Executive Summary

A New U.S. Industrial Backbone

Exploring Regional CCUS Hubs for Small-to-Midsize Industrial Emitters

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EFI FOUNDATION

HORIZON CLIMATE GROUP

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The EFI Foundation advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, the EFI Foundation conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI Foundation maintains editorial independence from its public and private supporters and sponsors.

Horizon Climate Group provides analysis, interactive tools, and easy to understand insight on energy, greenhouse gas emissions, and equitable climate solutions. Horizon's key areas of focus include industrial emissions quantification and solutions, energy systems planning, and transportation sector decarbonization. With a combined experience of over 20 years in climate, energy, and decarbonization, the team of analysts at Horizon specialize in life cycle GHG assessment, data analysis, geographic information systems (GIS), web & software development, graphic design, and data visualization.

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Previous Work on Carbon Management and Hubs

This report builds on the EFI Foundation's previous work on large-scale carbon management and net-zero hubs, including the following reports:

EFI Foundation, *Taking Root: A Policy Blueprint for Responsible BECCS Development in the United States,* June 2023, https://efifoundation.org/topics/carbon-management/taking-root-a-policy-blueprint-for-responsible-beccs-development-in-the-united-states/.

Energy Futures Initiative, Energy Futures Finance Forum (EF3), *Turning CCS Projects in Heavy Industry and Power into Blue Chip Financial Investments,* February 2023, https://efifoundation.org/reports/turning-ccs-projects-in-heavy-industry-into-blue-chip-financial-investments/.

Energy Futures Initiative, *The U.S. Hydrogen Demand Action Plan*, February 2023, https://efifoundation.org/reports/the-u-s-hydrogen-demand-action-plan-2/.

Energy Futures Initiative, *CO2-Secure: A National Program to Deploy Carbon Removal at Gigaton Scale,* December 2022, https://efifoundation.org/reports/co2-secure-a-national-program-to-deploy-carbon-removal-at-gigaton-scale/.

Energy Futures Initiative, *Building the Gulf Coast Clean Hydrogen Market: Summary of Public Workshop and Private Roundtable*, September 2022, https://efifoundation.org/reports/building-the-gulf-coast-clean-hydrogen-market/.

Energy Futures Initiative, *Surveying the BECCS Landscape*, January 2022, https://efifoundation.org/reports/surveying-the-beccs-landscape/.

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Energy Futures Initiative, *Workshop Summary: The Critical Role of CCUS: Pathways to Deployment at Scale*, December 2020, https://efifoundation.org/reports/the-critical-role-of-ccus/.

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Energy Futures Initiative and Stanford University, *An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions*, October 2020, https://efifoundation.org/reports/an-action-plan-for-carbon-capture-and-storage-in-california/.

Energy Futures Initiative, *Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies*, September 2019, https://efifoundation.org/reports/clearing-the-air/.

Energy Futures Initiative, *Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit*, May 2018, https://efifoundation.org/reports/advancing-large-scale-carbon-management/.

This report builds on the Horizon Climate Group authors' previous experience on large-scale carbon management and net-zero hubs, including contributions to the following reports:

Elizabeth Abramson, Dane McFarlane, Amy Jordan, et al. *The Landscape of Clean Hydrogen: An Outlook for Industrial Hubs in the United States.* Carbon Solutions and Industrial Innovation Initiative, May 2023, https://industrialinnovation.org/wp-content/uploads/2023/05/The-Landscape-of-Clean-Hydrogen.pdf.

Elizabeth Abramson, Dane McFarlane, Amy Jordan, et al. *An Atlas of Direct Air Capture: Opportunities for Negative Emissions in the United States.* Carbon Solutions and Great Plains Institute, March 2023, https://carboncaptureready.betterenergy.org/wp-content/uploads/2023/03/DAC-Hubs-Atlas-2023.pdf.

Dane McFarlane, Elizabeth Abramson, and Emma Thomley. *An Atlas of Carbon and Hydrogen Hubs for United States Decarbonization*. Great Plains Institute, February 2022, https://scripts.betterenergy.org/CarbonCaptureReady/GPI_Carbon_and_Hydrogen_Hubs_Atlas.pdf.

