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Identifying Opportunities and Cost for CO_2 Capture at Power and Industrial Facilities in the United States

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Abstract

The United States needs to rapidly reduce CO_2 emissions to achieve climate goals. Installing carbon capture at power and industrial facilities, when paired with geologic storage, is one way to reduce emissions. The selection and design of carbon capture equipment is complicated because each facility has unique characteristics that need to be considered. For example, some facilities have a variety of units that may consume different types of fuels and produce varying amounts of CO_2. Therefore, it is imperative to first screen facilities to determine which have units that are suitable for capture, and to estimate the cost of implementation.

We have developed CO_2NCORD, the CO_2 National Capture Opportunities and Readiness Database, a tool to identify facilities feasible for carbon capture retrofits and estimate the associated costs. CO_2NCORD combines 1) detailed emitter data from the EPA, EIA, and RFA, 2) capture cost estimates from literature, 3) NETL cost models and 4) experience-based classification to make this assessment.

This study will provide an overview of the number of facilities that are expected to have prime capture opportunities. Not all emitted CO_2 is expected to be captured because some facilities do not emit enough to make capture economic or are eligible for 45Q tax credits. Our analysis shows that there are many opportunities for carbon capture in the United States.

The novelty of this work is enhancing publicly available emitter data into information that can support screening facilities for carbon capture. One of the ways it does this is by identifying types of units and processes that can support capture equipment, as opposed to just overall CO_2 emissions at a facility. It also enables summarizing the amount of CO_2 emissions that may be expected to be economical for capture at state and national scales.

Introduction

Carbon capture and storage (CCS) is part of every major climate plan to limit CO_2 emissions. The International Energy Agency (IEA) estimates that 759 million tonnes of CO_2 per year ($MtCO_2$/year) need to be captured globally from power and industrial facilities to reach net zero emissions by 2030 (IEA, 2023). By 2050, the global CCS need for power and industrial facilities could increase to 3,736 $MtCO_2$/year (IEA, 2023). By 2050, the United States could need to capture between 700 and 1,700 $MtCO_2$/year (Larson, E., Greig, C., Jenkins, J. et al. 2021).

The United States Environmental Protection Agency (EPA) collects data under the Greenhouse Gas Reporting Program (GHGRP) for all facilities with more than 25,000 tonnes of non-biogenic CO_2 equivalent emissions per year, which was 6,521 facilities in 2021 (U.S. Environmental Protection Agency Office of Atmospheric Protection, 2023). In the United States, CCS is supported by the 45Q tax credit that currently provides \$85/tCO_2 for storage in saline aquifers (United States Code. 26 USC 45Q: Credit for Carbon Oxide Sequestration). The goal of this study to assess the carbon capture opportunities in the United States for power and industrial facilities.

Methods

To assess carbon capture opportunities, we applied CO_2NCORD (the CO_2 National Capture Opportunities and Readiness Database), which was developed by CARBON SOLUTIONS LLC under a National Science Foundation (NSF) Small Business Innovation Research (SBIR) grant. CO_2NCORD begins with CO_2 emissions data for facilities, estimates the amount of CO_2 that can be captured at locations within each facility (capture streams), projects the cost of capture, categorizes the facilities, and then filters results by user preference (Figure 1).

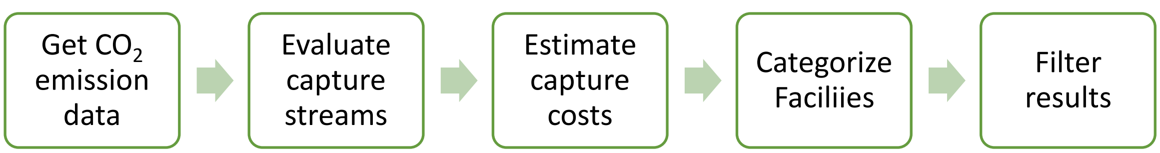

Figure 1. CO_2NCORD workflow for identifying carbon capture retrofit opportunities and costs.

The sources of emission data used for this study are shown in Table 1. GHGRP data was accessed via the Envirofacts API (U.S. Environmental Protection Agency, 2022). Emissions from some units are not expected to be suitable for capture, so these units are removed by CO_2NCORD when identifiable.

