Direct Air Capture Siting Considering Geologic Storage Capacity, Net-Zero Capacity Targets, and Environmental Justice

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Challenge

Direct air capture (DAC) is removing CO_2 from the air using machines built for that purpose, and deploying hundreds to thousands of DAC facilities across the country may be required to reach net-zero in the USA. **For example, the Princeton and the EPRI Net-Zero America studies conclude that up to 720 $MtCO_2$/yr and 134 $MtCO_2$/yr of DAC capacity may be required in 2050, respectively [5-6].**

While necessary, knowing where to deploy DAC is difficult: DAC is energy intensive, requires CO_2 storage, and its deployment may be influenced by environmental justice considerations like the locations of disadvantaged communities. But quantifying the effect of these considerations on cost is difficult because there are no quantitative geospatial siting tools for DAC. **Here, we address this gap.**

Approach

We develop and use the Negative CO_2 Emission Transition Roadmap (NECTAR), a geospatial siting tool for negative emission technologies. For this study, three geospatial siting considerations are considered within NECTAR:

1) Geologic CO_2 Storage

We use our Sequestration of CO_2 Tool (SCO_2T) to estimate the geospatial cost of CO_2 storage (Figure 1).

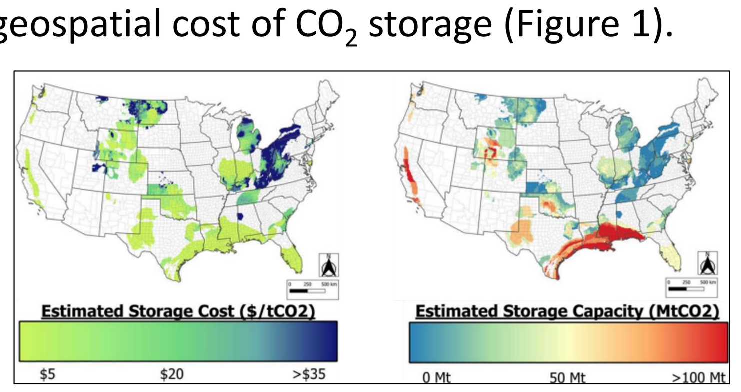

Fig. 1: Geospatial Cost and Capacity of Geologic CO_2 Storage [3].

2) Energy Requirements

The energy requirements are DAC system dependent, and we include two different DAC systems here:

- Low-temperature DAC (i.e., solid-sorbent, needing 100°C) heated with sedimentary basin geothermal resources. DAC performance and energy requirements are modeled following prior work [7]; the cost of sedimentary basin geothermal heat is estimated using genGEO [1] and SCO_2T [3]; wholesale electricity prices from EPRI Net Zero America study are used [5].
- High-temperature DAC (i.e., liquid solvent, needing 900°C) powered and heated from a natural-gas-fired standalone system. DAC performance and cost is modeled using data from prior work [2]. Natural gas was assumed to cost \$3.5/MMBtu [2].

3) Environmental Justice (EJ)

Disadvantaged community locations are defined using the Clean Energy and Energy Efficiency category from the Climate and Economic Justice Screening tool (Figure 2). We include three scenarios: deploying DAC 1) anywhere; 2) only in disadvantaged communities; and 3) not in disadvantaged communities.

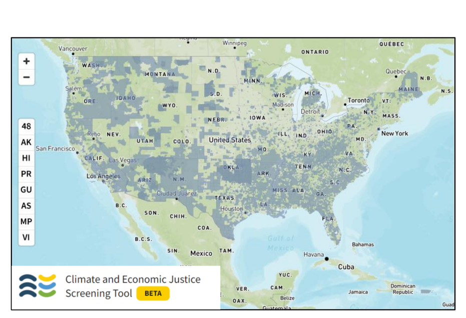

Fig. 2: Climate and Economic Justice Screening Tool [8].

