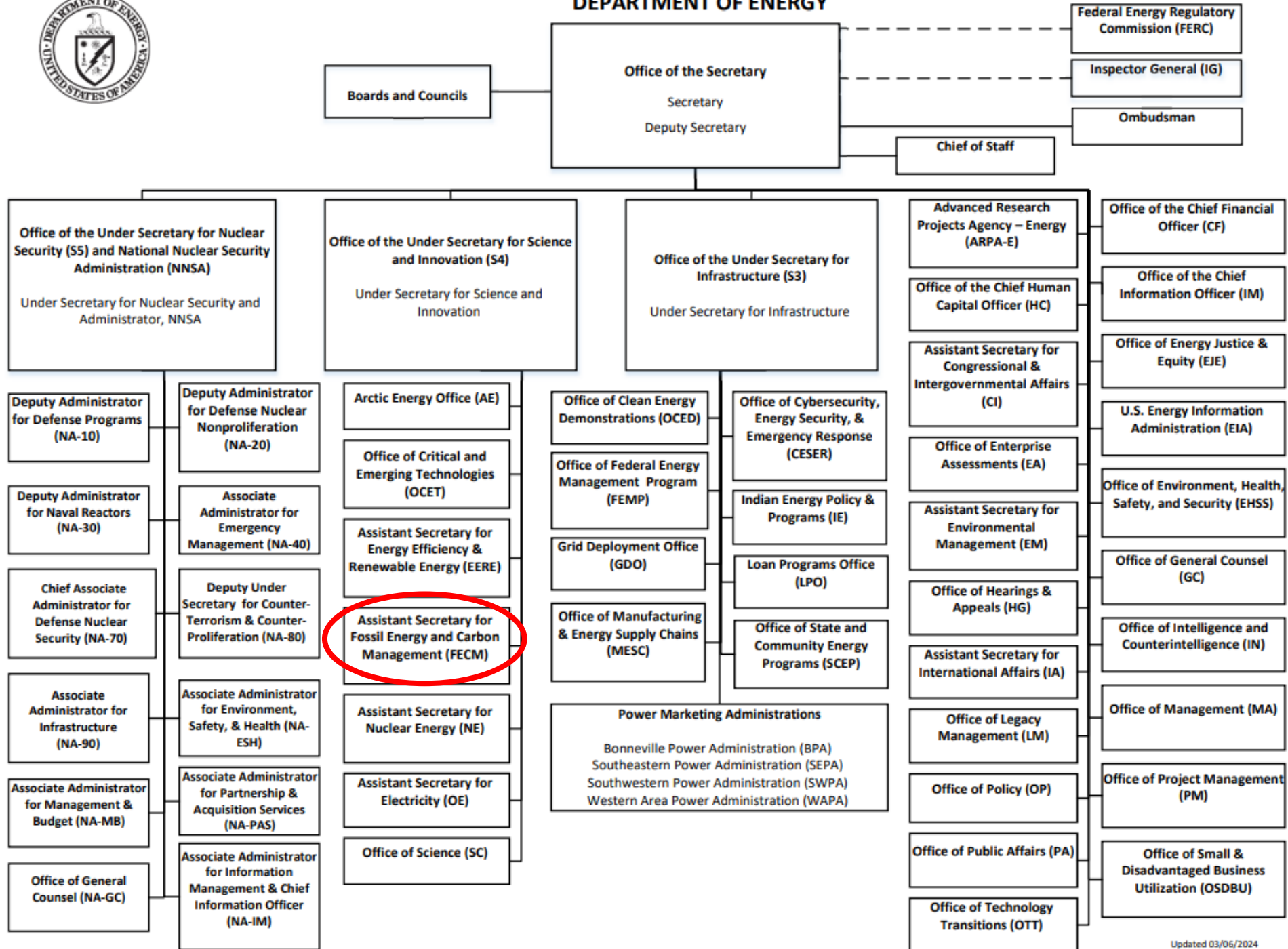
## NASEO Webinar

Grant Faber, DAC Hubs Program Manager  
August 15<sup>th</sup>, 2024





# DEPARTMENT OF ENERGY





**NATIONAL ENERGY TECHNOLOGY  
LABORATORY**  
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ENERGY AND CARBON MANAGEMENT**  
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DIRECTOR FOR AI AND  
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MARK ACKIEWICZ

**OFFICE OF RESOURCE SUSTAINABILITY (FE-30)**  
RYAN PEAY

**OFFICE OF OPERATIONS  
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JAMES WILSON (ACTING)

**OFFICE OF BUDGET AND FINANCIAL  
MANAGEMENT (FE-13)**  
SEAN JAMES

**FORMULATION (FE-131)**  
SCOTT BRECHMACHER (ACTING)

**EXECUTION (FE-132)**  
SCOTT BRECHMACHER (ACTING)

**OFFICE OF INFORMATION TECHNOLOGY  
(FE-14)**  
EUGENE DUAH

**OFFICE OF COMMUNICATIONS  
(FE-15)**  
MARC WILLIS

**OFFICE OF WORKFORCE MANAGEMENT  
& ADMINISTRATION (FE-16)**  
ALAN PERRY

**OFFICE OF ENVIRONMENT, SECURITY,  
SAFETY & HEALTH (FE-17)**  
CHRISTOPHER BEATTIE

**OFFICE OF CARBON  
MANAGEMENT TECHNOLOGIES  
(FE-22)**  
SARAH FORBES

**HYDROGEN WITH CARBON  
MANAGEMENT (FE-221)**  
ROBERT SCHRECEGOST

**CARBON TRANSPORT AND STORAGE  
(FE-222)**  
AMANDA RADDATZ BOPP

**CO<sub>2</sub> REMOVAL (FE-223)**  
RORY JACOBSON (IPA)

**CARBON CONVERSION (FE-224)**  
IAN ROWE  
EMILY CONNOR (ACTING)

**POINT SOURCE CARBON  
CAPTURE (FE-225)**  
DAN HANCU

**OFFICE OF POLICY, ANALYSIS &  
ENGAGEMENT (FE-26)**  
MARK DE FIGUEIREDO

**POLICY & ANALYSIS (FE-261)  
VACANT**  
GREGORY COONEY (ACTING)

**ENGAGEMENT (FE-262)**  
MARGO CORUM  
MARY ELLEN KWONG (ACTING)

**FEDERAL PARTNERSHIPS  
(FE-263)**  
ADAM EISELE

**OFFICE OF RESEARCH &  
DEVELOPMENT (FE-32)**  
DAVID ALLEMAN

**ADVANCED REMEDIATION  
TECHNOLOGIES (FE-321)**  
VANESSA NUNEZ LOPEZ

**METHANE MITIGATION  
TECHNOLOGIES (FE-322)**  
TIMOTHY REINHART

**MINERALS SUSTAINABILITY  
(FE-323) VACANT**  
GRANT BROMHAL (ACTING)

**OFFICE OF REGULATION,  
ANALYSIS & ENGAGEMENT  
(FE-34)**  
AMY SWEENEY

**POLICY AND  
ANALYSIS (FE-341)**  
THOMAS CURRY

**REGULATION (FE-342)**  
JENNIFER WADE

**ENGAGEMENT (FE-343)**  
RACHEL HALPERN

# CDR Division Background

## Vision Statement

- Advance **diverse CDR approaches** in service of facilitating **gigaton-scale removal by 2050**, emphasizing robust analysis of **life cycle impacts** of various CDR approaches and a deep commitment to **environmental justice**, including rigorously evaluating CDR, defining conditions for success and leveraging leadership and expertise.

## Funding Levels

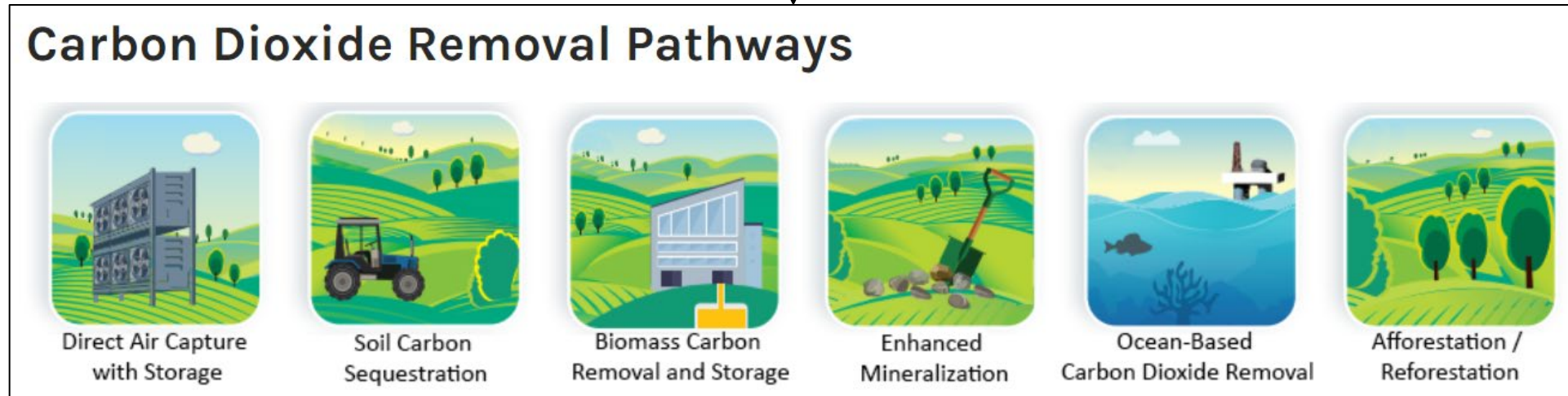
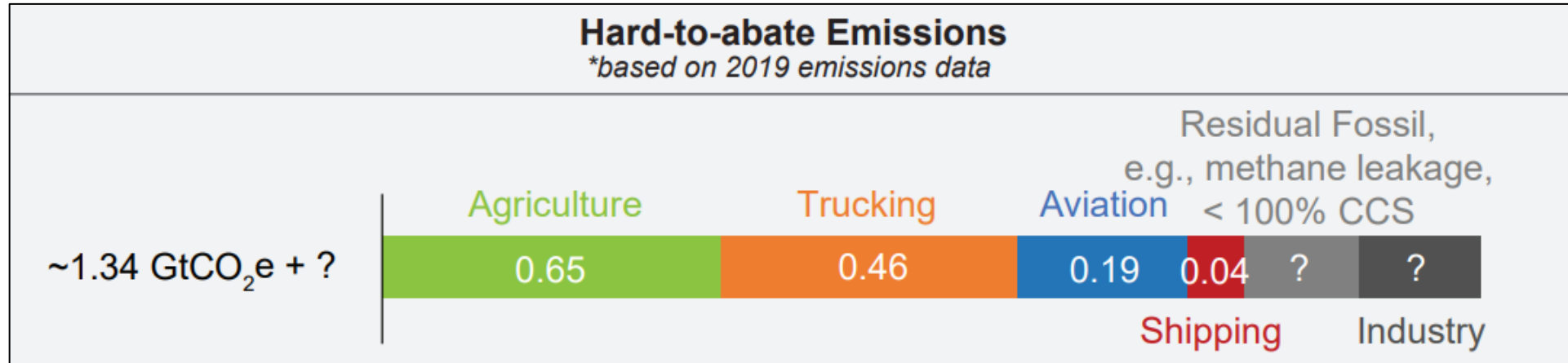
- Base appropriations of around **\$70M** annually
- Additional work on **\$3.5B** DAC Hubs, **\$115M** DAC prize competitions, CDR-related SBIR selections, and similar programs

## Key Partners

- National Energy Technology Laboratory CDR Program: direct R&D and program implementation
- EPA, NOAA, DOT, USDA, USGS/DOI, NIST/DOC, State, etc.

