

**U.S. Department of Energy
Office of Fossil Energy and Carbon Management**

Request for Information: DE-FOA-0003263

**Industrial Deployment and Demonstration Opportunities for Carbon Capture
Technologies**

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Program Area: Office of Fossil Energy and Carbon Management

RESPONSES DUE: March 14, 2024, by 5:00 p.m. ET

Description:

This is a Request for Information (RFI) issued by the U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management (FECM). The intent of this RFI is to obtain public input related to a DOE plan to support the demonstration and deployment of carbon capture technologies applied to industrial sources of greenhouse gas emissions. This plan will supplement the material included in the DOE report *Pathways to Commercial Liftoff: Industrial Decarbonization*¹ and support the Administration's goals of decarbonizing the economy by 2050.

The information being sought is intended to assist DOE in the planning of priorities and initiatives to catalyze the development, demonstration, and deployment of carbon capture utilization and storage (CCUS) for industrial decarbonization. The information collected may be used across DOE's research, development, demonstration, and deployment (RDD&D) portfolio, including, but not limited to, determining potential new areas of focus and innovation; identifying challenges and knowledge gaps; identifying funding opportunities; identifying regional opportunities; and determining the potential for clean energy and carbon management careers, all while considering potential impacts to local communities (including environmental justice² and equitable energy transition).

Specifically, this RFI seeks input from key partners (domestic and international) on what is needed to accelerate deployment of CCUS for industrial systems to support the energy transition, eliminate greenhouse gas emissions, produce clean energy, create well-paying union jobs, and enable a net-zero carbon emissions economy by 2050, all while prioritizing environmental justice. The information collected will also inform indicators of success for projects, programs, and the larger DOE portfolio. While some ongoing DOE RDD&D efforts are focused on similar issues, it is anticipated that responses to this RFI can inform planning future efforts.

¹ [Pathways to Commercial Liftoff: Industrial Decarbonization \(energy.gov\)](https://www.energy.gov/pathways-to-commercial-liftoff-industrial-decarbonization)

² Environmental justice means the just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in agency decision-making and other Federal activities that affect human health and the environment. See Executive Order 14096, Revitalizing Our Nation's Commitment to Environmental Justice for All, 88 Fed. Reg. 25,251 (April 21, 2023), available at [Executive Order on Revitalizing Our Nation's Commitment to Environmental Justice for All | The White House](https://www.whitehouse.gov/presidential-actions/2023/04/revitalizing-our-nations-commitment-to-environmental-justice-for-all/)

Organizations that respond to the RFI can respond *to all or only a portion* of the RFI. This RFI is solely a request for information and is not a Funding Opportunity Announcement (FOA). DOE is not accepting applications to this RFI, nor will DOE reimburse any of respondents' costs incurred in preparing a response.

Background:

The Infrastructure Investment and Jobs Act, also commonly known as the Bipartisan Infrastructure Law (BIL), appropriated more than \$62 billion to the DOE with a mandate to catalyze a clean and equitable energy transition.³ Over \$12 billion was allocated for carbon management including integrated carbon capture, transport, and storage demonstrations; large-scale pilots; point source carbon capture; and CCUS for industrial purposes.

DOE's carbon management efforts cut across offices and span the RDD&D continuum, i.e., the path to commercialization where a technology starts as an innovative idea in research, moves to development where the first prototype is created, proceeds to demonstration where the solution is tested in the real world and ends with commercial-scale deployment.¹ Different DOE Offices support varying stages of the RDD&D continuum, as noted in Figure 1.

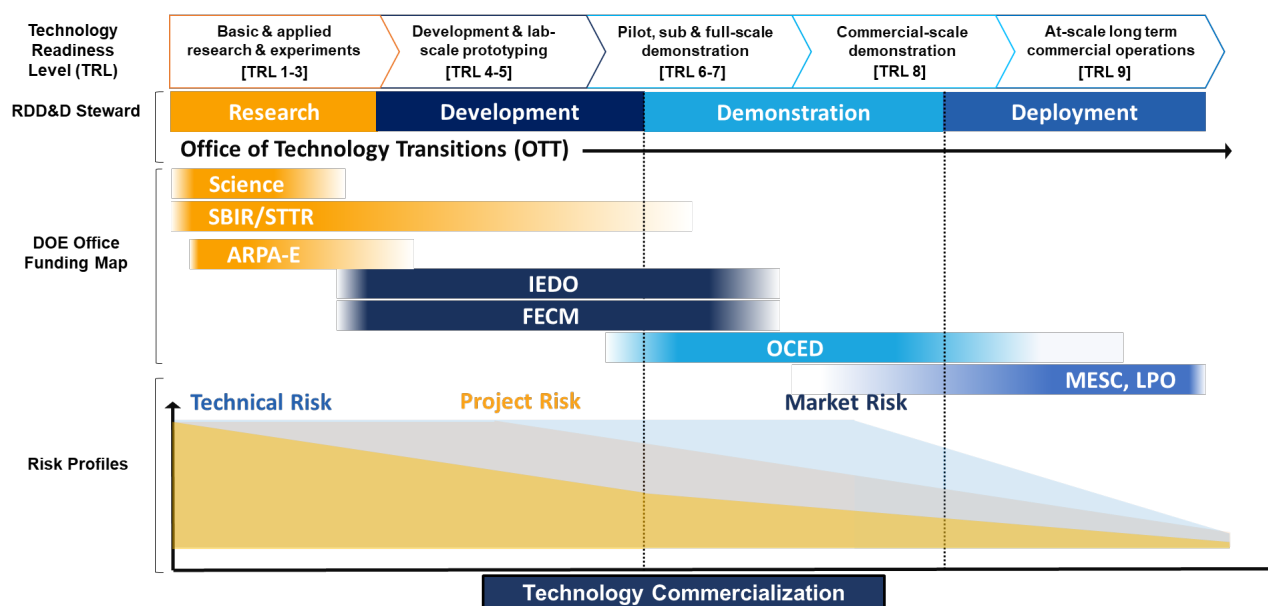


Figure 1. Roles of DOE Offices across the RDD&D continuum.