Geospatial Cost of Direct Air Capture

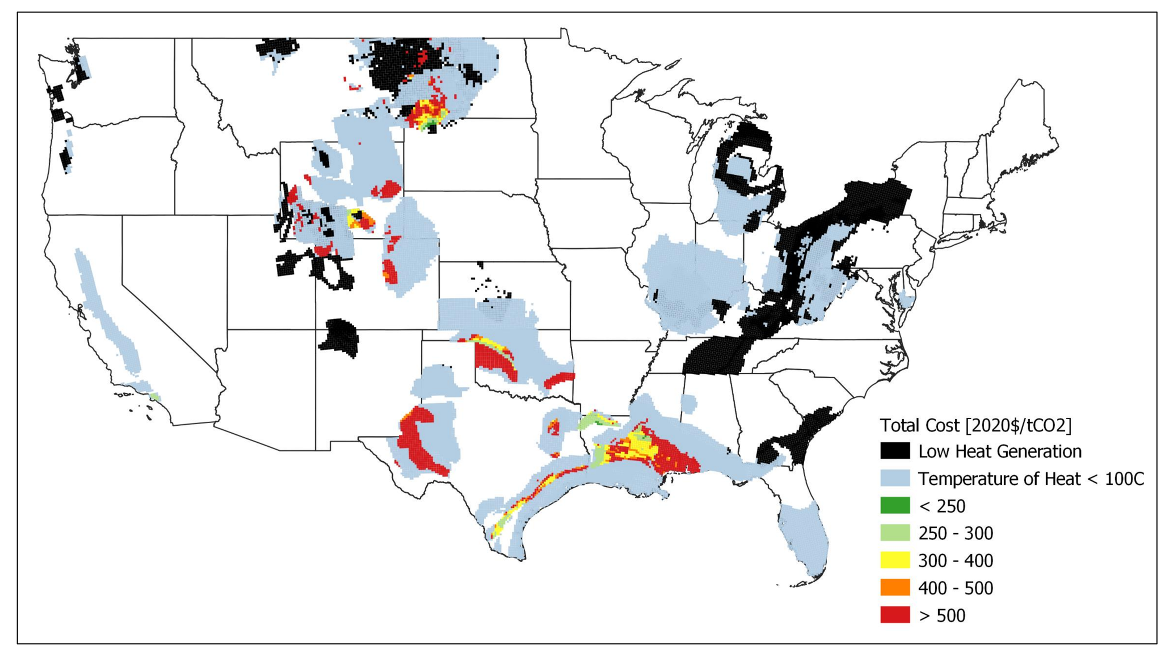

Fig. 3: Geospatial Cost and Capacity of Low-Temperature DAC. Blue areas either a) have insufficient geothermal temperature gradient or b) are too shallow to reach 100°C. Low-cost areas are those with the most geothermal heat. These results do not account for changes in air temperature or humidity.