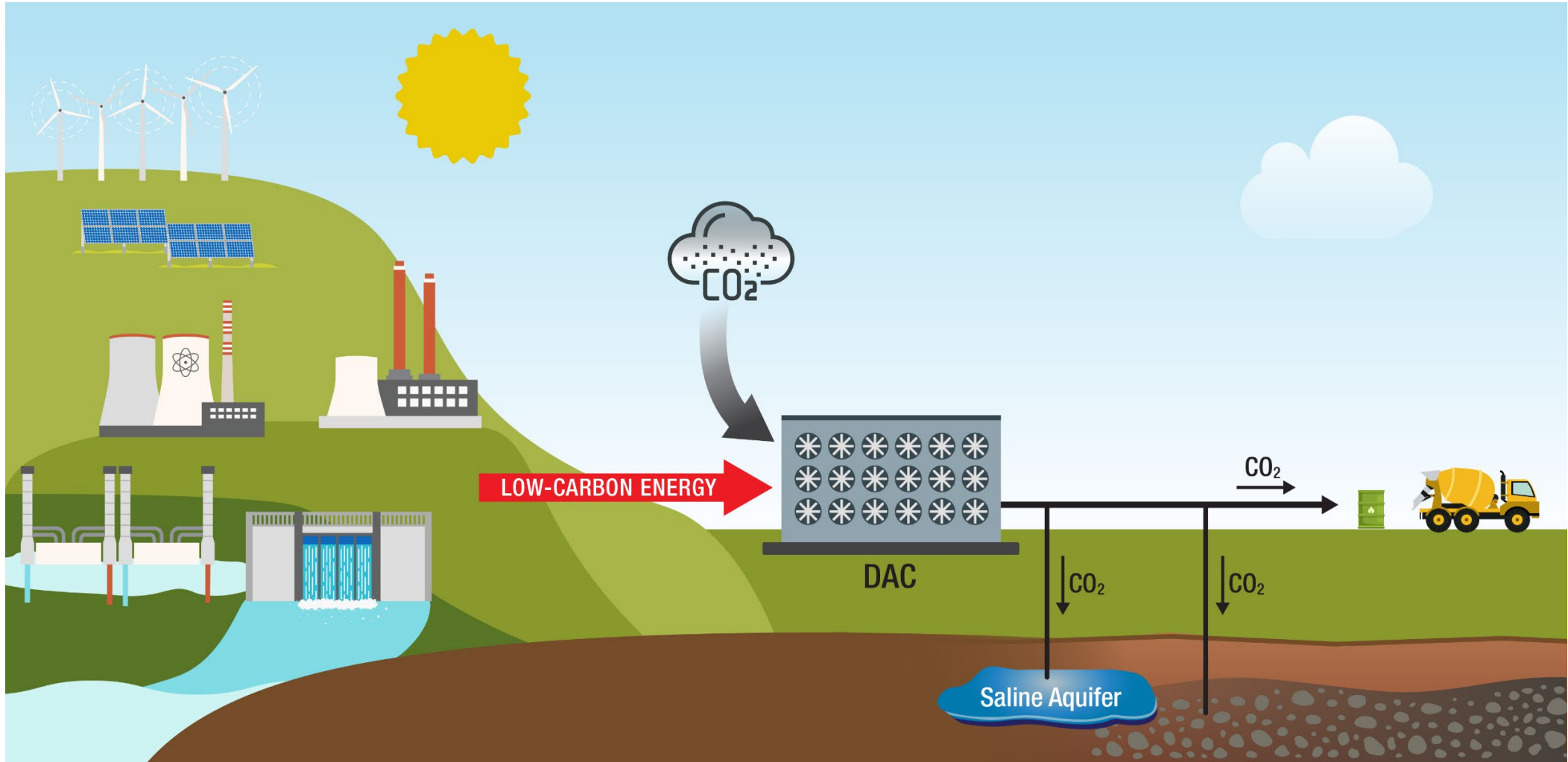
These are just U.S.-based hard-to-abate emissions, but countries around the world will also have these and address them with CDR.

# CDR Background

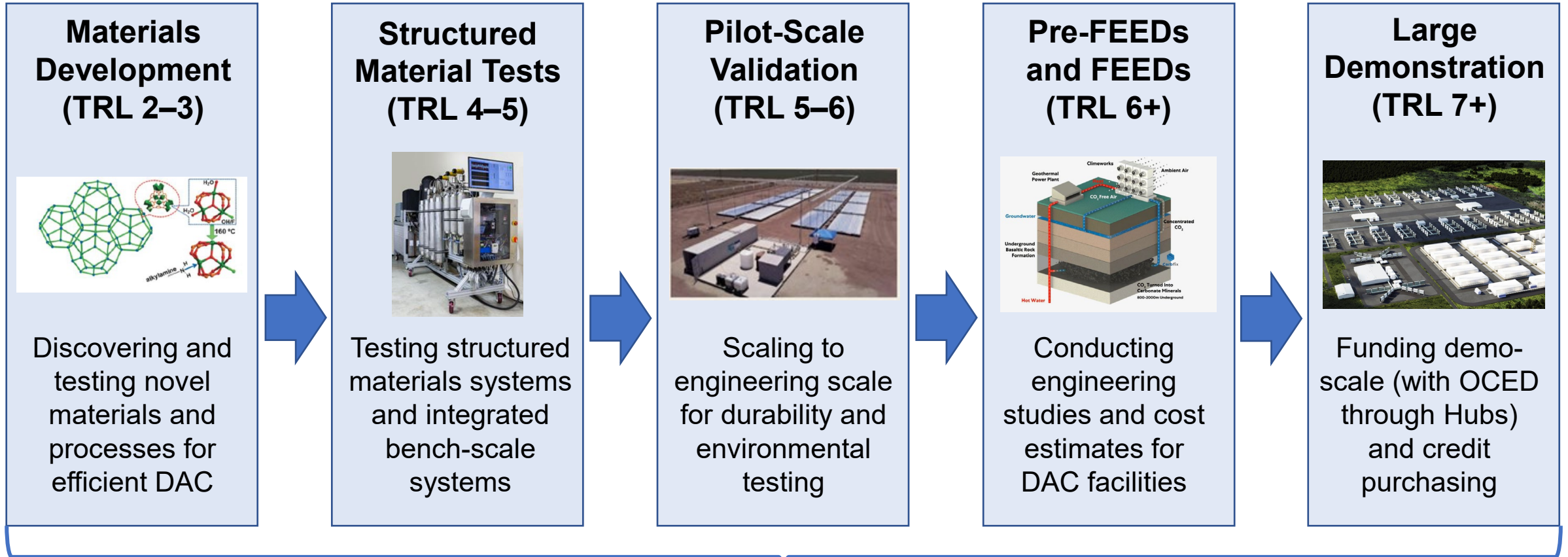




# DAC Overview

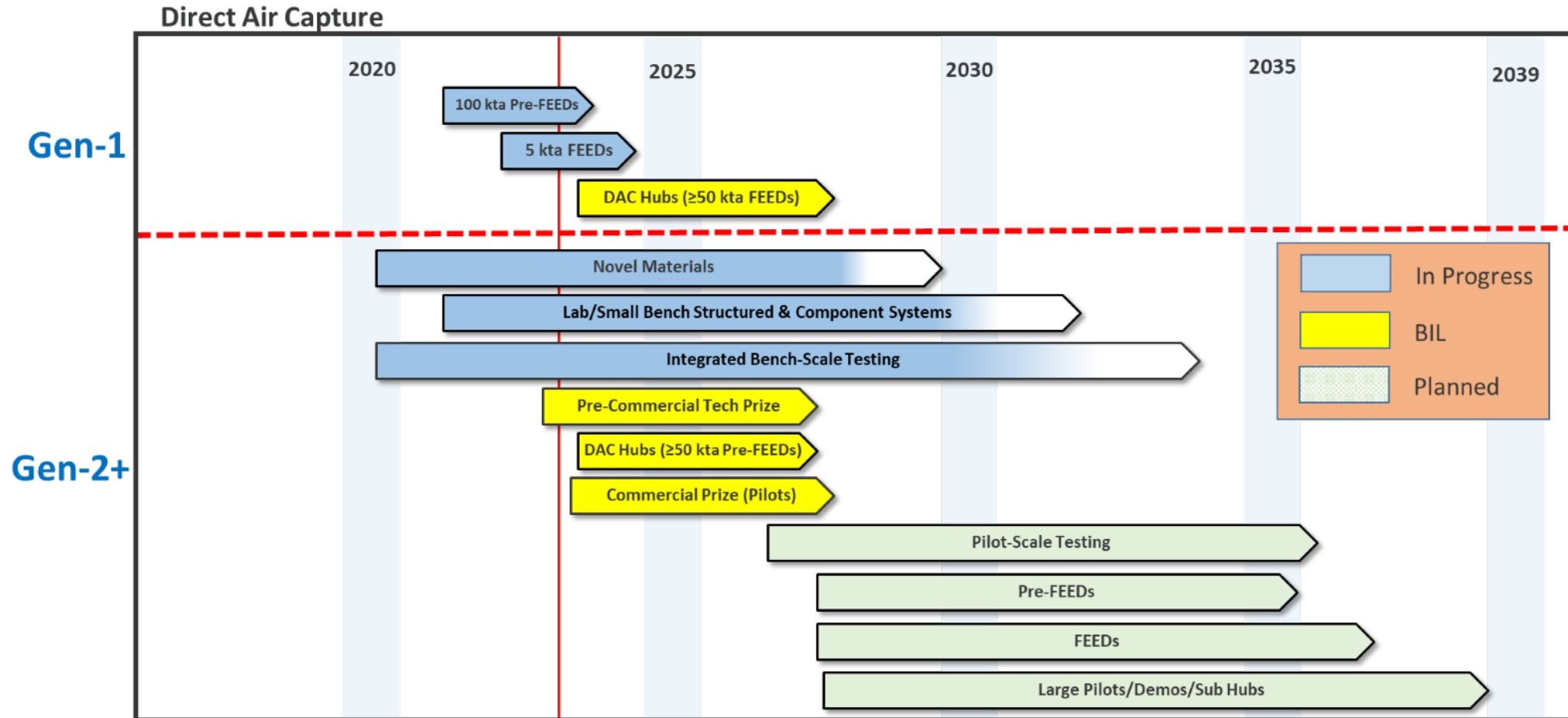


# Spectrum of DOE DAC Work by Technology Readiness Level (TRL)



Techno-economic and life cycle assessment, process modeling, systems analysis, and workforce development

# Approximate DAC Program Schedule



*We'll discuss just a few of our many programs on the following slides.*

# BIL: Regional Direct Air Capture Hubs

DOE is providing up to \$3.5B of funding from the Bipartisan Infrastructure Law (BIL) for the Regional Direct Air Capture Hub program, which to the extent practicable will:

- Establish **four geographically diverse DAC Hubs**, each demonstrating integrated capture and storage or conversion of at least 1 million metric tons per year
- Fund Hubs in areas with (a) current or retiring carbon-intensive fuel production; (b) high potential for carbon sequestration or utilization; (c) high scalability potential; and (d) **high employment potential**
- Facilitate the deployment of at least two Hubs in **economically distressed communities** with significant quantities of fossil fuel resources

# Regional DAC Hubs Progress

In August 2023, 21 DAC Hub project selections over three topic areas were announced to support initial industry-wide efforts to advance toward the goals of the DAC Hub program. Future Hub funding will continue sponsoring a variety of DAC projects to support achievement of program objectives.

