Rhodium Group

Direct Air Capture Deployment and Economic Opportunity: State-by-State

Methodology and Assumptions

MARCH 7, 2024

Whitney Jones
Associate Director
wjones@rhg.com

Eric O'Rear
Senior Analyst
eorear@rhg.com

Hannah Kolus
Senior Analyst
hkolus@rhg.com

Michael Gaffney
Research Analyst
mgaffney@rhg.com

Monioluwa Adeyemo
Research Analyst
madayemo@rhg.com

Naveen Dasari
Research Analyst
ndasari@rhg.com

Ben King
Associate Director
bking@rhg.com

Jaspreet Kaur
Data Visualization Analyst
jkaur@rhg.com

Table of Contents

Projecting the state-level potential for direct air capture capacity deployment

Scenario development

Timeframe scenarios

- This analysis looks at the potential for direct air capture (DAC) capacity deployment in two timeframes which we characterize as “Near-term” and “Mid-century”.
- To characterize the “Near-term” potential by state, we start with Rhodium estimates for national-level DAC deployment under current policy by 2035.
- To characterize the “Mid-century” potential by state, we start with Rhodium estimates for national-level DAC deployment required to decarbonize by 2050.

Deployment scenarios

- Within each timeframe scenario, this analysis looks at the potential for DAC deployment under two scenarios which we characterize as “Low Deployment” and “High Deployment”.
- In the “Near-term” scenario, the deployment potential uncertainty is characterized by uncertainty around DAC costs, and the speed of infrastructure scale-up and deployment, including uncertainty around the operation timeframe for DAC Hubs.
- In the “Mid-century” scenario, the deployment potential uncertainty is characterized by uncertainty around the pace of electrification in the end-use energy sectors, the pace of decarbonization of the electric power sector, the availability of biomass supply to the energy sector, and the amount of natural carbon dioxide removal (CDR) available.

Scenario development

Additional timeframe scenario details

Near-term

- *Timeframe:* cumulative million metric tons (MMT) of capture capacity per year by 2035
- *Underlying Rhodium analysis:* Rhodium's *Taking Stock 2023* report. This analysis found that 5 to 84 MMT of cumulative DAC capacity will be deployed under current policy in the US by 2035.
- *Policy assumptions:* Deployment under current policy. Includes section 45Q tax credit and DOE DAC Hubs program.
- *Deployment scenario uncertainty assumptions:* Low and high deployment ranges correspond to uncertainty around DAC costs, and the speed of infrastructure scale-up and deployment including uncertainty around the operation timeframe for DAC Hubs.

Mid-century

- *Timeframe:* cumulative million metric tons (MMT) of capture capacity per year by 2050
- *Underlying Rhodium analysis:* Rhodium's 2019 *Capturing Leadership* report. This analysis found that 689 to 2,258 MMT/year of DAC capacity would be required for the US to decarbonize economy-wide by midcentury.
- *Policy assumptions:* US economy-wide decarbonization. This modeling uses a 105% below 2005 levels in 2050 net economy-wide emissions constraint that is policy agnostic.
- *Deployment scenario uncertainty assumptions:* Low and high deployment ranges correspond to uncertainty around the pace of electrification in the end-use energy sectors, the pace of decarbonization of the electric power sector, the availability of biomass supply to the energy sector, and the amount of natural carbon dioxide removal (CDR) available.

Deriving state-level deployment potential

- Using national-level estimates described previously we assess where national-level DAC capacity deployment could be located by state.
- To do this, we attribute national-level DAC capacity by state based on a range of inputs characterizing a state's relative level of access to major variables required for DAC plant construction and operation.
- Because this is not a bottom-up technical potential study, we don't explicitly model DAC technologies. That said we assume liquid solvent, solid sorbent, solid solvent/mineralization, and electrochemical mineralization approaches will all be available by mid-century. Where necessary in our analysis, we hybridize DAC cost and performance data to stay as technology-agnostic as possible.
- We assume deriving DAC capacity potential by state from national-level estimates is dependent on 2 major factors—the availability of carbon capture transportation and storage infrastructure and the low-carbon electricity and heat inputs required to run a DAC facility. We break these down further into 6 major variables.
- We look at the availability or access of individual states to 6 major variables:
    - Existing carbon capture, transportation and storage infrastructure
    - Geologic carbon dioxide (CO_2) storage
    - Low-carbon electricity from renewable sources
    - Low-carbon electricity from natural gas with carbon capture
    - Waste heat for process heat
    - Natural gas for process heat