Elizabeth Abramson, Elizabeth, Dane McFarlane, and Jeff Brown. *Transport Infrastructure for Carbon Capture and Storage: Whitepaper on Regional Infrastructure for Midcentury Decarbonization*. Great Plains Institute, June 2020, https://betterenergy.org/wp-content/uploads/2020/08/GPI_RegionalCO2Whitepaper.pdf.

Executive Summary

The purpose of this report is to assess the potential of CO_2 emissions reduction from small-to-midsize U.S. industrial emitters through the formation of carbon capture, utilization, and storage (CCUS) hubs. The report's core findings are that there are sizable CO_2 emissions from these facilities and that they are clustered in several regions across the United States that could support the development of hubs.

Hubs can be important for realizing the emissions reduction opportunity of CCUS because their shared infrastructure can significantly decrease the economic, technical, and logistical barriers to CCUS deployment for small-to-midsize emitters.

The screening assessment identified 10 regions of the country with high concentration of small-to-midsize CO_2 emitters and proximity to potentially attractive underground geologic storage capacity. Further in-depth analysis of four of these regions delineated key characteristics of the emissions sources, the initial step in assessing the feasibility of CCUS hub formation.

CO_2 emissions from the industrial sector account for about one-quarter of total U.S. greenhouse gas (GHG) emissions.[1] Decarbonizing industrial emissions is challenging because of differences in the size of individual sources, the variety of industrial processes and uses of energy within each process, and the combination of process emissions (e.g., waste products from steel and cement production) and emissions from fossil fuel combustion.

Industrial Decarbonization Through CCUS

There is a wide range of potential industrial decarbonization options. A recent U.S. Department of Energy (DOE) study identified four "pillars" of industrial decarbonization: energy efficiency; electrification; low-carbon fuels, feedstocks, and energy sources; and CCUS.[a,2]

Choosing specific technology solutions within these four pathways involves weighing multiple business objectives, including product quality, workforce requirements, asset values, market competitiveness, and innovation opportunities.[3] CCUS offers advantages such as addressing difficult-to-decarbonize combustion and process emissions, as well as harnessing existing infrastructure and workforces.[4]

Early CCUS projects have focused on power plants, larger industrial facilities, and those with relatively higher CO_2 concentrations. These projects typically use carbon capture technologies, such as amine scrubbers, which rely on large volumes of CO_2 to be economically and technically feasible. These large emitters also capture enough CO_2 to justify investment in transport and storage infrastructure. Small-to-midsize emitters typically have not been addressed in previous studies of CCUS because they do not meet these thresholds. Recent policy, technology, and business model developments, however, have changed the equation:

[a] DOE also found that other pathways beyond these pillars (e.g., non-energy emissions reduction) may be needed to reach net zero in industry.

- The Inflation Reduction Act (IRA) raised the value of the Section 45Q tax credit for CO_2 capture and storage and extended the credit to smaller industrial CCUS projects.[5]
- Recent technology advances make smaller-scale applications of carbon capture viable, alongside the possibility of business models that could offer CCUS as a service to industrial emitters.
- Single large-scale CCUS projects under development could serve as anchor tenants for local and regional CCUS hubs that include small-to-midsize industrial units as well. These hubs could create the necessary economies of scale to support CO_2 transport and storage infrastructure, which those emitters would lack as standalone projects.

Key Study Findings

There are more than 3,000 small-to-midsize industrial CO_2 emitters in the United States aligning with key study criteria, constituting around 266 million metric tons of CO_2 emissions per year, or 25% of annual U.S. industrial CO_2 from point sources.[b,6,7]

Small-to-midsize emitters of interest to this study, referred to as capture targets, are industrial units with annual emissions between 12,500 tons of CO_2 (tCO_2) and 600,000 tCO_2. The units were screened with additional criteria (e.g., CO_2 concentration level, capacity factor, unit type) to evaluate suitability for carbon capture.