## Topic Area 1: Feasibility Studies and Site Selection

Conceptual and pre-FEED studies followed by site and tech selection

*24 months and ≤\$3M DOE funding per project*

**14 selections by FECM/NETL**  
**~\$40.9M total DOE share**  
**~10 states**

## Topic Area 2: FEED Studies and Project Development

FEED studies and other activities to support project development

*24 months and ≤\$12.5M DOE funding per project*

**5 selections by FECM/NETL**  
**~\$58.7M total DOE share**  
**~5 states**

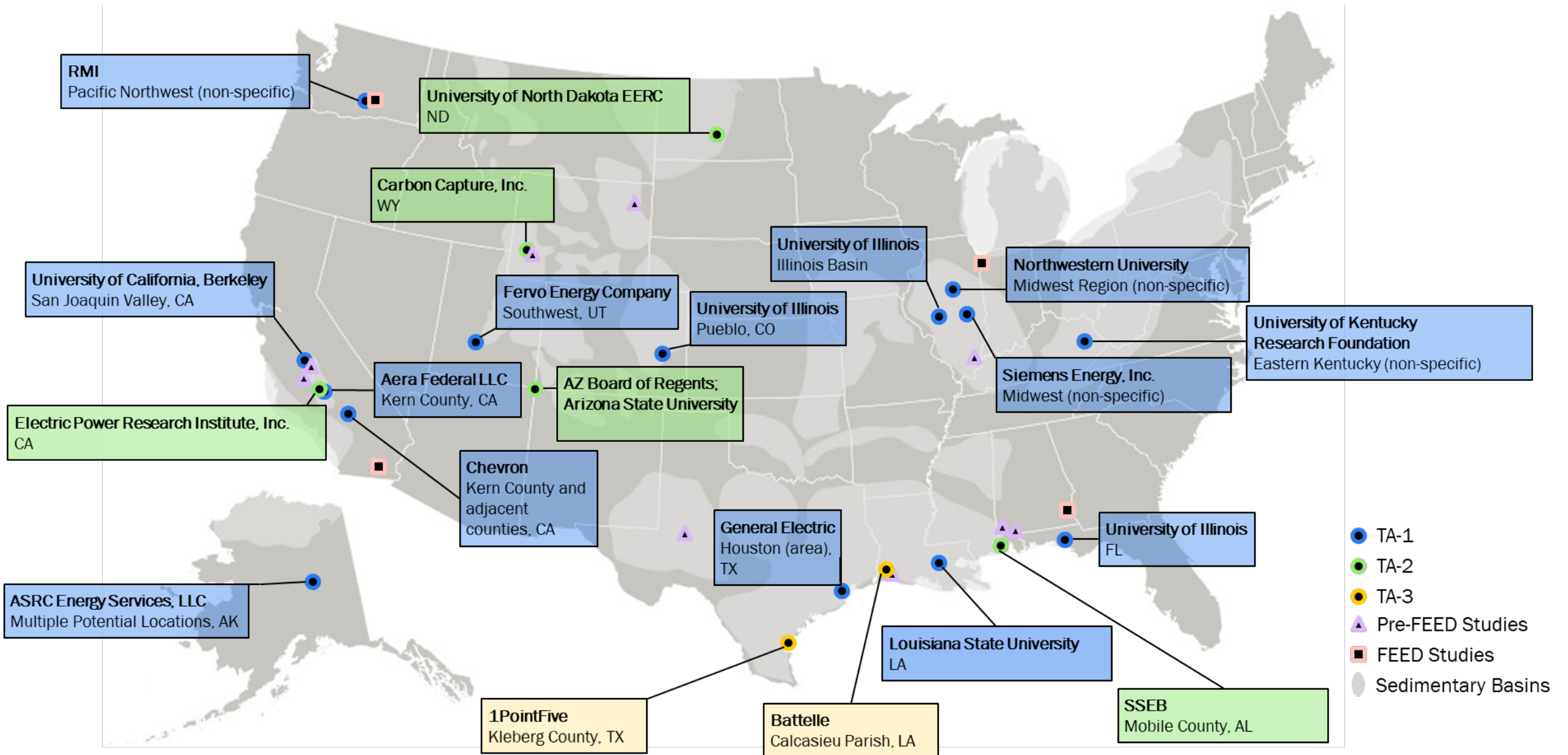
## Topic Area 3: Permitting and Construction

Detailed design and NEPA followed by construction and operation

*≤10 years and ≤\$600M DOE funding per project*

**2 selections by OCED**  
**Up to \$1.2B total DOE share**  
**2 states**

# DAC Hub and Pre-FEED/FEED Initial Locations



**NOTE: Specific sites have not necessarily been chosen, and locations are subject to change.**

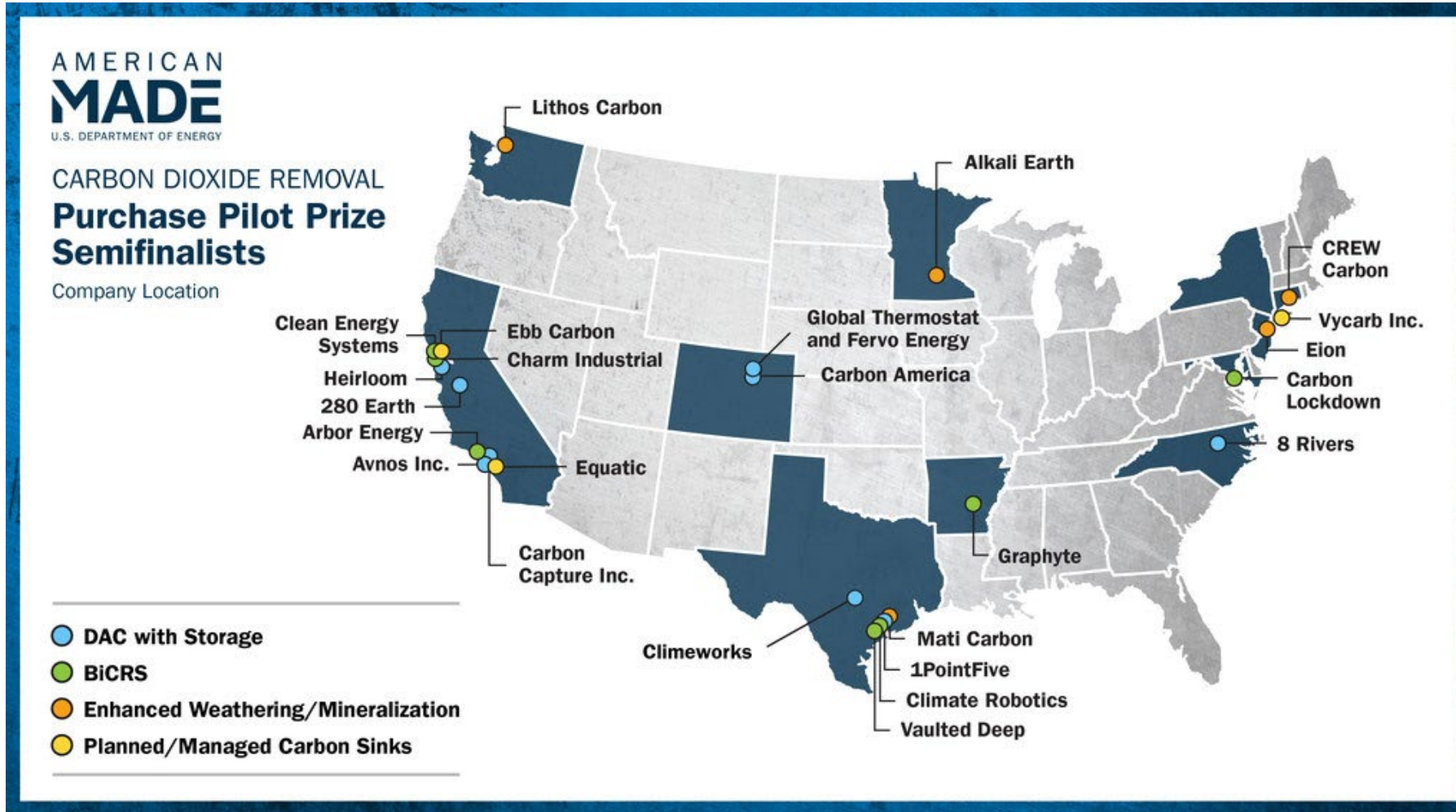
# BIL: Pre-Commercial DAC Prizes

Funded by BIL, these prize competitions are awarding over \$7M to early-stage startups and accelerators to advance DAC entrepreneurship across the country.

Technology Prize Finalists	Location
Arizona Board of Regents (CNCE)	Tempe, AZ
Capture6	Berkeley, CA
Carbon To Stone	Ithaca, NY
Rhoic	San Leandro, CA
Giner	Newton, MA
Holocene	Knoxville, TN
Nūxsen	New York, NY

Accelerator Prize Finalists	Location
Activate Global	Berkeley, CA
Impossible Labs (AirMiners)	San Mateo, CA
gener8tor DAC Accelerator	Chicago, IL
Newlab DAC Slingshot Program	Brooklyn, NY
Radicle Development Center	Malvern, PA

# BIL: CDR Purchase Pilot



- Funded by BIL, the \$35M CDR Purchase Pilot will pilot government CDR procurement and validate MMRV methodologies.
- Nine DAC teams have been selected as semifinalists, offering ~27K tons of credits over the 36-month delivery period.