³ Public Law 117-58 (November 15, 2021).

FECM currently funds the Point Source Carbon Capture Program to support deep decarbonization of the power and industrial sectors. FECM has supported previous carbon capture demonstration projects, and over the past several years, has funded a number of feasibility and Front End Engineering Design (FEED) studies of commercial-scale projects that can lead to the development and planning of carbon capture technologies for industrial applications.

However, much work remains to be done and will involve collaborative carbon management/decarbonization efforts of several DOE offices. For example, DOE's Industrial Efficiency and Decarbonization Office (IEDO) provides funding, management, and the strategic direction necessary for a balanced national program of research, development, and demonstration (RD&D), as well as technical assistance and workforce development, to drive transformative innovation in energy, materials, and production efficiency and to accelerate decarbonization across the industrial sector. IEDO's RD&D strategy focuses on two complementary approaches: tackling subsector-specific decarbonization challenges through the energy- and emissions-intensive industries and pursuing cross-sector challenges that are common across many industries.

Additionally, Congress and DOE established the Office of Clean Energy Demonstrations (OCED) to help scale the emerging technologies needed to tackle our most pressing climate challenges and achieve net zero emissions by 2050. OCED manages the BIL and IRA funding for first-of-a-kind (FOAK) large scale pilots and commercial demonstration efforts in carbon management technologies for industrial decarbonization. It is anticipated that these large-scale pilots and demonstrations will accelerate deployment, market adoption, and the equitable transition to a decarbonized economy.

DOE also recognizes that rapid deployment at the scale necessary to achieve a net-zero carbon economy by 2050 will require significant support from industry as well as early engagement with workers and host communities.

Purpose:

The purpose of this RFI is to solicit feedback (domestic and international) from industry members, investors, developers, academia, research laboratories, government agencies, unions, Tribes, non-profit organizations, potentially impacted communities, and other partners on potential industrial carbon capture demonstration and deployment projects and their associated locations, including potentially ideal locations for these projects in the United States, all while considering the urgent need for a clean and equitable energy transition to address the climate crisis, environmental justice, a just transition for workers, and impact to Tribal and marginalized or overburdened communities. DOE is requesting input related to the **Scope 1 CO₂e emissions** and their potential for mitigation using CCUS for the specific industrial sectors noted in Table 1. Scope 1 emissions are direct greenhouse emissions that occur from sources that are controlled or owned by an organization (e.g., emissions associated with fuel combustion in boilers, furnaces, vehicles).⁴ **Input is encouraged from domestic and international entities.**

⁴ [Scope 1 and Scope 2 Inventory Guidance | US EPA](#)

Table 1. Annual US and Global Scope 1 CO₂e Emissions for Specific Industrial Sectors

Industrial Sector	Annual <u>US</u> Scope 1 CO₂e Emissions (million tonnes/year) ⁵ [% of total Scope 1 industrial emissions]	Annual <u>Global</u> Scope 1 CO₂e Emissions (million tonnes/year)
Aluminum	2.9 [< 1]	270.0 ⁶
Ammonia	34.0 [4]	500.0 ⁷
Cement	69.0 [7]	2420.0 ⁵
Glass	7.8 [1]	95.0 ⁸
Iron-Steel	66.0 [7]	2620.0 ⁵
Lime	27.0 [3]	494.5 ⁹
Petrochemicals	63.0 [7]	1330.0 ⁵
Paper	25.0 [3]	150.0 ⁵
Refining	165.0 [17]	1590.0 ¹⁰
Soda Ash	5.3 [< 1]	17.4 ¹¹
LNG	14.0 [1]	unknown
Total for the Sectors Noted	479.0	9487.0

While there will be commonalities both across and within sectors, it is understood that some issues related to deployment of carbon capture technologies will be region-specific. With that in mind, DOE values input that falls into both categories – i.e., broadly applicable and region-specific. Figure 2 shows industrial facilities in the US along with locations of potential storage sites, which may impact deployment decisions (e.g., collaboration opportunities). Comments related to specific regions within the US are encouraged. Figure 3 shows industrial facilities with international parent companies. Responses relating to the impact of US-based technology development and testing on international decarbonization efforts are encouraged.

⁵ EPA Flight Data (2021)

⁶ <https://www.ica.org/energy-system/industry>

⁷ <https://royalsociety.org/-/media/policy/projects/green-ammonia/green-ammonia-policy-briefing.pdf>

⁸ <https://www.statista.com/statistics/1071205/carbon-dioxide-emissions-from-glass-production-worldwide/>

⁹ <https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-lime.pdf>

¹⁰ <https://www.sciencedirect.com/science/article/pii/S2666675822001576>

¹¹ <https://www.statista.com/statistics/1013480/sodium-carbonate-production-worldwide-by-type/>