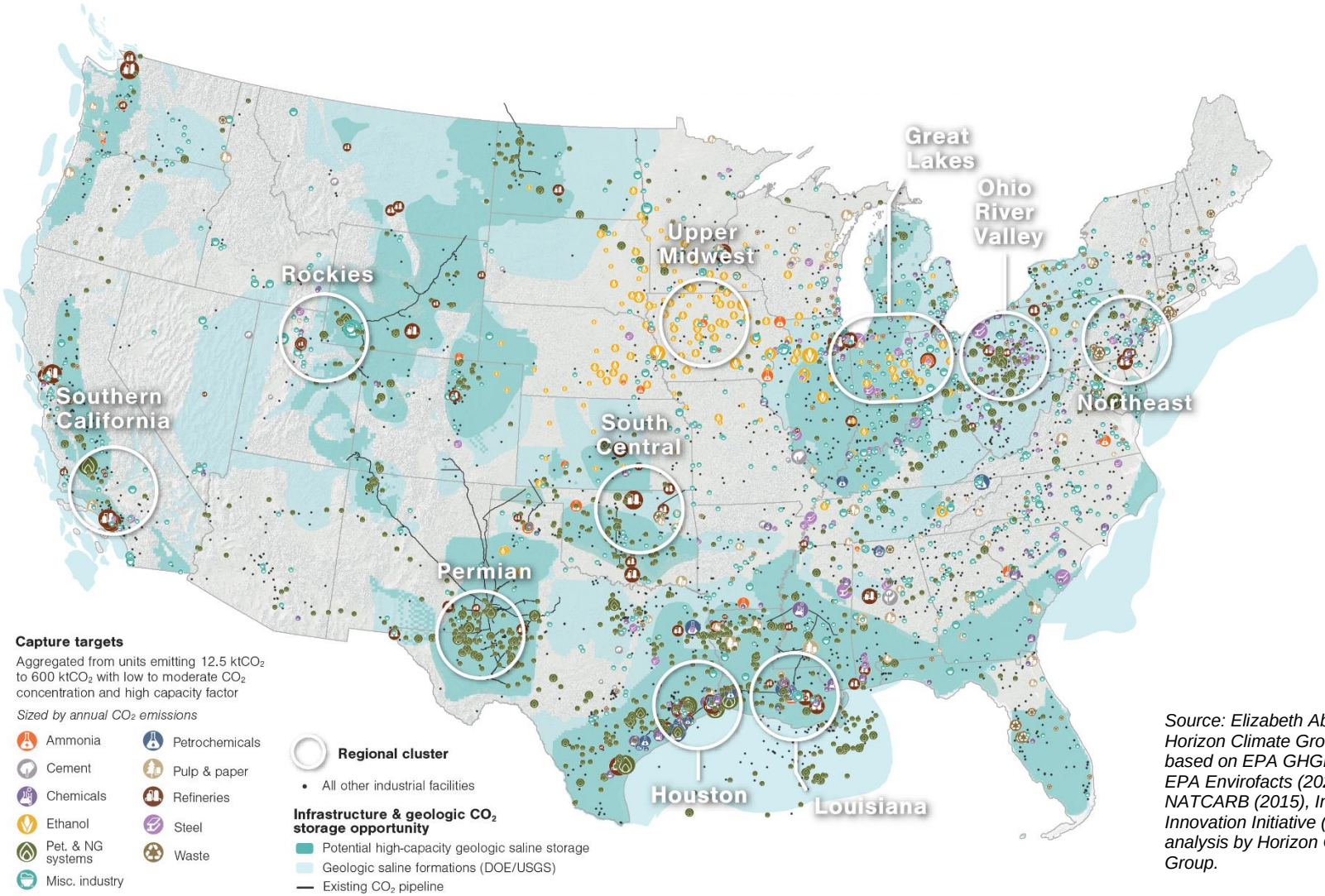
- 41% of all industrial facilities nationwide are home to at least one industrial unit identified as a capture target in this study.
- The analysis assessed capture opportunities across 11 general industrial subsectors. Over half of the emissions from capture targets identified in this study come from facilities engaged in petroleum and natural gas production, transport, and processing, petroleum refining, ethanol production, and petrochemical production.
- The use of natural gas makes up almost three-quarters of the total CO_2 emissions from identified capture targets.