# BIL: DAC Pilot Prize

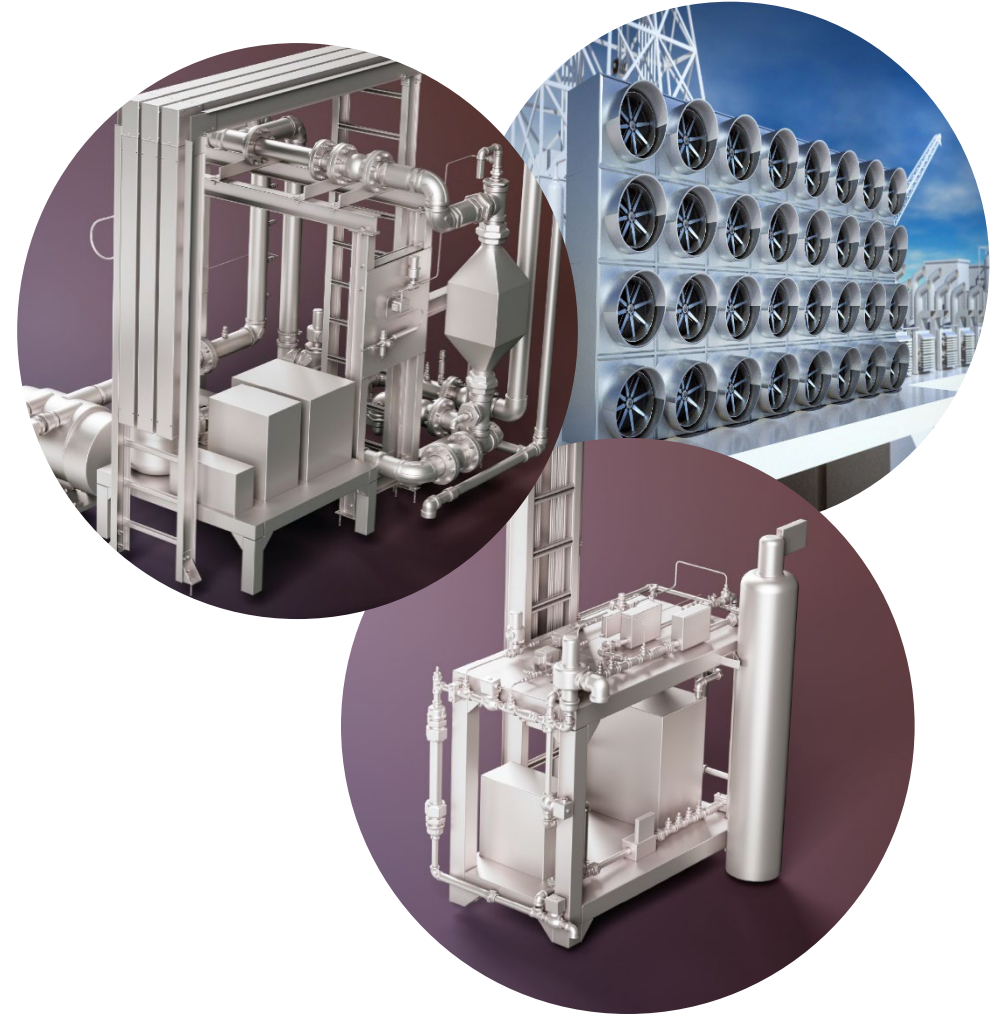
**Commercial Direct Air Capture Pilot Prize** **Win up to \$12,000,000!**

PHASE 1 <b>CONCEPT</b>	PHASE 2 <b>ENGINEER</b>	PHASE 3 <b>PERMIT</b>	PHASE 4 <b>OPERATE</b>
<i>Pilot concept and Pre-FEED</i>	<i>Front-end engineering design</i>	<i>Permit and detailed design</i>	<i>Construct and operate</i>
<ul style="list-style-type: none"><li>• Up to 5 winners</li><li>• \$500,000 cash prize per winner</li><li>• \$2,500,000 total cash prize pool</li></ul>	<ul style="list-style-type: none"><li>• Up to 5 winners</li><li>• \$4,000,000 cash prize per winner</li><li>• \$20,000,000 total cash prize pool</li></ul>	<ul style="list-style-type: none"><li>• Up to 4 winners</li><li>• \$1,000,000 cash prize per winner</li><li>• \$4,000,000 total cash prize pool</li></ul>	<ul style="list-style-type: none"><li>• Up to 4 winners</li><li>• Up to \$6,500,000 cash prize per winner</li><li>• \$26,000,000 total cash prize pool</li></ul>

This recently launched prize will award DAC developers as they progress from existing small-scale units (1–100 tpa) to pilots capturing at least 500 tons per year, which is the next stop on the way to mid-scale (5–25 kta) and eventually large-scale facilities. Phase 1 apps are due February 7<sup>th</sup>, 2025.

# NETL DAC Test Center

- Represents a one-of-a-kind facility dedicated to supporting private-sector DAC maturation (with **several agreements signed** and more under negotiation)
- Leverages **two decades of experience** in point-source carbon capture technology development and National Laboratory resources and capabilities
- Integrates **experimental and modeling techniques** to efficiently support scale-up
- Tests capture materials and processes under **variety of climatic and environmental conditions**



# NETL DAC Test Center Testing Scales



## Material Scale

Novel Material Assessments  
(~0.1 kg CO<sub>2</sub>/day)



Operational



## Module Scale

Form Factor Evaluation  
(~10 kg CO<sub>2</sub>/day)

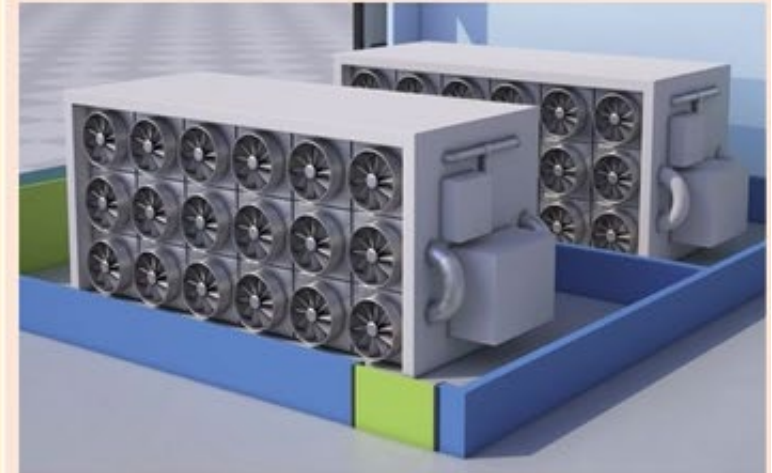


2024



## Prototype Scale

Developer-built Unit Testing  
(~100 kg CO<sub>2</sub>/day)



2025

# Potential Role of States in Scaling DAC

## Demand-Side and Regulatory Support

- Incorporating DAC into compliance carbon markets (e.g., SB 308) or even directly purchasing DAC credits could help drive demand for the nascent DAC market and send a key signal to investors and other buyers. Regulatory support for geologic CO<sub>2</sub> storage is vital as well.

## Community Engagement

- Successful DAC megaprojects will rely on community acceptance, and states are in a unique position to discover, communicate, and enforce community expectations and desires for new facilities.

## Workforce and Company Development

- Structuring educational curricula, university programs, apprenticeship programs, and startup accelerators/incubators to support DAC are important means of developing the people and companies needed to support the industry.

## Roadmap Development and Project Promotion

- Modeling and communicating the expected role of DAC for state decarbonization efforts and uplifting DAC projects or companies in the state could increase public awareness of, acceptance of, and investment in DAC.

## Innovative Ideas

- Innovative approaches such as providing low-cost loans, engaging in public–private partnerships, and exploring community/state ownership could have unique impact potential. If anyone has any other innovative ideas, please share them in the Q&A!

*These items are provided solely as ideas or topics for discussion and are not necessarily endorsed by FECM, DOE, or USG.*

# Specific DOE Programs of Interest to States

- **Utilization Procurement Grants**: Funding for states, local governments, and public utilities to procure goods made with captured carbon (apply by 4/30/25)
- **Voucher Program**: In-kind support for wide variety of innovation, commercialization, and collaboration opportunities (see ENERGYWERX VO3 for an active carbon management siting/permitting support opportunity)
- **Office of State and Community Energy Programs**: Technical assistance and contact for general clean energy programming

**Be sure to follow FECM's Solicitations and Business Opportunities and similar pages for other DOE offices to stay up to date with available funding opportunities!**

# Key Takeaways

- FECM and NETL leverage **decades of experience** in point-source capture and substantial base and BIL appropriations to advance DAC in support of U.S. climate goals.
- Sponsored projects cover a **wide range of technologies**, scales, technological maturities, organizations, approaches, and geographies to hedge against risk via diversification and ensure a robust build-out of the U.S. DAC ecosystem.
- To support rapid scaling, **many stakeholders** are and will be involved in DAC deployment, including governments of all levels, startups, corporates, universities, investors, and beyond.

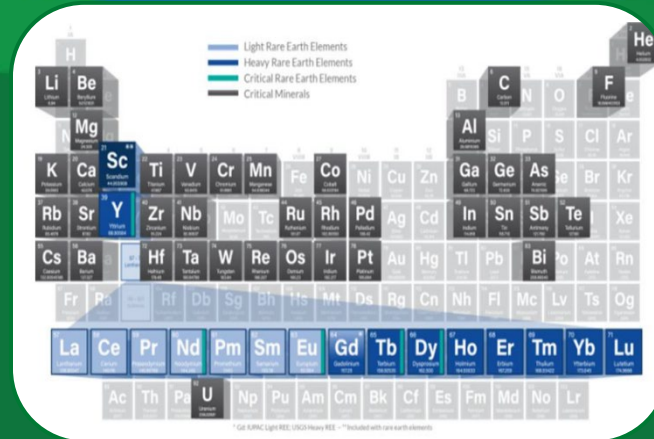


U.S. DEPARTMENT OF  
**ENERGY**

Fossil Energy and  
Carbon Management

# Questions?

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# Climeworks

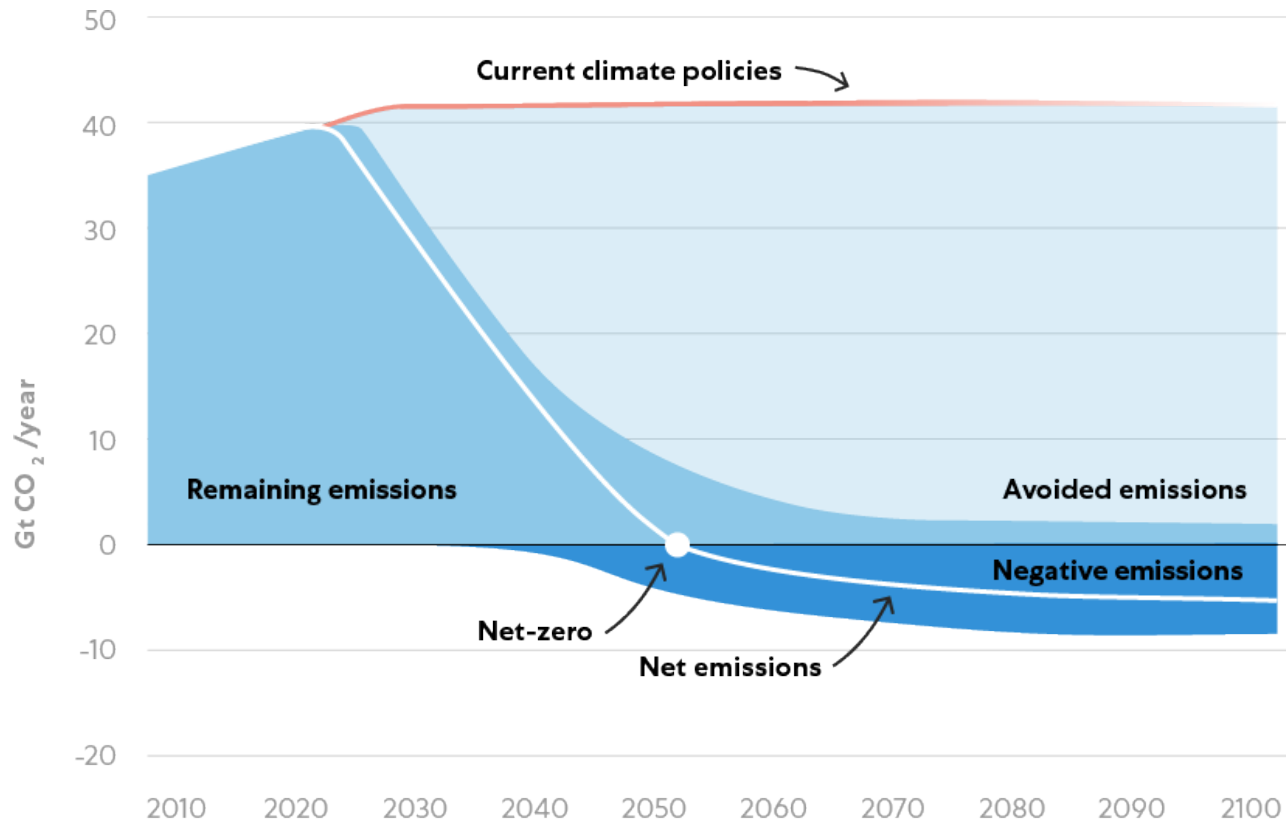
**Removing CO<sub>2</sub> from the air permanently.**