The EPA groups emissions reported to GHGRP into subparts. Each subpart contains emissions from similar types of units. For example, a facility may have refining emissions (Subpart Y) and emissions from hydrogen production (Subpart P). Capture costs are unique to each process type; therefore, CO_2NCORD estimates are based on the emissions grouped by subpart at the facility. Certain facilities are expected to combine emissions reported under two subparts together. For example, cement and lime plants typically combine process (Subpart H or S) and combustion emissions (Subpart C). Therefore, CO_2NCORD combines these emissions together into a single capture stream. Some EPA subparts include both fossil and biogenic CO_2 emissions, which are suitable for capture and included in capture estimates.

Table 1. Overview of data sources by emission type.

Emission source	Data Source	Reference
Industrial and power facility emissions	GHGRP	(U.S. Environmental Protection Agency Office of Atmospheric Protection, 2023)
Power facility emissions	eGRID	EPA eGRID (U.S. Environmental Protection Agency. 2023)
Ethanol production	U.S. Fuel Ethanol Plant Production Capacity	(U.S. Energy Information Administration, 2023)
	RFA Website	(Renewable Fuels Association, 2023)

After capture streams are identified at each facility, costs are assigned. Capture rates and costs were taken from recent National Energy Technology Laboratory (NETL) reports when available and supplemented with literature as needed. These are summarized by sector in Table 2. CO_2NCORD also has the ability to remove from consideration facilities projected to have less capturable emissions than required by the 45Q tax credit. GHGRP does not include ethanol fermentation emissions, so ethanol emissions are estimated based on the theoretical amount of CO_2 produced from ethanol fermentation (Xu, Y., Isom, L., and Hanna, M.A., 2010). Costs are inflated to the current dollar year using the gross national product (U.S. Bureau of Economic Analysis, 2023).

Table 2. References used for carbon capture pricing by sector.

Sector	Reference
Power	
Biomass	(Buchheit, K., Lewis, E., Mahbubani, K. et al., 2021)
Coal	(Schmitt, T. Leptinsky, S., Turner, M. et al., 2022)
Natural gas	(Schmitt, T. Leptinsky, S., Turner, M. et al., 2022)
Industry	
Aluminum	(Psarras, P.C., Comello, S., Bains, P. et al., 2017)
Ammonia	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Cement	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Chemicals	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Hydrogen	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Iron & steel	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Lime & gypsum	(Psarras, P.C., Comello, S., Bains, P. et al., 2017)
Natural gas processing	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Oil & gas	(Schmitt, T. Leptinsky, S., Turner, M. et al., 2022)
Petrochemicals	(Hughes, S., Zoelle, A., Woods, M. et al., 2022)
Pulp & paper	(Psarras, P.C., Comello, S., Bains, P. et al., 2017)
Refineries	(Psarras, P.C., Comello, S., Bains, P. et al., 2017)
Solid Waste	(Pour, N., Webley, P.A., and Cook, P.J., 2017)

Results

For this study, CO_2NCORD was applied to power and industrial facilities in the contiguous United States to estimate each facility's capturable emissions and capture cost. The location and quantity of emissions at each facility are shown in Figure 2. Each circle represents a facility, and it is color-coded by its primary industry category. Next, we created a supply curve to summarize the cost of capturing CO_2 against the cumulative amount of CO_2 available for capture. The results are shown in Figure 3. Supply curves help identify the set of lowest-cost capture options to meet a particular capture target.