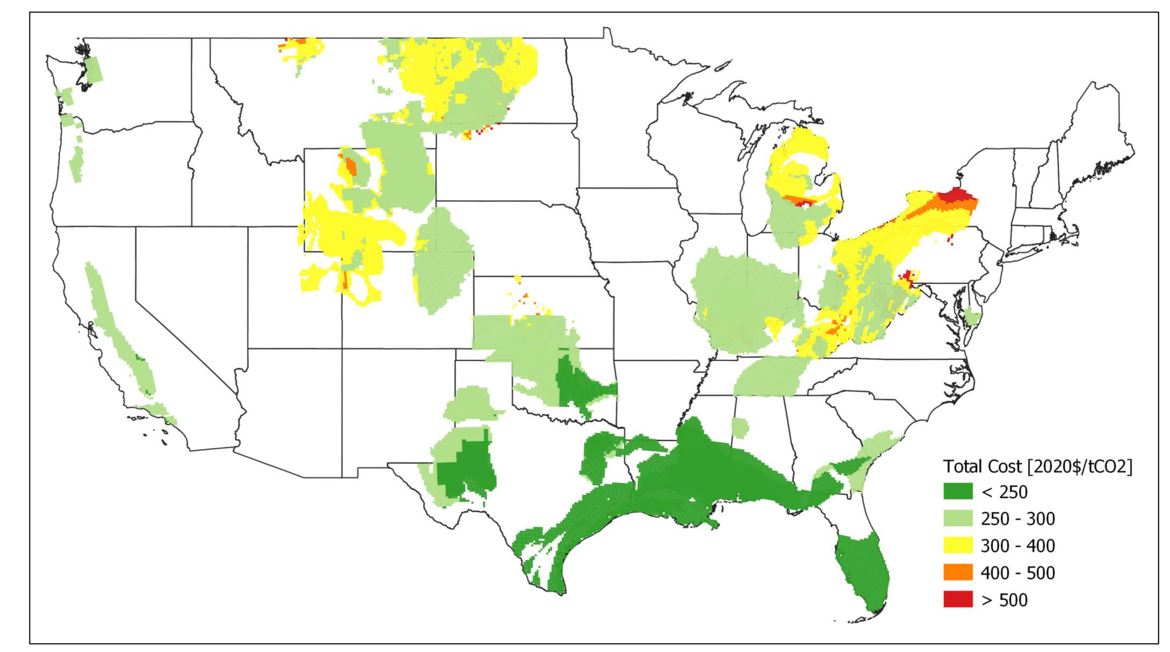

Fig. 4: Geospatial Cost and Capacity of High-Temperature DAC. Low-cost areas are those with the hottest air temperatures and highest relative humidity. Average annual air temperature and relative humidity data taken from [4].

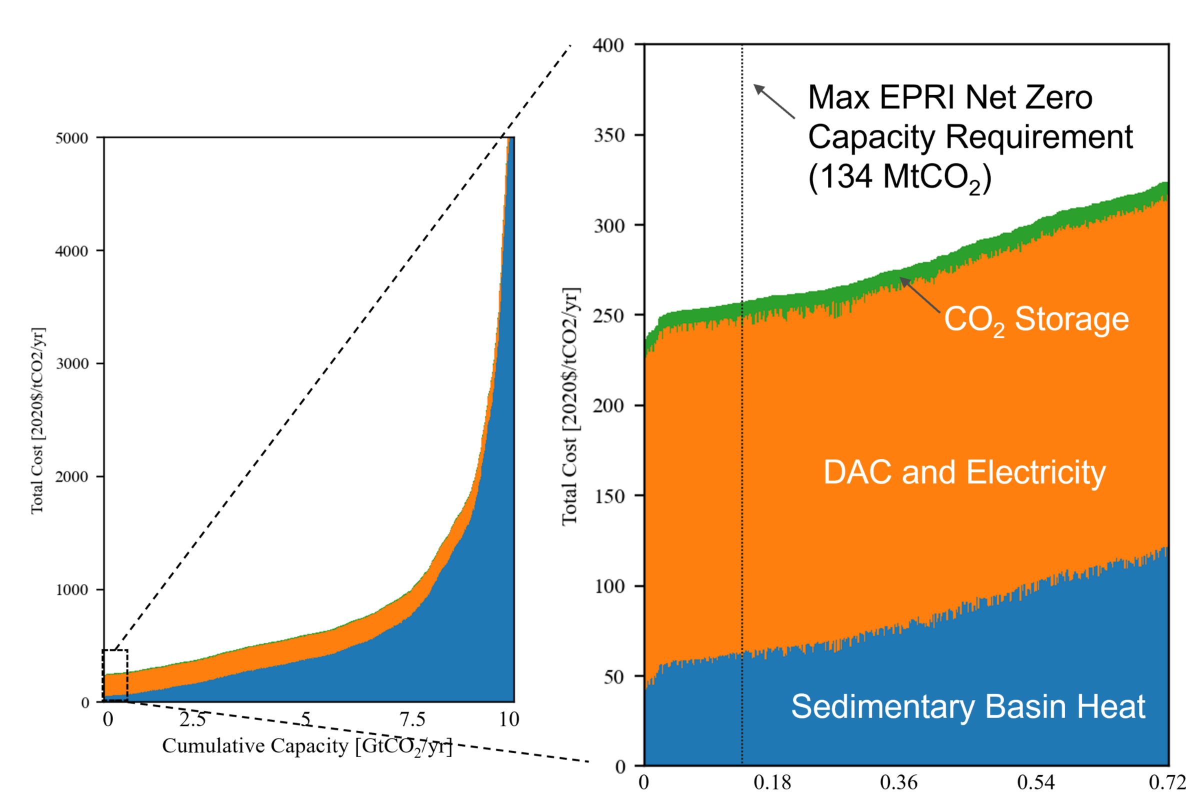

Fig. 5: Supply Curves for Low-Temperature DAC. The total capacity is limited by the geothermal heat availability and capacity of CO_2 storage because the sedimentary basin resource is "shared" between providing heat (i.e., brine) and storing CO_2. The cost of DAC comprises most of the total cost until more expensive sedimentary basin heat resources are used.