Prepared for NASEO  
August 15, 2024





# Net Zero requires drastic emissions reductions *and* carbon dioxide removal



Source: Adapted from IPCC (2022) & United Nations Environment Programme (2021)

## Reduce as much as possible

Conventional mitigation technologies



## Remove unavoidable emissions

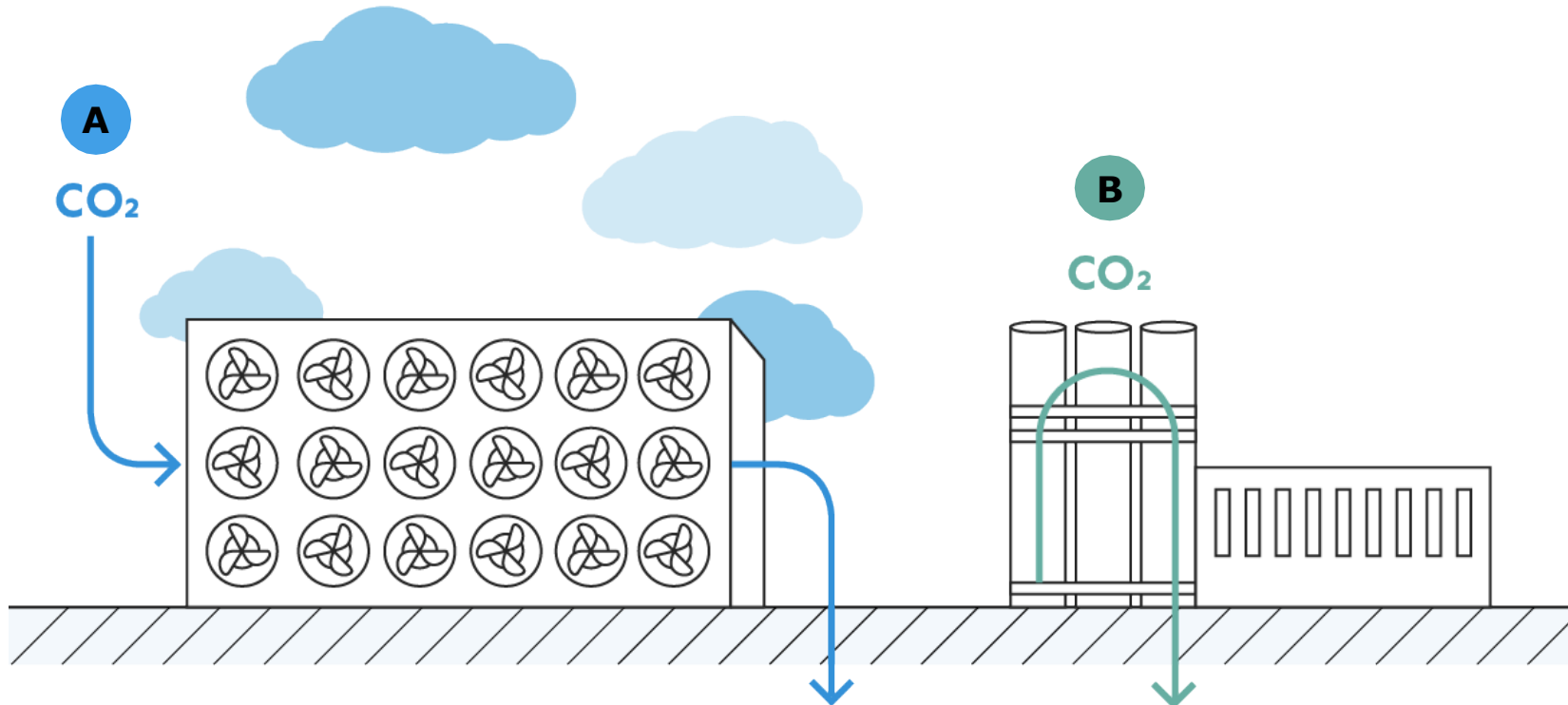
Carbon removal solutions



Climeworks provides **Carbon Dioxide Removal (CDR)** services to address:

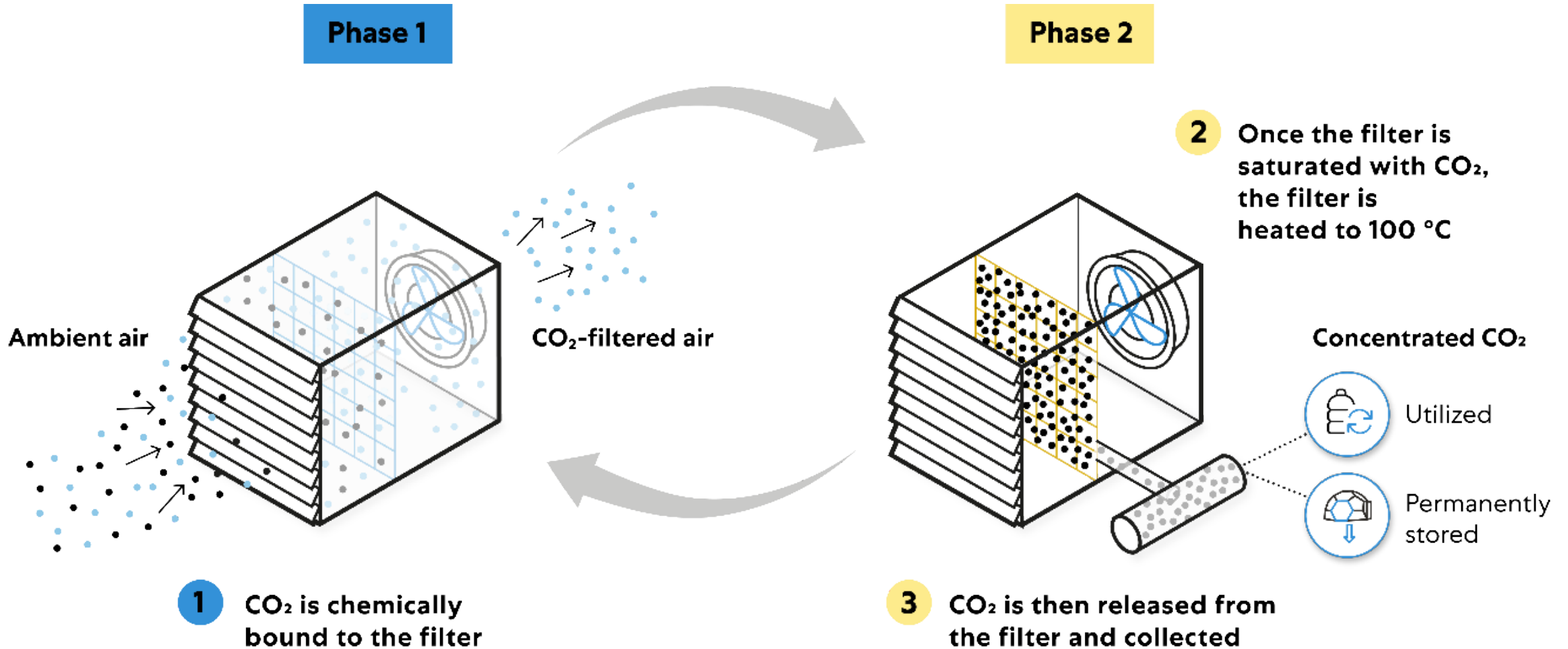
- 1 Hard-to-abate emissions**
- 2 Historical emissions**

# Direct air capture and storage (DAC+S) vs. carbon capture and storage (CCS)



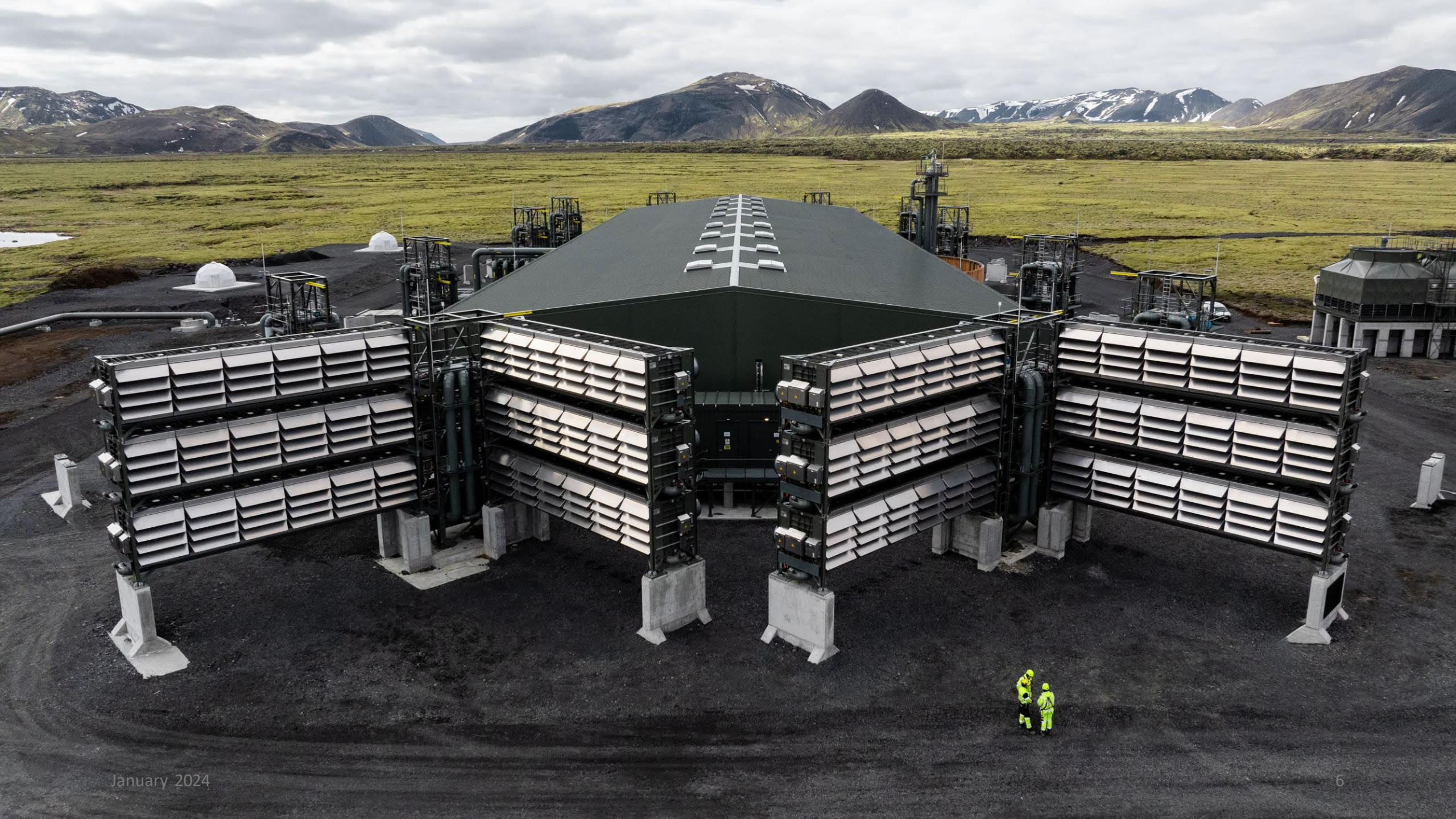
- A** CDR via **DAC+S** removes CO<sub>2</sub> directly from the atmosphere, resulting in **negative emissions**
- B** **CCS** captures fossil CO<sub>2</sub> at point sources before it enters the atmosphere & stores it, resulting in **avoided emissions**