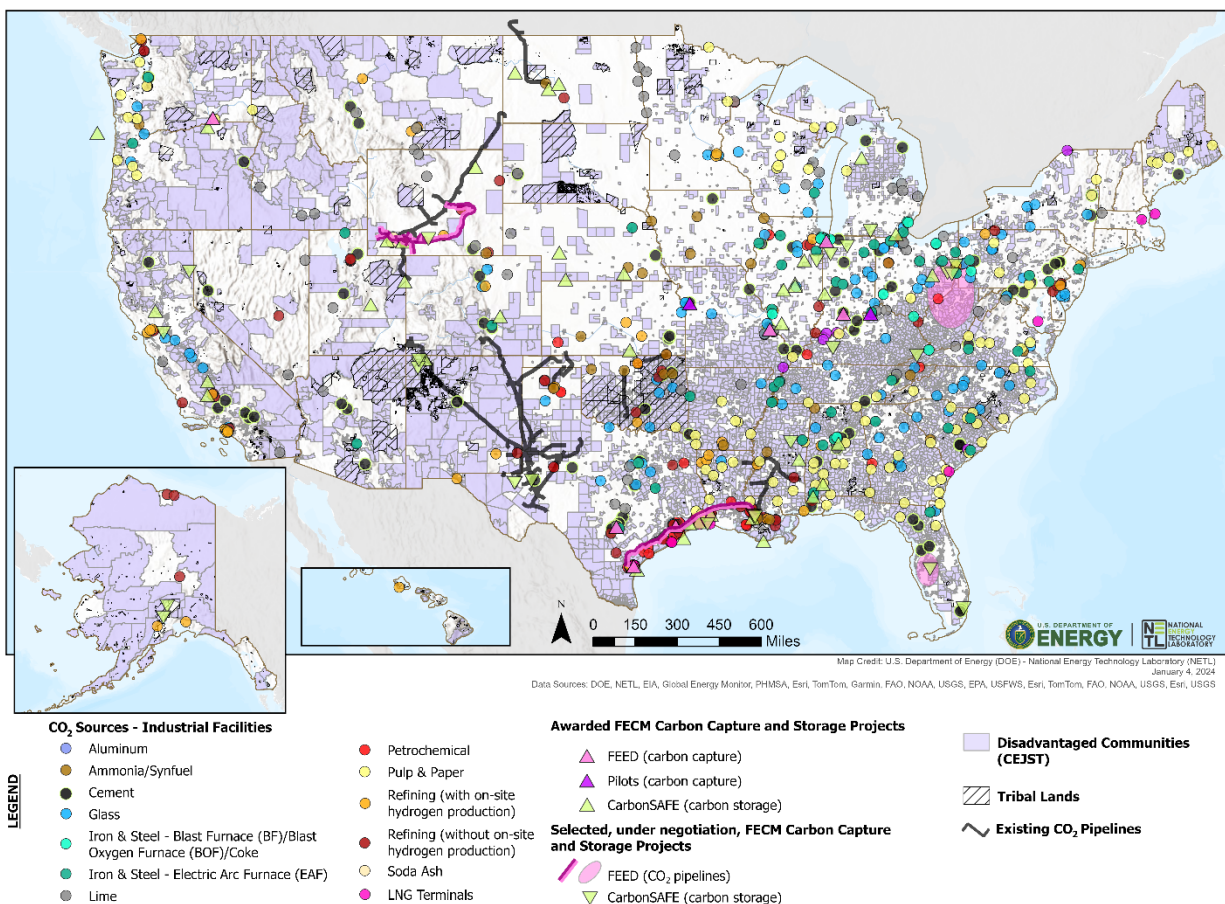


Figure 2. Industrial facilities and FECCM carbon capture and storage projects.

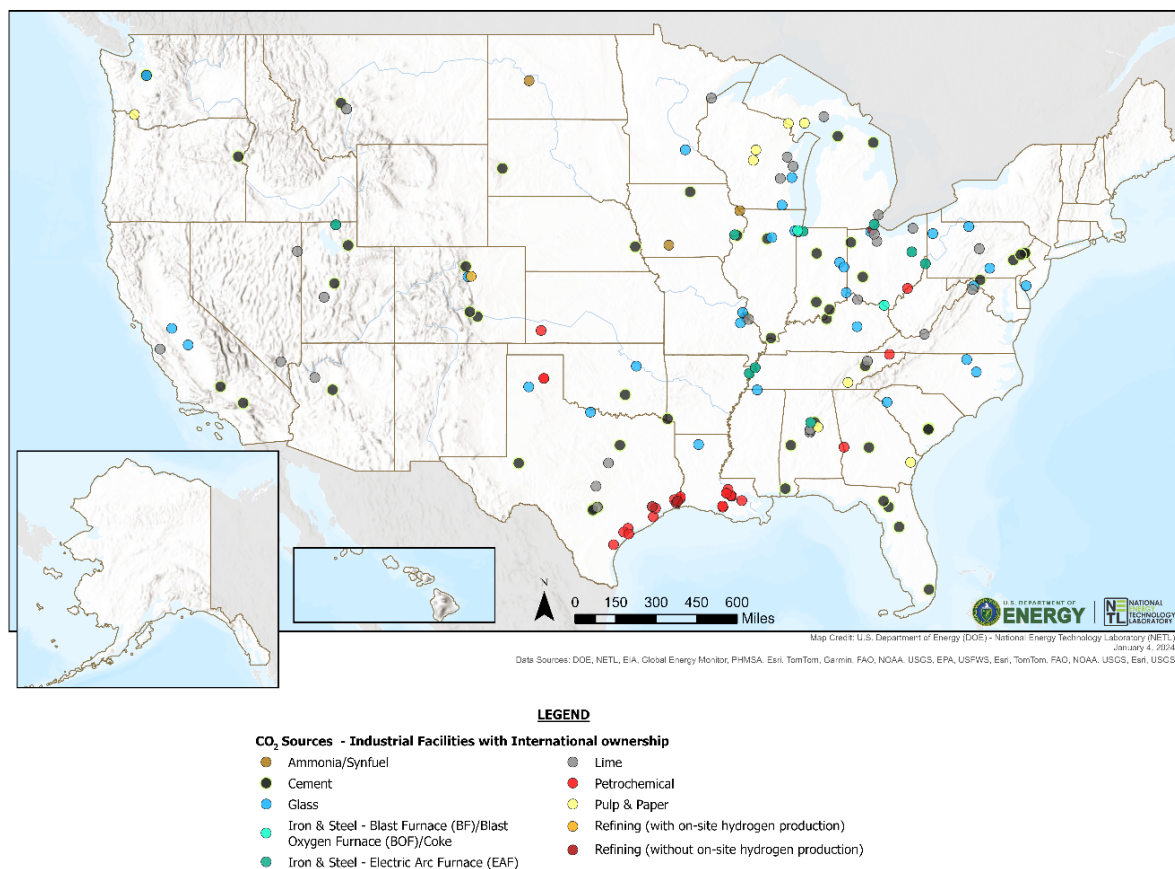


Figure 3. Industrial facilities with international parent companies.

Section A.