This study identified 10 U.S. regions with a relatively high concentration of capture targets in areas that have (or are near areas with) favorable geological characteristics for underground CO_2 storage (Figure 1).[8,9,10,11,12]

[b] All emissions data in this report are given in metric tons.

Figure 1

Small-to-midsize industrial capture targets for potential CCUS hubs



Source: Elizabeth Abramson, Horizon Climate Group (2023), based on EPA GHGRP (2022), EPA Envirofacts (2023), DOE NATCARB (2015), Industrial Innovation Initiative (2023), and analysis by Horizon Climate Group.

Four of the 10 regions were selected for further detailed characterization of local capture opportunities. These include southeastern Texas, centered on Houston; the Louisiana Gulf Coast; the eastern Ohio River Valley; and the southern Great Lakes region.

- These four regional clusters each have more than 70 small-to-midsize sources with combined annual emissions from capture targets totaling at least 8 million tons of CO_2 ($MtCO_2$) in each cluster and are located close to high-quality geologic storage. These conditions are the basic ingredients for formation of CCUS hubs with cost-effective CO_2 transport and storage.
- Capture targets in these four regional clusters emit around 70 $MtCO_2$ per year, approximately equivalent to the annual net emissions of Washington state.[13,14]
- Two of the selected regional clusters are two-state regions but largely a single state (Texas and Louisiana); one regional cluster covers a three-state area (Pennsylvania, West Virginia, and Ohio); and the fourth covers a four-state area (Illinois, Indiana, Ohio, and Michigan). While the multistate regions will have more challenges in forming hubs, there are sufficient concentrations of small-to-midsize emitters within individual states to facilitate the initiation of intrastate efforts that could grow into multistate hubs.
- Individual states within these four study regions have varying degrees of state-level policies, regulations, and financial incentives that can enable hub formation. No state currently has a full complement of authorities and programs, but several have sufficient scope to enable the initiation of CCUS hub planning on an intrastate level. For example, states within three of the four study regions are currently seeking primary authority to permit underground injection needed for geologic CO_2 storage.[15]
- All four regions have several larger-scale CCUS projects in the development pipeline (operational, planned, or under development) that could serve as "anchor tenants" for a much larger CCUS hub buildout.[16,17,18]

Moving from Clusters to Hubs

The screening analysis shows clear patterns of clustering of small-to-midsize industrial emitters in specific regions that could form the basis of CCUS hubs. The hub concept offers several benefits that can facilitate and incentivize widespread CCUS deployment, including:

- **Shared resources.** This can include shared supply chain within a region as well as pooled funding of needed CO_2 transport and storage infrastructure. This can also include sharing of CCUS assets with natural gas-derived "blue" hydrogen hubs and sharing of transport and storage infrastructure with direct air capture (DAC) hubs.
- **Shared risks.** This allows for large-scale CCUS deployment to proceed even if one or more individual carbon capture projects do not.

- **Economies of scale.** Aggregation of captured carbon "supply" would enable economies of scale in the sizing of CO_2 transport systems and in the development of CO_2 storage facilities.
- **Economies of effort.** Regionwide CCUS deployment will enable not only scaling of supply chains and workforces, but also coordination of permitting and licensing, as well as coordinated, place-based public engagement efforts.

Previous EFI Foundation studies have identified five elements that will be needed to convert these concepts into action.[19] These include:

1. **A governance plan** to guide the deployment effort, including information sharing among participants and coordinated interaction with policymakers in the region.
2. **A business plan** that consolidates project-specific deployments, including scheduling, permitting, financing, management, and contracting
3. **An infrastructure development plan** that provides details on the ownership, financing, permitting, and operation of common CO_2 transport and storage infrastructure.
4. **A community and workforce plan** that provides a proactive strategy for public engagement, workforce recruitment and training, and an ongoing public liaison.
5. **An innovation plan** that translates lessons learned into data to enable continuous enhancements in the implementation of the CCUS hub.