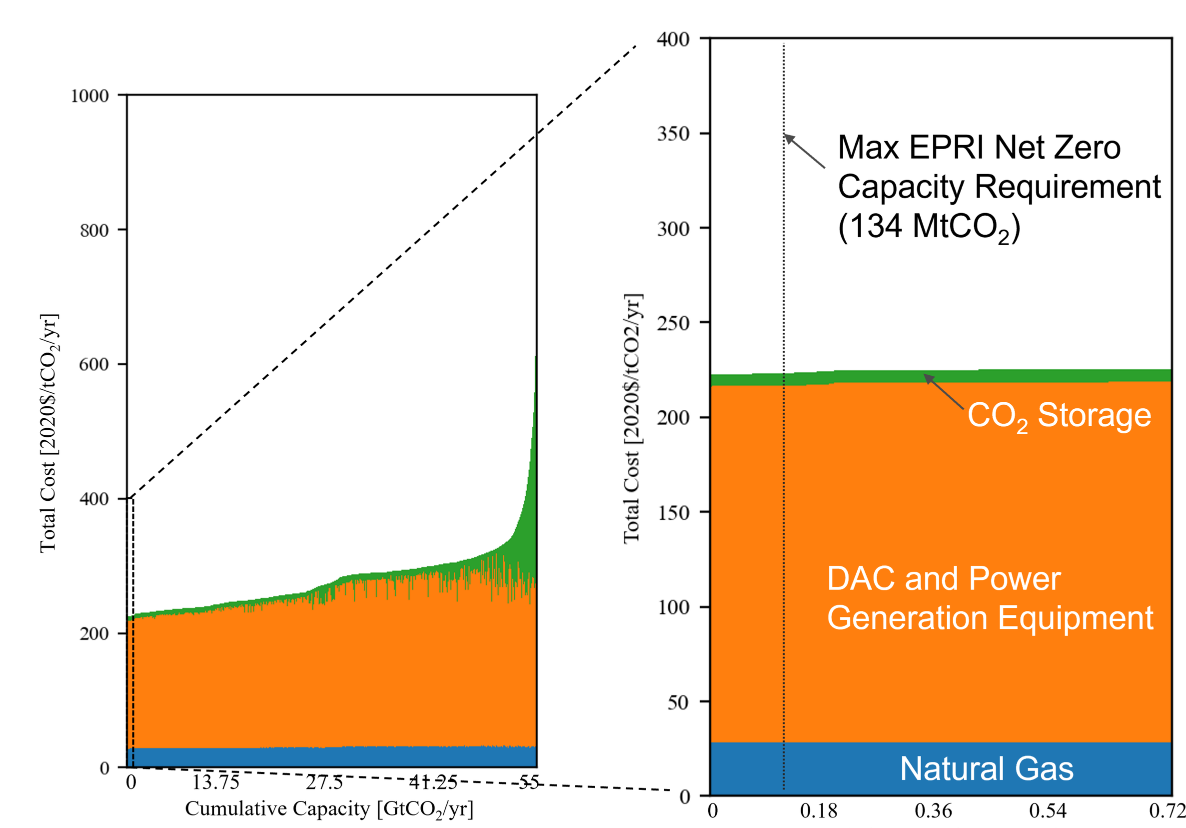

Fig. 6: Supply Curves for High-Temperature DAC. The total capacity is limited by the capacity of CO_2 storage because heat is provided by natural-gas. The cost of DAC comprises most of the total cost until the cost of CO_2 storage exponentially increases.