Input is sought from domestic and international stakeholders, including plant owners, facility managers, corporate fleet owners, technology providers, research organizations, and other stakeholders that is broadly applicable across sectors and geographies and includes the following:

1. Strategy
 - a. What are your short- and long-term decarbonization strategies and goals and their implementation timelines?
 - b. What decarbonization strategies for your assets (including but not limited to carbon capture) do you consider:
 - i. Most cost-effective today?
 - ii. Likely to be most cost-effective by 2035?
 - iii. Simplest to integrate into your existing operations?
 - iv. Most resilient to future market and supply chain changes?

- c. To what extent are you expecting to rely on multiple decarbonization approaches (e.g., fuel switching, energy efficiency improvements, electrification) in addition to CCUS to decarbonize your assets?
- d. Can these decarbonization approaches be implemented with your existing workforce? What needs have you identified? What labor unions, universities, community colleges, or other training and workforce development partners have you worked with to secure a skilled and trained workforce?
- e. How has your strategy been impacted by recent legislation or policy changes?

2. Business model

- a. What sectors or customer types, (e.g., private, government, non-profit, etc.) do you primarily sell to, and what are unique challenges in selling low-carbon products to your specified customer base?
- b. Are your customers actively seeking lower-carbon-intensity versions of your product?
- c. Approximately what price premium do you expect is required today and by 2030 to deliver a near-zero carbon product?
- d. To what extent are customers willing to pay that price premium today?
- e. To what extent are voluntary carbon markets important for the economic feasibility of delivering near-zero carbon products?
- f. Are you aware of tax incentives such as 45Q, 45V, 45Z? Do you plan to utilize these credits?
- g. Are you aware of the 48C tax credit that is available for investments that reduce greenhouse gas emissions in industrial facilities? Do you plan to apply for these tax credits when a second round of funding opens later this year?
- h. Have you sought any other public grants, loans, or tax credits to support the production of low-carbon products?
- i. What is the cost target for carbon capture technologies? How does the 45Q tax credit eligibility timeline or other tax incentives that you plan to utilize affect the ability to invest in carbon capture assets?
- j. What additional challenges do you anticipate for securing offtake of your low carbon intensity products?
- k. What solutions/strategies do you think would help to accelerate offtake of low-carbon intensity products?
- l. Would it help to increase demand for your low-carbon intensity products if federal and/or state governments prioritized purchases of low-carbon intensity products for infrastructure, public buildings, and other projects, as contemplated in the Federal Buy Clean Initiative?
- m. Are there additional ways that government procurement policies could help to increase demand for your low-carbon intensity products?
- n. Do imports of inexpensive, higher-carbon intensity products make it more difficult for you to produce low-carbon intensity products? If so, are there any particular trade policies that could help to solve this problem?

- o. Do you plan to obtain an Environmental Product Declaration – a standardized, verified accounting of emissions intensity in products – to demonstrate that your products are low-carbon intensity? If not, what are the barriers to obtaining an Environmental Product Declaration?
 - p. Are you part of an existing industrial decarbonization “hub” consortium?
 - i. If yes,
 - a. What is most valuable about this hub consortium?
 - b. How have the geographic bounds of the hub been set?
 - ii. If no,
 - a. Have you considered such a hub and decided against joining? If so, why?
 - b. How beneficial do you think such a hub would be and why?
 - iii. Would region-specific funding from the DOE be helpful in catalyzing industrial decarbonization hubs? If yes, in what ways?
3. Emissions
- a. What are your typical effluent or flue gas stream compositions? (CO₂, N₂, other co-pollutants, other GHGs)
 - b. CO₂ capture processes typically require tight control on incoming criteria pollutants to ensure optimal operations of the equipment. Is your facility equipped to handle stringent incoming criteria pollutant (e.g., NO_x, SO_x, PM, etc.) limits required by CO₂ capture processes? If not, what modifications would be necessary?
 - c. What monitoring do you plan for emissions associated with the capture unit?
 - d. What are the total emissions, in metric tons of CO₂ equivalent (MT CO₂e) from US facilities, that your company is looking to decarbonize?
 - i. Across how many sites?
 - ii. In what regions?
4. Do you have facilities located outside of the US? If yes, what are your decarbonization strategies and implementation timelines for these facilities?
- a. Can the FEEDs or demonstration projects at these facilities be leveraged for US facilities?
 - b. Do the decarbonization strategies for the US and non-US facilities differ? If yes, how?
5. How do you generate heat and power to meet your industrial and manufacturing needs (e.g., pulling from the grid, district heating and power, on-site generation, other (please specify))?
6. What fossil fuel feedstocks (e.g., coal, natural gas, fuel oil, diesel, etc.) are currently being used in your plant?

Section B.

If you are considering the application of carbon capture technology at a specific site, input is sought as follows:

1. What type of facility(s)?
2. What is the location of the asset? What are the locations of the CO₂ transport and storage infrastructure (s)? If possible, please provide city, state, and zip code.
 - a. Is the site located on or near Tribal lands?
 - b. Is the site vulnerable to changes from a changing climate including impacts such as hurricanes/flooding/drought?
 - c. Please describe possible impacts - such as climate risk, regulatory challenges, or community acceptance, etc. - to future operations.
3. To what extent does the project depend on enabling infrastructure, such as pipelines? Is that infrastructure already in place, or will it need to be built as part of a broader effort?
4. Point Source Carbon Capture Technology and Application
 - a. What is/are the primary technologies that you are considering?
 - i. Is the capture technology integrated with other emissions reduction strategies (e.g., criteria pollutants)?
 - b. What is the production capacity for the primary product *and* the anticipated quantity of captured carbon dioxide?
 - c. Do you have any spatial constraints regarding an on-site carbon capture retrofit? For the retrofit process, what are your operational and business case considerations for potential downtime?
 - d. What is the Technology Readiness Level (TRL)¹² of the carbon capture technology being considered?
 - e. Based on the particular CO₂ capture technology being considered, are you aware of the potential creation of any new air, water, or solid waste emissions that may be introduced as a result of specialty chemicals/process changes required for CCUS implementation? Have you developed monitoring and mitigation plans for these emissions?
 - f. What is the status of development of the engineering controls for flue gas pre- or post-treatment to limit the environmental impact of implementing CCUS at your facility?
 - g. To what degree has the carbon capture technology been demonstrated on the specific application?
 - h. What is the nature and degree of integration of the carbon capture technology with the host facility (e.g., waste heat integration, use of existing cooling capacity, etc.)?
 - i. Energy impacts:
 - i. How much additional heat and energy would be required for carbon capture?