# How our direct air capture technology works

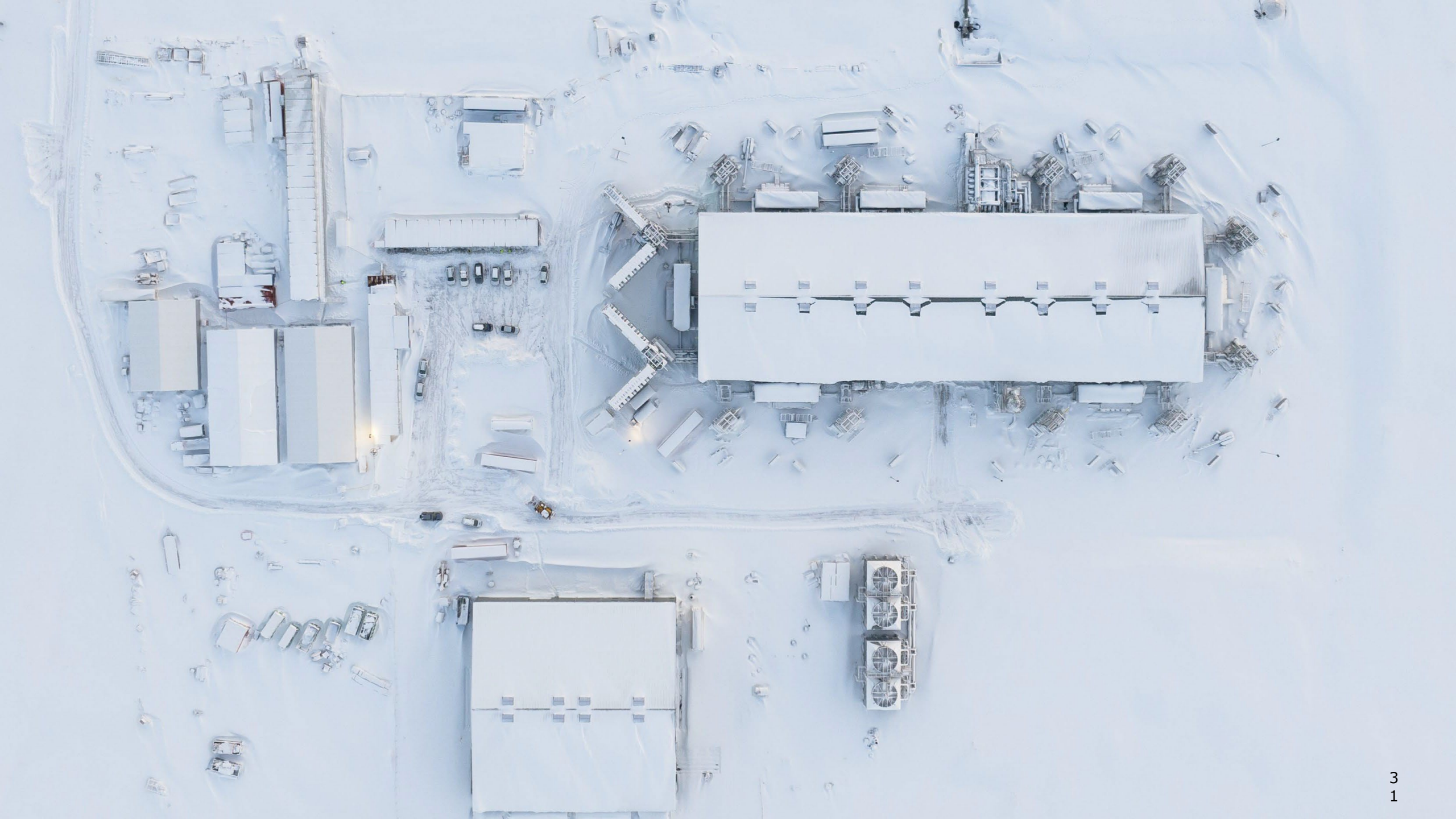




climeworks







# Our business model has two legs – B2B & B2C



## B2B – Corporate CDR clients

**Leading companies** from various industries sign long-term contracts (up to 10 years)

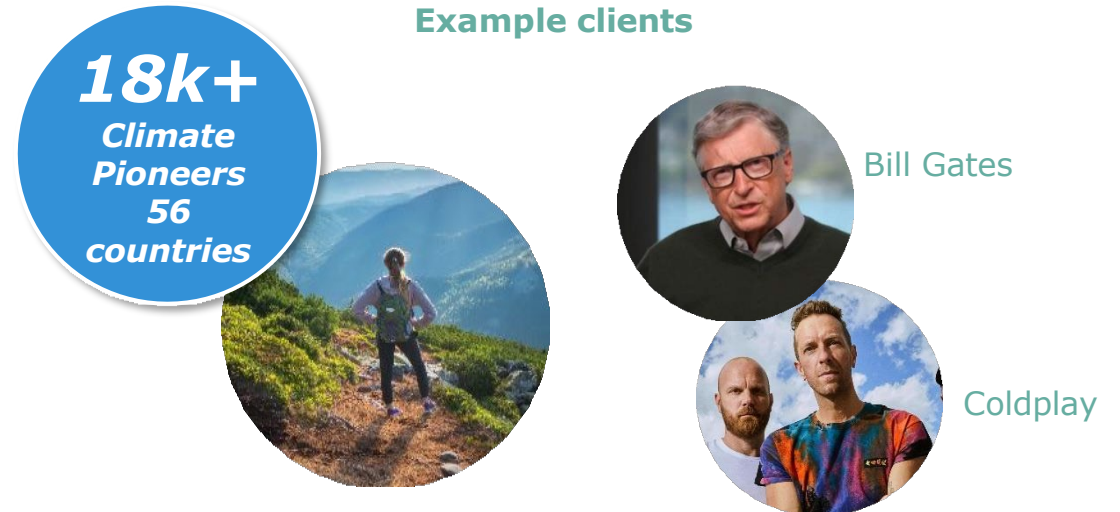
### Key contracts (examples)



## B2C – Private/Retail CDR clients

**Vibrant community** of climate pioneers with monthly subscriptions or one-time gifts

### Example clients



*US market with strongest demand, followed closely by Europe*





**500+**  
**Climeworks**  
dedicated to fighting  
global warming



**\$810**  
**million**  
raised



**> 120,000**  
hours operational  
experience



**< 10%**  
**life cycle emissions**  
renewable energy  
powered



**Since 2009**  
**>15 DAC facilities**  
Including the world's first and  
only large-scale commercial  
DAC+S  
facility