Considering EJ

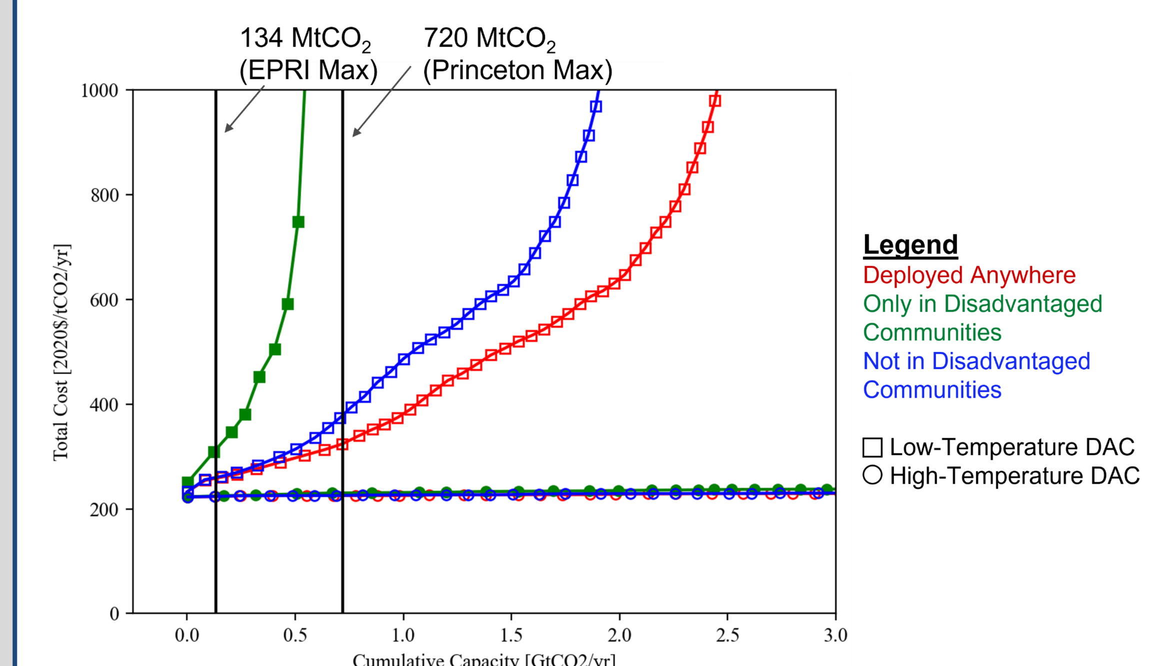

Fig. 7: Supply Curves When Considering the Location of Disadvantaged Communities.

Table 1: Change in Cost Relative to Deployed Anywhere Scenario For Low-Temperature DAC. Little to no change in cost for high-temperature DAC because of larger total capacity.

	Only in Disadvantaged Communities	Not in Disadvantaged Communities
Average Cost at 134 $MtCO_2$	\$30/tCO_2	\$1/tCO_2
Marginal Cost 134 $MtCO_2$	\$53/tCO_2	\$4/tCO_2
Average Cost at 720 $MtCO_2$	\$638/tCO_2	\$19/tCO_2
Marginal Cost at 720 $MtCO_2$	\$10,103/tCO_2	\$53/tCO_2

Conclusions

1. The cost and capacity of DAC can change geospatially depending on the cost geologic CO_2 storage, cost and availability of energy, and environmental justice considerations. The effect on cost of many of these considerations is DAC system dependent.
2. Sedimentary basin resources can provide sufficient geothermal heat and CO_2 storage to hit net-zero capacity targets via low-temperature DAC systems. Depending on how environmental justice is considered, costs could increase by tens to thousands of dollars per tonne of CO_2.
3. Compared to low-temperature systems, there is more capacity for high-temperature DAC because its deployment is not contingent on the availability of geothermal heat. For this reason, the cost may be less sensitive to how environmental justice is considered.

References and Funding Acknowledgement

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This material is based upon work supported by the U.S. Department of Energy, Office of Science, Small Business Innovations Research program under Award DE-SC0022486. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Department of Energy.