¹² [DOE G 413.3-4A, Technology Readiness Assessment Guide](#)

- ii. Where do you plan to source this additional energy from?
 - iii. To what extent is new clean energy a barrier to your project?
 - iv. To what extent do you anticipate operating your capture unit in response to energy prices and/or coupled to energy storage processes?
 - j. Are performance guarantees necessary for the project to be realized? If yes, what is the status of discussions/negotiations with “responsible parties”?
5. CO₂ capture design and engineering effort(s)
- a. What groups have been/will be included in design efforts (e.g., cross-disciplinary engineering teams, community representatives, labor representatives, local government, local regulatory commissions, etc.)?
 - b. What is the nature and degree of site-specific design work that is either completed or presently underway?
 - c. What is the scope of the design effort (e.g., carbon capture unit only; integrated plant, inclusive of physical infrastructure for CO₂ transport and storage activities; full life cycle, inclusive of fuel/input acquisition through waste management)?
 - i. How big of a barrier is access to CO₂ transport at present or expected in the future?
 - ii. How big of a barrier is access to CO₂ storage at present or expected in the future?
 - d. What is/are the primary design risk(s)?
 - i. What factors might undermine confidence in a design and engineering study?
 - e. CO₂ offtake
 - i. Are you planning to store CO₂ directly?
 - a. If yes, where are you in the permitting process?
 - b. What is the type of storage reservoir? (depleted oil/gas, coal seam, saline aquifer, cavern, mineralization, etc.)
 - ii. If not, have you negotiated a CO₂ offtake agreement yet?
 - a. If not, what are the biggest barriers to doing so?
 - iii. How attractive is CO₂ conversion as an offtake and/or integrated process option for this project?
 - f. How long do you expect it will take to complete detailed, integrated project design encompassing capture, transport, and storage/utilization?
 - g. What design approach have you used or will use (e.g., front-end engineering and design (FEED), front-end loading (FEL), other)?
 - i. What level of engineering has been/will be completed?
 - ii. What is the expected accuracy at the end of the design effort?
 - h. Has a procurement plan for construction of CCUS equipment been developed?
 - i. Has the supply chain been assessed to identify critical components and consumables that may be subject to cost and/or availability risk?
 - ii. If so, what factors in the upstream value chain might be involved with cost and/or availability risks, such as critical minerals, workforce development, manufacturing capacity, etc.?
 - i. What is the past experience with projects of similar size, scope and complexity of the design/engineering firm(s) responsible for the site-specific design effort?

- j. What is the approximate cost of the design effort (preferably absolute and/or percent of full project scope through construction and start-up)?
 - k. Have you evaluated what the potential cost increase to the final product will be as a result of installing CO₂ capture equipment?
6. Community and Labor Engagement, Benefits, and Impacts
- a. Do you have dedicated staff and personnel responsible for implementing community and labor engagement, benefit, and impact planning activities?
 - i. Do they have expertise or relevant training in environmental justice, labor and workforce development, and diversity, equity, inclusion, and accessibility?
 - b. What type of community and labor consultation, engagement, and/or outreach have you conducted to date?
 - i. What communities and worker organizations have been engaged with, at what stage in the planning, and with what frequency for each?
 - ii. What are some potential positive community and worker benefits, and what feedback/response has the community or workforce given to these points?
 - iii. What are some potential negative impacts, and what feedback/response has the community or workforce given to these points?
 - iv. What steps have been taken to amplify positive benefits and mitigate potentially negative impacts in response to community and labor feedback?
 - c. What type of engagement with communities do you plan to conduct?
 - i. Describe mechanisms or processes used to share or solicit community and labor feedback (public meetings, community liaison, community advisory board, etc.)?
 - ii. Did you provide information to the community and workforce about the risks and benefits of the project in advance of engagement?
 - iii. Do you plan to consult the community and workers regarding aspects of the project design?
 - iv. How is feedback considered or integrated into project design or approach to implementation?
 - v. What barriers exist, if any, for deeper engagement with communities and workers impacted by this project?
 - vi. What, if any, opportunities exist for alternative ownership/partnership structures, including utility participation; community ownership; or other structures that are not purely private ownership?
 - vii. What, if any, formal agreements are planned or have been established between the project, community, labor, and/or other stakeholders (i.e., community benefit agreements, good neighbor agreements, project labor agreements)?
 - viii. What specific benefits for workers and communities are planned as part of the project (i.e., wages, benefits, community investments, health and safety protections)?

- ix. How will the project honor workers' free and fair chance to join a union (e.g., union neutrality agreements, card check)?
- x. How will the project contribute to Diversity, Equity, Inclusion, and Accessibility goals (e.g., equitable hiring practices, local hire, training to prevent discrimination and harassment)?
- xi. How will the project contribute to workforce development (e.g., registered apprenticeships, pre-apprenticeships, labor-management partnerships)?
- d. What is your approach to characterizing the community landscape with particular attention to historical context and with environmental justice concerns?
 - i. What are the demographics of the area immediately surrounding the location of the project/activity being considered?
 - ii. What are the characteristics of the area immediately surrounding the location of the project/activity being considered? (e.g., residential, industrial, rural, urban)?
 - iii. Is additional construction anticipated in the area immediately surrounding the location of the project/activity being considered?
 - iv. What tools or resources do you use to identify communities with environmental justice concerns in your project area (e.g., Climate and Economic Justice Screening Tool (CEJST) which identifies disadvantaged communities¹³, EJ Screen [Policy Brief: Climate and Economic Justice Screening Tool and Justice40 - Our Climate], state tool)?
 - v. Describe, with specificity, anticipated economic opportunities for local communities in the region.
 - vi. Describe, with specificity, potential benefits and negative impacts on groups in the region and potential mitigation measures that could be employed for the latter.
 - vii. What environmental and health burdens are experienced by surrounding communities, and how would this project impact those existing burdens? If there are opportunities for this project to remediate existing community concerns, please explain those concerns and potential mitigation strategies. If this project could exacerbate existing concerns, please explain.
 - viii. What is the community's relationship with this site and past/ongoing activities at this site?
 - ix. Are there other industrial facilities located near this site? If so, what is the historical and current community relationship with those facilities?