As noted earlier, these actions could be initiated on an intrastate level for those states with large in-state clusters of small-to-midsize industrial emitters. This could facilitate a quicker and easier start to hub development that could evolve into a larger multistate CCUS hub.

Finally, the experience of other countries in forming CCUS hubs could provide further lessons for CCUS hub formation. These hubs are typically focused not only in areas with large clusters of industrial CO_2 emissions, but specifically in areas with concentrations of oil and gas facilities, providing infrastructure that can serve as a foundation for a buildout of CO_2 transport and storage. In particular, some of the hubs are repurposing existing natural gas pipelines for CO_2 transport or using depleted oil and gas reservoirs for CO_2 storage. The non-U.S. hubs also have the benefit of strong national policies and government cost sharing of the upfront investment required for hub development.

Recommendations

The initial screening analysis identified regional clusters of small-to-midsize industrial emitters that could form the basis of regional CCUS hubs. The initial screening analysis, however, focused solely on technical factors. Additional analysis would be needed on several aspects, including:

- Techno-economic analysis to further refine the potential universe of hub participants and to

develop initial estimates of the economics of hub development.

- More detailed geospatial analysis to begin to assess the extent of CO_2 transport and storage infrastructure, including possible repurposing of existing infrastructure or use of existing infrastructure rights of way.
- Further evaluation of geologic storage potential and sites within the identified cluster regions.
- Convening of interested parties within each region, including facility owners, policymakers, vendors, and stakeholder groups, to begin discussions of possible hub development.

Additional federal policy and programmatic actions could be considered by Congress and executive-branch agencies to further incentivize, accelerate, and facilitate industrial CCUS hub formation that includes small-to-midsize emitters.

Section 45Q enhancements. The recent changes to the Section 45Q tax credit have created the potential to extend CCUS deployment to small-to-midsize industrial facilities.[20] Previous EFI Foundation work identified several additional recommendations to build upon the new and improved 45Q incentive.[21] These include modifications to further facilitate transferability of the credit and amendments to expand eligibility for optional direct pay.

Targeted direct funding. The Bipartisan Infrastructure Law (BIL) and the IRA funded several new direct spending programs to support development of geologic storage and demonstration projects for carbon capture.[22] DOE could consider actions to integrate and further leverage these funding initiatives to enhance the prospects for industrial CCUS hub formation:

- Expanded use of DOE loan guarantee authorities to allow financing of multiple CCUS deployment projects for specific industrial applications.[23]
- Funding one or more demonstration “packages” of the same CCUS technology at multiple sites to accelerate learning and facilitate establishment of supply chains.
- Implementation of Phase IV of the DOE’s CarbonSAFE grant program for CO_2 storage and expansion of support for planning activities leading to hub formation, including pre-feasibility studies of small-to-midsize carbon capture projects within prospective hubs.
- Improved coordination among DOE funding programs for different carbon management value chain segments (capture, transport, and storage).
- Encouraging developers of blue hydrogen hubs and DAC hubs to accommodate opportunities for broader industrial CCUS hub development.

State and local governments could be encouraged to share in the funding support for these initiatives if they are designed and implemented in a way that provides a clearer potential path to the formation of a regional industrial CCUS hub that includes small-to-midsize emitters.

Class VI permitting. The federal government could seek to prioritize and expedite approval of state "primacy" over permitting for Class VI geologic CO_2 storage wells within the lead states of prospective industrial CCUS hub regions. EPA also should accelerate the process of reviewing and approving Class VI wells under federal jurisdiction. While the authority for delegation and permitting resides with the EPA, DOE could play a coordination and ombudsman role in working with those states interested in supporting industrial CCUS hub development that incorporates small-to-midsize emitters.

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