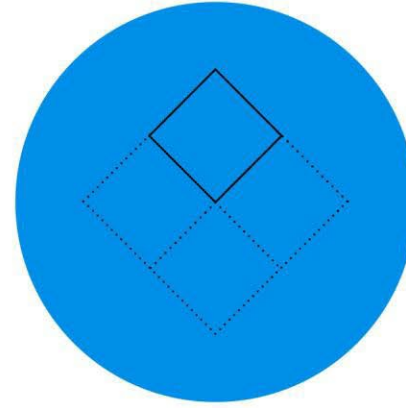
# 5

# success factors

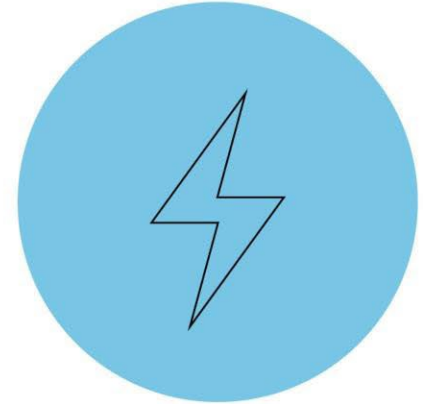
January 2024



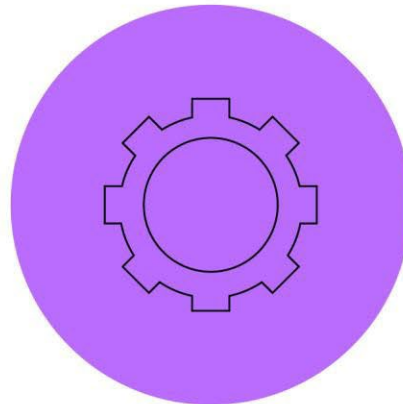
Market  
readiness



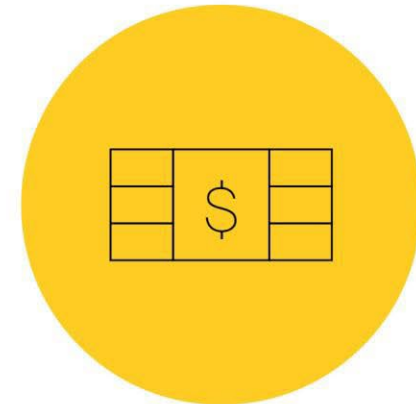
Land/storage  
availability



Energy



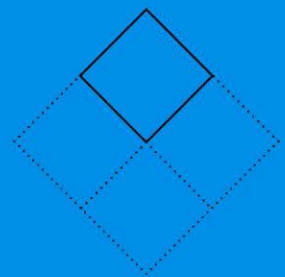
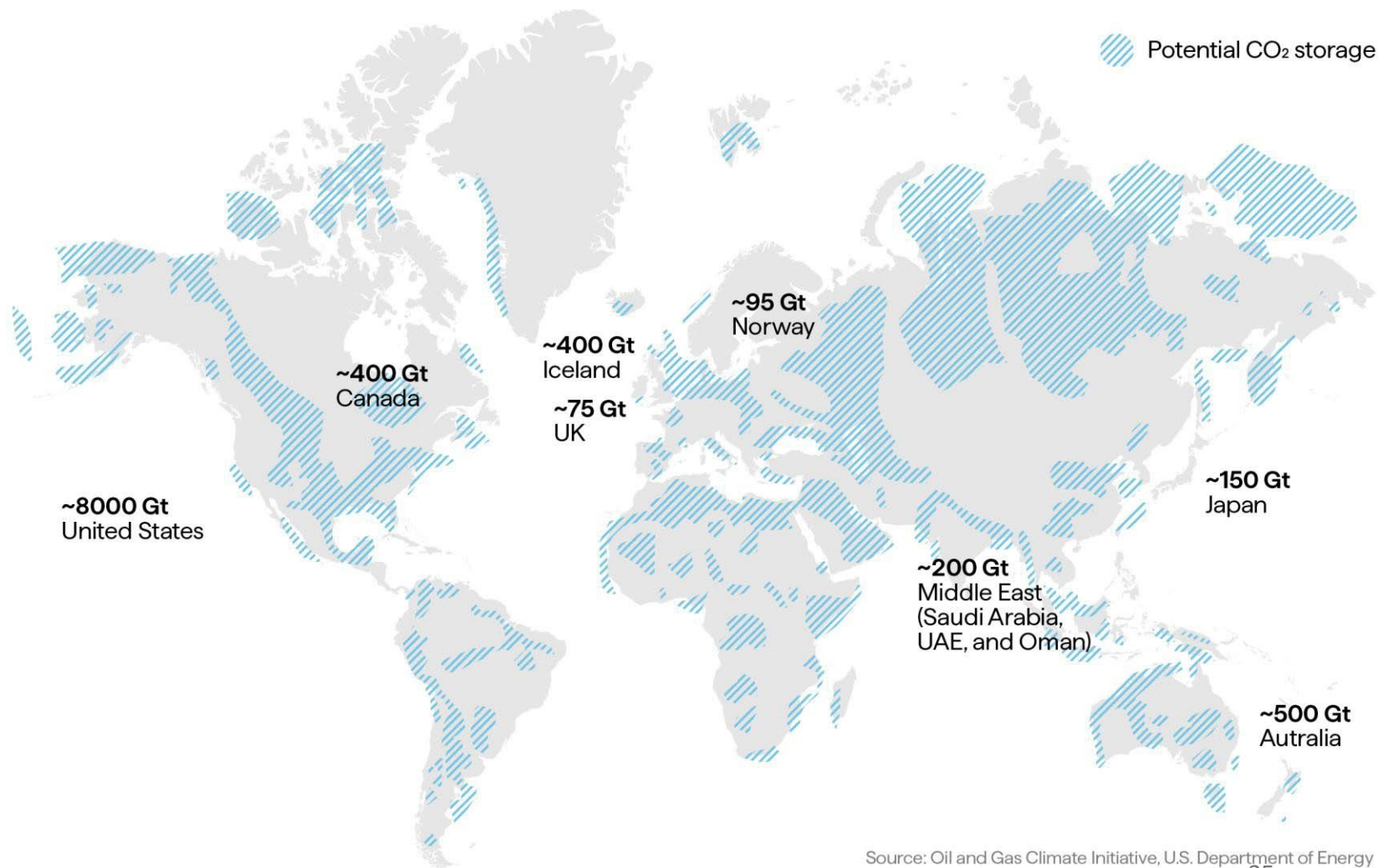
Technology



Cost

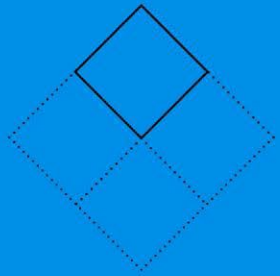
# 1

## Over 9,000 Gt of storage capacity potential



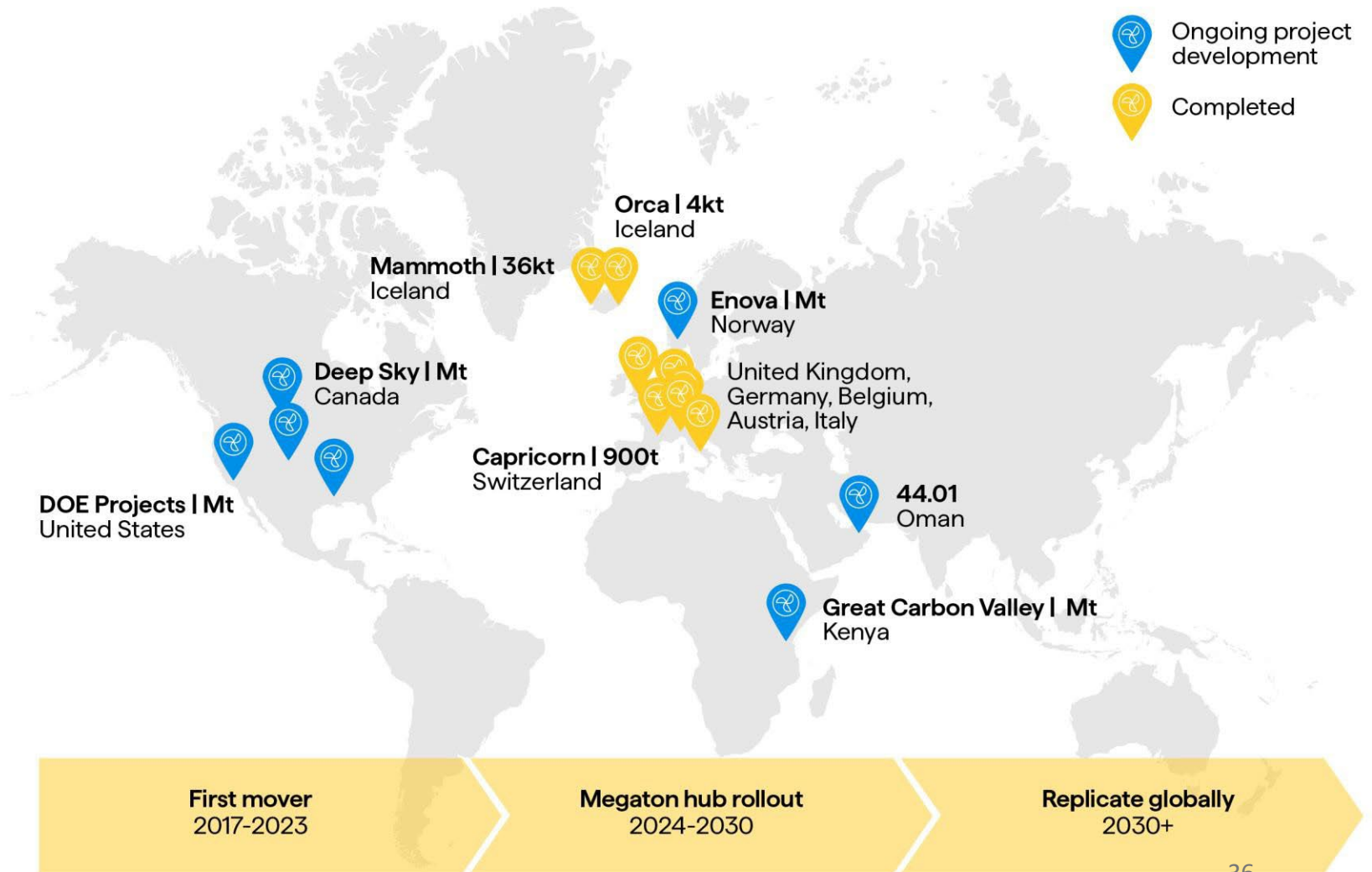
Land/storage availability  
January 2024