7. Integrating Carbon Capture to Fossil Supply Chain Considerations

- a. What entities produce, process, and transport these fossil inputs (e.g., natural gas, oil, etc.)? Be as specific as possible and include locations. General regions are valuable even if very little information is available. If this is unknown or unknowable, describe why (e.g., spot natural gas purchasers from the pipeline network).

¹³ <https://screeningtool.geoplatform.gov/en/#3/33.47/-97.5>. Guide

- b. Describe the primary resource, environmental, and health or safety risks associated with these fossil inputs (e.g., longevity of supply; extraction and/or other life cycle environmental impacts; local community health risks; etc.). Consider risks along the whole supply chain, from extraction through use, and include detail on risks to both the workforce and host communities.
 - c. What are the cradle-to-gate greenhouse gas emissions (e.g., upstream emissions) associated with each input unit (e.g., tonne, gigajoules (GJ))? Please provide supporting documentation or describe barriers to estimating this value.
 - d. Is a multicriteria life cycle assessment (LCA) available for the CO₂-producing input? What barriers exist to obtaining one?
 - e. Describe how negative upstream impacts could be mitigated. How much control does the project team have over input sourcing and upstream extraction, processing, and transport practices? Explain.
- 8. Business case
 - a. Has the project reached Final Investment Decision (FID)?
 - i. If yes:
 - a. Who are the primary funders?
 - ii. If no:
 - a. What funding has been secured to date?
 - b. What is the nature of public funding (e.g., direct funding, loan guarantee, production, or investment tax credits) necessary for the project to proceed?
 - b. Are existing federal funding mechanisms (e.g., loan guarantee program, 45Q, 45V etc.) sufficient to support the project? If yes, which are most impactful?
 - c. Does the project rely on state- or local-level incentives/contributions? If yes, which are most impactful?

Liftoff analysis deep dive: within these sectors, CCUS is the least-cost abatement solution for just thirteen specific emissions sources

Sector	Product / value chain step	Emissions source and decarbonization solution	Solution abatement potential, million metric tons CO ₂ e	Abatement cost, \$/ton CO ₂ e ¹	Share of sector abatement, %
Refining	Refining	Install CCS on process heating- refining (high temp)	50	\$95	32%
	Refining	Install CCS on FCC- refining (high temp)	26	\$100	
	Refining	SMR with CCS for refining (high temp / process)	21	\$85	
Chemicals	Ethylene	Cracking furnace with postcombustion CCS (high temp)	32	\$165	52%
	Other chemicals	Cracking furnace with postcombustion CCS (high temp)	22	\$165	
	Ammonia	Syngas unit with postcombustion CCS (high temp)	20	\$108	
	NG processing	Install CCS on associated CO ₂ - NGP (process)	17	-\$5	
Iron & steel	Pig iron	CCS on remaining BF & BOF (high temp)	24	\$90	37%
	HBI	CCS on NGDRI/HBI (switch from B&BOF) (high temp)	9	\$160	
	HBI	CCS on NGDRI/HBI (add CCS to NGDRI) (high temp)	7	\$160	
Cement	Cement	Post-combustion CCUS (process)	24	\$50	35%
Aluminum	Refinery & smelting	CCS on process emissions (process)	2	\$165	15%
Glass	Glass	CCS	2	\$148	15%
Pulp & paper	Pulp and paper	CCS	0	\$100	0%
			256 MMT CO ₂ e; 30% of total abatement potential		

Source: Industrial Decarbonization Liftoff analysis
¹ Colors represent \$50 increments of \$/t CO₂e cost

Figure 4. Various hard-to-abate sectors in which CCUS is the least-cost abatement solution, their respective abatement potential, abatement cost, and share of sector abatement.¹

Section C.

In addition to the input noted above, DOE is interested in sector-specific input, particularly in hard-to-abate sectors (Figure 4), as follows:

1. Cement

- a. What are the primary feedstocks currently in use at your facilities, and how do you inventory and procure them?
- b. What efficiency improvements have you made (e.g., pre-calciner, waste heat recovery, and reuse, etc.)?
- c. Do you have regional opportunity for fuel-switching (e.g., sustainable biomass, renewable natural gas, hydrogen (H₂))? If yes, what percentage of your total fuel requirement can be substituted with these alternatives? If you are considering biomass, how secure is your supply?
- d. Would you consider next-generation kiln technology, and if so, which ones might be possible to retrofit with pre-existing facilities (oxy-fired, electric, indirect heating, etc.)?
- e. Which alternate feed and/or product blends are you considering, and what are their characteristics?
- f. Are you considering next-generation blends (Limestone Calcined Clay Cement (LC3), engineered Supplementary Cementitious Materials (SCMs), etc.)?
- g. What is the footprint of the carbon capture equipment you are considering?
- h. Have you considered application/use of carbon utilization approaches?
- i. What are your plans regarding hydrogen utilization?