Variables impacting state-level deployment potential

Geologic CO_2 storage

- Data on the location of saline geologic formations comes from DOE/NETL's National Carbon Sequestration Database (NATCARB).
- We restrict where DAC facilities can be located based on the land exclusion approach employed by NREL in their *The Renewable Energy Potential (reV) Model* report.
- We account for economic CO_2 transportation by including a buffer around eligible storage land.

Existing carbon capture, transportation and storage infrastructure

- Data based on Rhodium's Industrial Carbon Abatement (ICAP) platform, using central cost assumptions from *Taking Stock 2023*.

Low-carbon electricity from renewable sources

- Data comes from NREL's *US Renewable Energy Technical Potentials* analysis.
- The near-term scenario considers only solar and wind potential, while the long-term scenario also includes geothermal and biomass potential.

Low-carbon electricity from natural gas with carbon capture

- Natural gas power generation with carbon capture deployment projections through 2050 are based on NREL's *100% Clean Electricity by 2035* study.
- This variable is only considered in the long-term scenario, as deployment is expected to be negligible by 2035.

Natural gas for process heat

- US natural gas pipeline data comes from EIA.

Waste heat for process heat

- We assume that waste heat availability will only play a role in DAC siting in the near-term.
- Data comes from ORNL's *Waste Heat to Power Market Assessment*.

Weighting variables to simulate real-world importance

- We assign each variable a weighting value based on our assessment of its relative importance to DAC deployment in the near-term and mid-century timeframes.
- Weights are applied to each variable at the state level and are summed to arrive at a total state-level opportunity score.
- Weighting values vary across scenarios and are independently assessed by Rhodium.

Near-term

- Geologic CO_2 storage [20%]
- Existing carbon capture, transportation and storage infrastructure [30%]
- Low-carbon electricity from renewable sources [20%]
- Low-carbon electricity from natural gas with carbon capture [0%]
- Natural gas for process heat [20%]
- Waste heat for process heat [10%]

Mid-century

- Geologic CO_2 storage [40%]
- Existing carbon capture, transportation and storage infrastructure [10%]
- Low-carbon electricity from renewable sources [25%]
- Low-carbon electricity from natural gas with carbon capture [5%]
- Natural gas for process heat [20%]
- Waste heat for process heat [0%]

SECTION 2

Quantifying the state-level investment and employment impact of direct air capture deployment

Assumptions and methodology for economic analysis

Cost characterization

- The capital investment and operations & maintenance (O&M) costs are associated with the construction and operation of representative 500,000 kiloton DAC facility in the US.
- Costs are independently assessed by Rhodium to ensure consistency with existing data trends.
- Costs are based on median values across all DAC processes that we have internal Rhodium data and access to publicly available data on. This analysis is not an attempt to project which technologies will deploy across states therefore we structure our methodology to be as technology agnostic as possible.

Employment and occupational analysis

- We use the economic model IMPLAN's state-level (2021 data year) tools for the employment analysis.
- Occupational analyses are also conducted using IMPLAN, supplemented by BLS data.
- We estimate in-state jobs and occupations associated with the investment in new DAC facilities within each state.
- Jobs associated with capital investments are the average annual jobs over a 5-year construction period.
- Ongoing operations jobs depict the on-site and off-site jobs associated with operating a DAC facility each year.
- Employment per industrial output is assumed to stay constant over time.

Direct Air Capture Deployment and Economic Opportunity: State-by-State

Methodology and Assumptions

MARCH 7, 2024

NEW YORK | CALIFORNIA | WASHINGTON, DC | PARIS
TEL: +1 212-532-1157 | FAX: +1 212-532-1162
www.rhg.com