# 1



Land/storage  
availability  
January 2024

## We are on track: Our journey to impact at scale



# 2



Energy  
January 2024

Geothermal



Solar

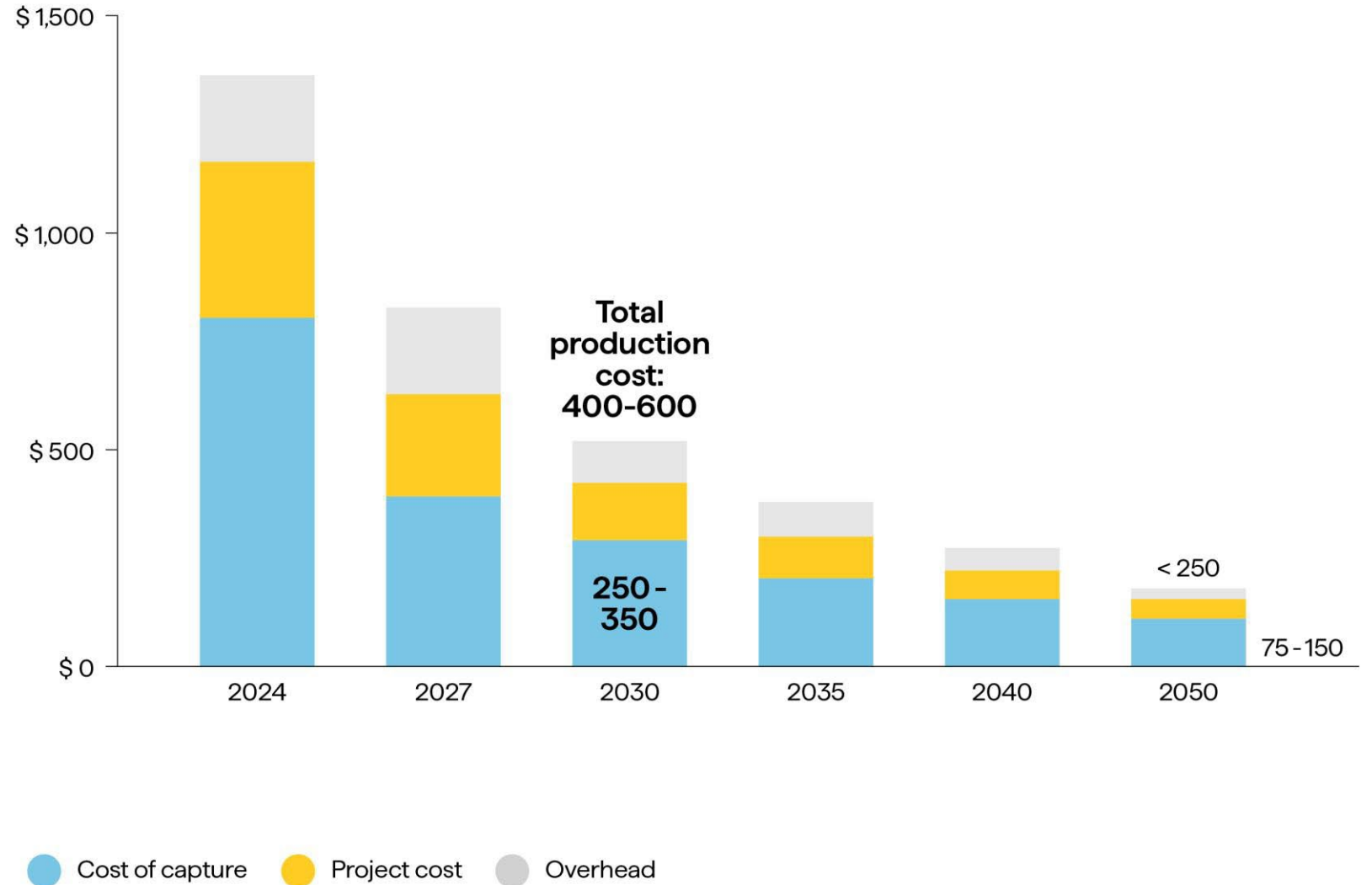


Heat integration



# 3

## DAC cost (real, \$ / tCO<sub>2</sub>)



# Our technology evolution

2014

2017

2021

2024

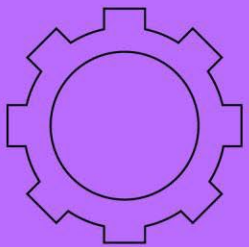
2024



Gen 1

Gen 2

# 4



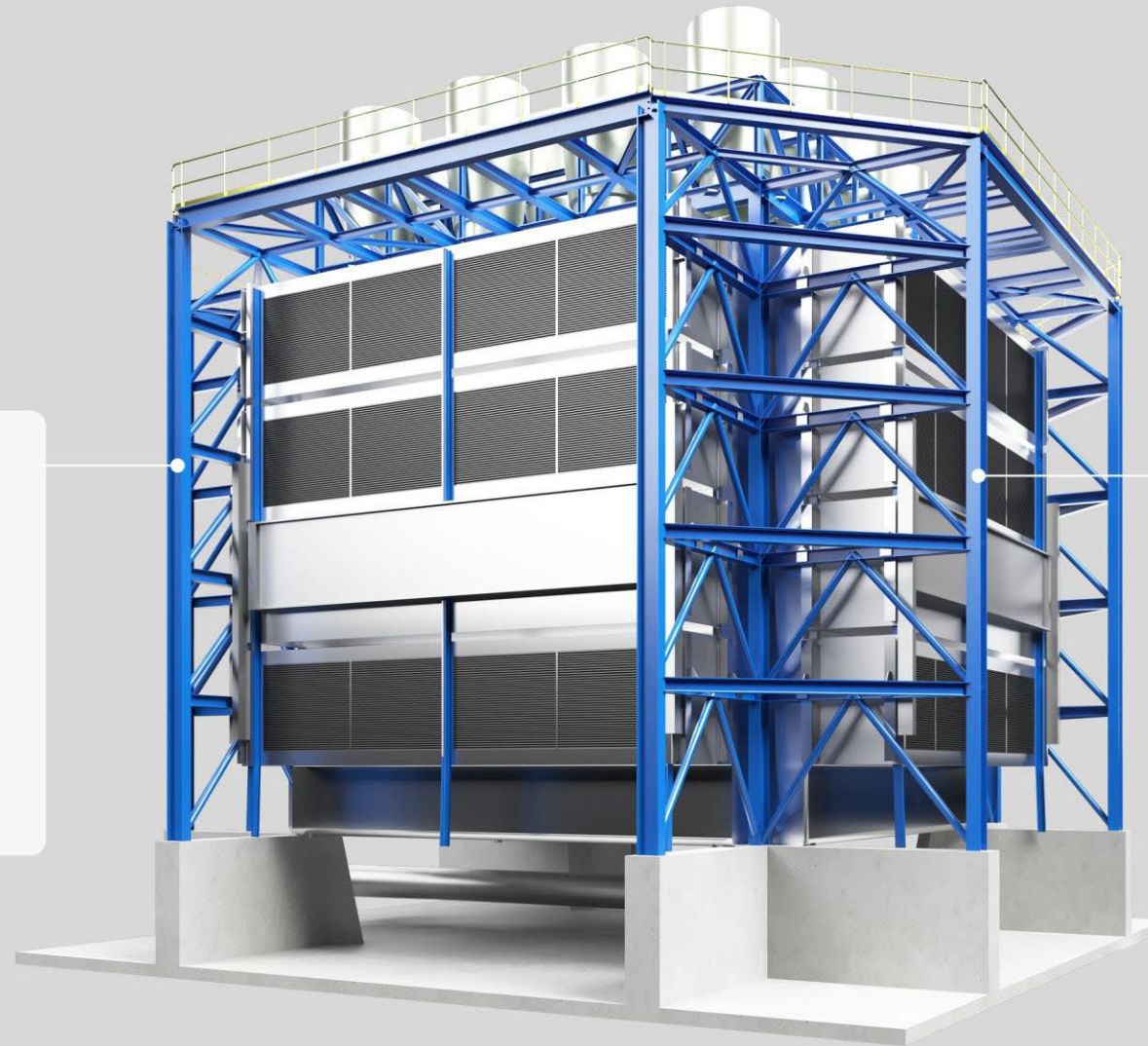
# Technology

January 2024





# Generation 3



## New system layout

- Improved energy utilization
- Increase robustness
- Reduced footprint

## Different sorbents allowing for:

- Faster kinetics
- Higher throughput
- Faster desorption

# Goals

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↑ Increase capture capacity

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↑ Increase filter material lifetime

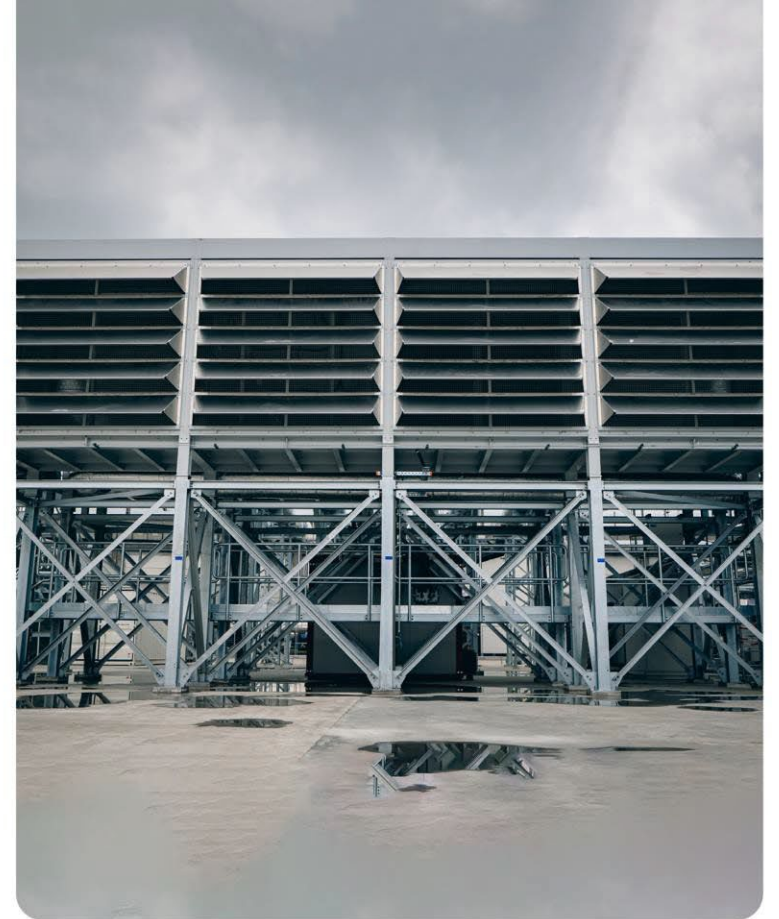
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↓ Reduce energy consumption

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↓ Reduce overall cost

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 **Basel, Switzerland**  
January 2024

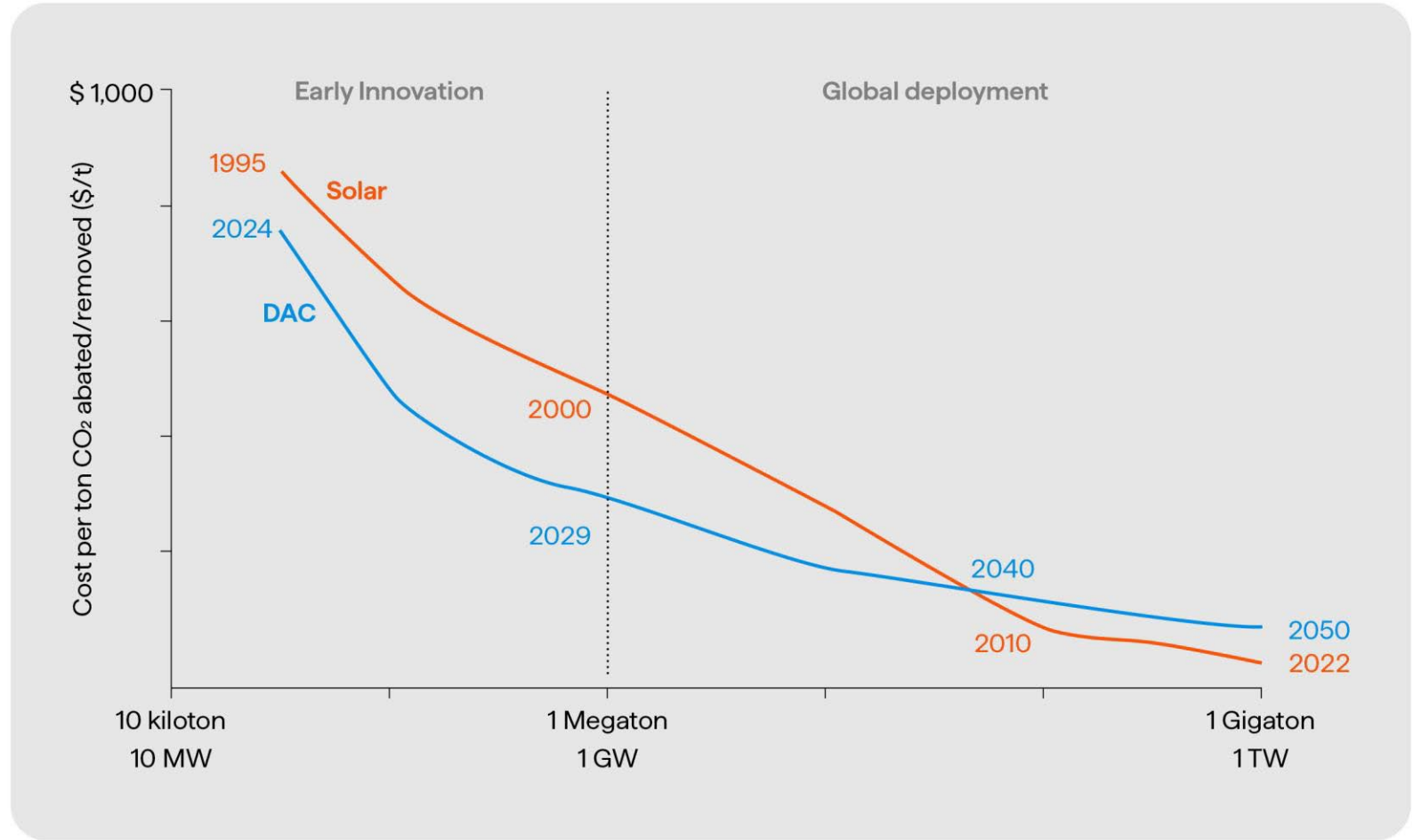
# 5



Market  
readiness

January 2024

## Let's make DAC the new solar



Actual 2020 solar capacity was **20x higher** than forecasted in 2005 and **120x higher** than forecasted in 2000.



**Andrew Fishbein**

Lead Government Affairs North America

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