2. Refining and petrochemicals

- a. Which on-site process emissions might be suitable for carbon capture?
- b. Which, if any, of the following have you considered as an approach to achieve decarbonization? Please specify and describe economic and/or technical opportunities and challenges in your answers.
 - i. Carbon capture retrofit to catalytic cracker unit
 - ii. Electrified cracker designs that meet thermal requirements for operations
 - iii. Combination of dilute process heat streams with CCS
 - iv. Fuel-switching to hydrogen on-site
 - v. Leveraging catalytic and other on-site process units for advanced refinery opportunities (e.g., transforming feedstocks such as waste plastic or biomass to syngas for fuels production)
 - vi. Alternative H₂ production methods, such as nuclear or renewable-generated H₂, and coupling the H₂ with CO₂ for conversion to products (please explain how existing refinery equipment could be utilized or modified)
- c. If your facility generates hydrogen from steam-methane reforming, do you already co-produce CO₂ for food, beverage, or other CO₂ markets?
- d. Do you have byproduct fuel sources that would require disposal if they were not being used to supply heat on-site? If so, have you considered advanced reforming of residual fuel for hydrogen production?

3. Ammonia

- a. Do you have a method today that already combines carbon capture (e.g., pressure swing adsorption post steam methane reforming (SMR)) in your process?
- b. Do you have the flexibility to produce urea as a means to use your CO₂ (from hydrogen production) on site?
- c. What is the carbon intensity of the energy you are using today to achieve the conditions required of Haber-Bosch?

4. Iron/Steel

- a. What type of furnace (blast furnace (BF), basic oxygen furnace, electric arc furnace (EAF)) do you use at your facility?
 - i. Are you flexible to furnace modifications or would a shift (BF to EAF) of furnace type impact the quality of your product?
- b. What are the factors – economic or technical – that might influence your ability to shift from BF production to EAF operation?
- c. What are some practical and economic considerations that influence shifting to direct reduced iron production?
- d. Have you considered biochar or sustainable biomass to replace coking coal to reduce emissions?
- e. Have you considered H₂ for your iron reduction process? If so, what are the key considerations for implementation in your facility (i.e., economics, safety, environmental, etc.)?

5. Aluminum

- a. Aluminum production can employ several methods for decarbonization, including the use of inert anodes (rather than conventional carbon anodes that produce CO₂ during the electrolysis process), the use of carbon capture, the use of renewable electricity, electrification of processes, the use of low-carbon fuels, etc. Which decarbonization approaches are expected to be implemented for aluminum production and in what timeframe?
- b. Could the heat/steam needs be supplied through unconventional processes that do not use fossil fuels, such as through the use of hydrogen, electric boilers, electric calcination, or heat pump technologies?
- c. Is the low concentration of CO₂ in the process gas (~1 %) expected to hamper the use of carbon capture during aluminum production? What amount of CO₂ capture (e.g., 90%) is economically conceivable to achieve? Do you have room on site for a CO₂ capture facility?
- d. Are there impurities of concern in the aluminum process gas that may impair the use of conventional carbon capture technologies (such as amine solvents)?
- e. Are there options for energy storage onsite that could enable the use of variable renewable electricity?
- f. What proportion of raw material could be substituted with recycled material?

6. Glass

- a. The majority of CO₂ emissions from glass production result from the combustion of fossil fuels to provide heat for melting and calcination of raw materials, but there are also inherent process CO₂ emissions resulting from the chemical conversions involved in the production of glass. Which decarbonization methods of these CO₂ streams are of highest interest to you and on what timeframe could they be employed? (Some examples of decarbonization approaches would be to use low-carbon fuels rather than fossil fuels or to capture the produced CO₂).
- b. Is clean hydrogen being considered for the replacement of natural gas (or other fossil fuel) heat sources? If yes, what factors have motivated serious consideration of clean hydrogen use? If no, what factors have limited consideration of clean hydrogen?
- c. Is electric melting a viable option for large-scale glass production? Up to what production capacity is electric melting a viable option? In what sectors would electric melting be most challenging to implement for large-scale glass production?
- d. Is there concern that certain carbon capture technologies, such as chemical looping, are not feasible due to the potential of metal oxides in the combustion chamber reacting with the glass batch? In other words, which carbon capture approaches are most feasible, and would the existing flue gas cleaning techniques sufficiently remove NO_x, SO_x, or other impurities such as HCl and HF to make post-combustion carbon capture feasible?
- e. To improve the economics of carbon capture and to further decarbonize indirect raw material procurement emissions, is there interest in using captured CO₂ to produce soda ash (Na₂CO₃) raw material through CO₂ mineralization processes?
- f. To decarbonize, is there an opportunity for raw material substitution through recycling or through using silica alternatives?

7. Lime

- a. What efficiency improvements have you made or are you considering to make (e.g., parallel flow regenerative (PFR) kiln type, waste heat recovery and reuse, etc.)?
- b. Do you have regional opportunity for fuel-switching (e.g., sustainable biomass, renewable natural gas, hydrogen)? If yes, what percentage of your total fuel requirement can be substituted with these alternatives?
- c. Are you considering using next-generation kiln technology (oxy-fired, electric, indirect heating, etc.)?
- d. Is your site footprint able to accommodate the installation and operation of a carbon capture facility? Are there any clear advantages for a particular capture technology (e.g., carbonate looping, membranes, solvents, sorbents, etc.)?
- e. Is it practical to incorporate carbon capture on aging kiln infrastructure (much of which is more than 40 years old)?

8. Pulp and Paper

- a. What proportion of your energy needs (thermal and/or electric) are provided by biogenic sources compared to fossil sources? Could more or all of your energy needs be met by using biogenic feedstocks? Are you able to produce and supply your own electricity, or is electricity purchased to meet your needs?
- b. To decarbonize, do you envision an approach that focuses more on increasing the use of improved thermal management, such as with heat pumps, and on using low-carbon electricity and/or electric boilers and calciners, or will incorporating post-combustion carbon capture be necessary?
- c. Is there consideration to use alternative fuels (such as clean hydrogen in boilers) or consideration to incorporate processes to produce alternative fuels for use, such as pyrolysis or gasification?
- d. Are there any unique challenges specific to paper production that would inhibit the use of post-combustion carbon capture? Would the energy requirements for carbon capture exceed what you can produce onsite (especially if using biogenic sources)? Is there sufficient physical space to accommodate a retrofit post-combustion capture system?
- e. Are all the flue gas streams (boilers, burners, and calciner) mixed together and sent to the same stack? Or is there a provision for multiple stacks?
- f. If needed, how easy or difficult is it to redesign your existing steam cycle?