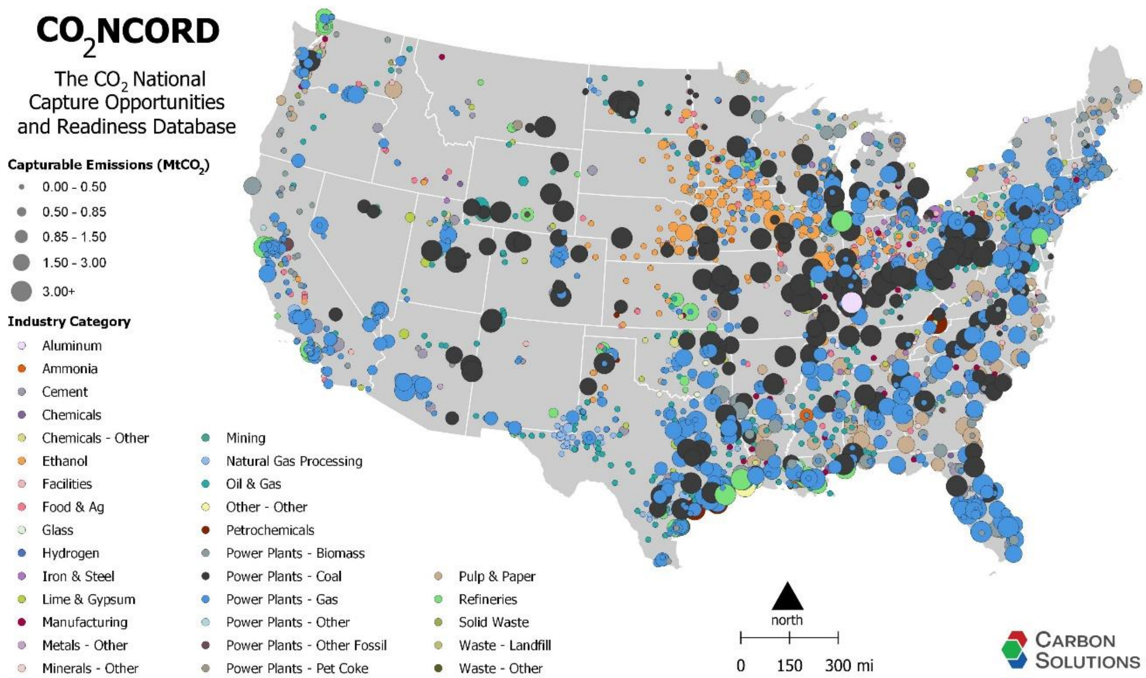

Figure 2. Capturable CO_2 emissions identified by CO_2NCORD at power and industrial facilities in the United States.

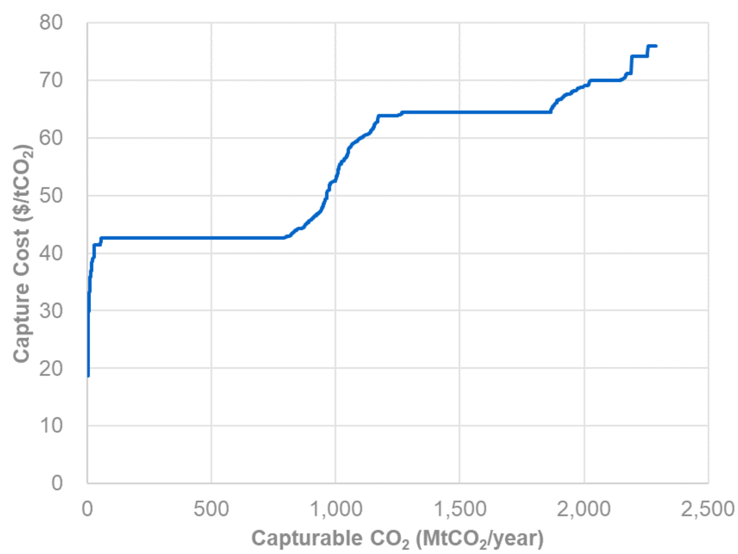

Figure 3. Supply curve of CO_2 capture opportunities in the United States.

Discussion

As shown in Figure 2, this analysis identified sources of capturable CO_2 across the United States. 3,182 facilities were found to have capturable emissions. The location of the sources and amount of capturable CO_2 varied. Some industries, such as coal and natural gas power plants, are spread throughout the country. Other sectors, such as ethanol, are concentrated in a specific portion of the country.

Based on the supply curve, the average cost to meet a target of capturing 1,000 $MtCO_2$/year is \$43/tCO_2, with the maximum cost for a single facility being \$53/tCO_2. This cost only considers capturing the CO_2

and does not include transportation or storage. Just as the sources of CO_2 are spread across the country, so are geologic storage opportunities. Therefore, to determine the full cost of carbon capture and storage, planning would need to optimize the cost and location of capture, transport, and storage.

Conclusions

This study performed an assessment of carbon capture opportunities in the contiguous United States using CO_2NCORD. Capturable emissions were identified at 3,182 facilities grouped into 31 sectors. The average cost to capture 1,000 $MtCO_2$/year was estimated at \$53/tCO_2.

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