9. Soda Ash

- a. To decarbonize soda ash production, do you envision the switch to low-carbon or renewable energy sources as being a viable option or will carbon capture need to be applied to energy-related CO₂ emissions? In what timeline could these decarbonization efforts be made and what is needed to accelerate this timeline? Do you have interest in capturing and using your CO₂ emissions as a feedstock for the production of soda ash through alternate reaction mechanisms?
- b. Conventional soda ash production results in the emission of CO₂ from both fossil fuel produced heat and electricity and from the excess CO₂ (more than stoichiometric) used to drive forward chemical reactions in the process. Could carbon capture technologies be applied to any or all of these sources of waste CO₂ during soda ash production? Would each waste CO₂ stream require its own distinct carbon capture process, or can all CO₂ waste streams be combined prior to carbon capture?
- c. What impurities, such as NO_x or otherwise, may be present in the waste CO₂ stream(s) from the soda ash production process?

10. Liquefied Natural Gas (LNG)

- a. The liquefaction of natural gas provides several opportunities for applying carbon capture. For instance, the CO₂ that would otherwise be vented during upstream acid gas removal from the natural gas stream could be captured. Furthermore, CO₂ could be captured from the flue gas resulting from gas turbines or other sources used to power the natural gas liquefaction process. There may also be opportunity, depending on the power source, to capture CO₂ released during the production of power for the rest of the LNG facility. Which sources of CO₂ are

you most focused on decarbonizing, and which are most suitable for carbon capture? In what timeline?

- b. What proportion of your facility energy needs are produced onsite? For energy produced onsite, do you see more opportunity for post-combustion or pre-combustion carbon capture?
- c. Is there interest in improving onsite power production efficiencies and reducing CO₂ emissions by moving to aeroderivative or combined-cycle turbines?
- d. There is concern that retrofitting or adding post-combustion capture to onsite gas turbines (if applicable) could face issues due to lack of available space, considering the low concentration of CO₂ in the flue gas. Could your onsite power production facilities support the use of hydrogen or a mixture of hydrogen and natural gas so that pre-combustion carbon capture could be applied to onsite hydrogen production (through SMR, autothermal methane reforming (ATR), partial oxidation of methane (POX), etc.), whereby smaller CO₂ recovery units could be used?

DISCLAIMER AND IMPORTANT NOTES

This is a RFI and not a FOA, therefore applications are not being accepted at this time. There is no guarantee that a FOA will be issued as a result of this RFI. Responding to this RFI does not provide any advantage or disadvantage to potential applicants if U.S. DOE chooses to issue a FOA regarding the subject matter.

Any information obtained as a result of this RFI is intended to be used by the Government on a non-attribution basis for planning and strategy development, and for development of topics for a funding opportunity announcement. This RFI does not constitute a formal solicitation for proposals or abstracts. Your response to this RFI will be treated as information only. U.S. DOE will review and consider all responses. U.S. DOE will not provide reimbursement for costs incurred in responding to this RFI. Respondents are advised that U.S. DOE is under no obligation to acknowledge receipt of the information received or provide feedback to respondents with respect to any information submitted under this RFI. Responses to this RFI do not bind U.S. DOE to any further actions related to this topic.

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Responses received under this RFI are subject to public disclosure under the Freedom of Information Act. Because information received in response to this RFI may be used to structure future programs and funding opportunity announcements and/or otherwise be made available to the public, **respondents are strongly advised to NOT include any information in their responses that might be considered business sensitive (e.g., commercial or financial information that is privileged or confidential), trade secrets, proprietary, or otherwise confidential unless clearly marked in accordance with the following instructions.**

Consistent with 10 CFR 1004.11, DOE requires that any person submitting information that they believe to be confidential and exempt by law from public disclosure should submit **two well-marked copies**: one copy of the document marked “confidential” which must clearly and conspicuously identify the business sensitive, trade secrets, proprietary, or otherwise confidential

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EVALUATION AND ADMINISTRATION BY FEDERAL AND NON-FEDERAL PERSONNEL

Federal employees are subject to the non-disclosure requirements of a criminal statute, the Trade Secrets Act, 18 USC 1905. The Government may seek the advice of qualified non-Federal personnel. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The respondents, by submitting their response, consent to DOE providing their response to non-Federal parties. Non-Federal parties given access to responses must be subject to an appropriate obligation of confidentiality prior to being given the access. Submissions may be reviewed by support contractors and private consultants.

REQUEST FOR INFORMATION RESPONSE GUIDELINES

Responses to this RFI must be submitted electronically to DE-FOA-0003263@netl.doe.gov with the subject line "DE-FOA-0003263 - RFI" no later than 5:00 pm (ET) on March 14, 2024. Responses must be provided as attachments to an email. It is recommended that attachments with file sizes exceeding 25 MB be compressed (i.e., zipped) to ensure message delivery. ***Responses must be provided as an Adobe Acrobat PDF (.PDF) attachment to the email, and no more than 25 pages in length, with 12-point font and 1-inch margins. Only electronic responses will be accepted.***

For ease of replying and to aid categorization of your responses, please copy and paste the RFI questions, including the question numbering, and use them as a template for your response. Respondents may answer as many or as few questions as they wish.

The U.S. DOE will not respond to individual submissions or publish publicly a compendium of responses. A response to this RFI will not be viewed as a binding commitment to develop or pursue the project or ideas discussed.

Respondents are requested to provide the following information at the start of their response to this RFI:

- Company / institution name;
- Company / institution contact;
- Contact's address, phone number, and e-mail address.

Please feel free to provide any additional background about yourself or your organization.

On behalf of the Fossil Energy and Carbon Management team, thank you in advance for providing your input on this important topic and contributing to the U.S. DOE's success in achieving its objectives.