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Office of Fossil Energy and Carbon Management
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585

RE: DE-FOA-0001660: Request for Information on Deployment and Demonstration Opportunities for Carbon Reduction and Removal Technologies

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INTRODUCTION

Thank you for the opportunity to provide insight into DOE's Office of Fossil Energy and Carbon Management's (FECM) ongoing efforts to jumpstart a national carbon capture and sequestration (CCS) and direct air capture (DAC) industry. The Information Technology and Innovation Foundation (ITIF) is a non-profit, non-partisan research and educational institute—a think tank. Its mission is to formulate, evaluate, and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress. Clean energy and climate innovation are some of ITIF's primary issue areas. CCS and DAC will be essential technologies to reduce and eliminate carbon emissions across the economy to achieve the nation's climate goals.

Leading energy and climate experts acknowledge that the United States and the world will need billions of tons of carbon sequestration per year by 2050 to meet emission reduction targets established by the Paris Agreement and elsewhere.[1] Without CCS and DAC it will be much more difficult and costly to reduce and eliminate emissions across various economic sectors, including electricity, cement, iron and steel, and heavy transportation. CCS and DAC complement existing clean energy technologies such as renewable energy and hydrogen by providing alternatives to emissions sources that would otherwise be too costly and/or difficult to decarbonize. Finally, CCS and DAC work in tandem to reduce the flow of emissions and the total stock of emissions.

There are remaining technical, financial, and regulatory hurdles, however, to scaling these technologies in the United States to meet the need for billions of tons of carbon storage. The significant funding provided by the Infrastructure Investment and Jobs Act opens the most significant opportunity to date to build pilot and commercial-scale demonstration projects. Our comments below are not specific to any one project but rather reflect our views on the broad technical areas and questions.

TECHNICAL AREA 1: REMAINING TECHNOLOGICAL RISKS FOR CARBON CAPTURE AND STORAGE

One important challenge for carbon capture technology is retrofitting existing fossil fuel electric power plants. Many analysts project that a large number of fossil fuel power plants will be required to cost-effectively and reliably support an electric grid with a high penetration of renewable energy (~70-90 percent). To meet emission targets, these remaining fossil fuel power plants must be equipped with carbon capture technology. In addition to retrofitting fossil fuel plants with significant useful life, it is critical that carbon capture facilities be cost-effectively built onto newly planned fossil plants, such as advanced natural gas combined cycle units. Currently, there are no carbon capture projects in the United States on advanced large-scale combined cycle units.

The application of carbon capture technology in the power sector has largely been a failure to date. Only one retrofitted power plant is currently operating in the world. These technologies are complex industrial-scale systems with hundreds of moving parts and processes. Simplifying and perfecting the carbon capture process, particularly improving amine-based solvent/sorbent absorption and regeneration, will be critical to effectively deploying these technologies on a much broader scale over the next few decades. In addition, lowering the vampiric-energy load required to power the capture process will be necessary to accelerate the adoption of retrofits.

Potential site-selection criteria for such facilities should prioritize medium-age coal- and natural gas-fired power plants that still have a significant useful life. These projects would demonstrate the ability to deploy new technologies alongside existing infrastructure. In addition, while all projects should be designed to capture the greatest amount of carbon dioxide that is technically and economically feasible, federally-funded project selection should focus on those that can scale from initial single-unit projects to multi-unit projects. These would include projects that start with one generation unit at a facility and later expand to others at the same site or the whole facility.

Project selection should also prioritize diverse types of CCS technology, including pre-, post-, and oxy-combustion. All three of these methods have advantages and disadvantages and varying energy and cost requirements. However, applications beyond post-combustion have not been tested in real-world conditions.

Finally, we note that global interest in developing low-carbon blue hydrogen production has increased dramatically in recent years. Many new large-scale projects were announced in 2021. This application of CCS is an essential element of any strategy to decarbonize the hydrogen production that the net-zero global economy of the future will rely upon. However, any blue hydrogen project must also account for and reduce upstream methane emissions, which could otherwise limit its overall net-environmental benefit.

TECHNICAL AREA 2: VALIDATION OF CARBON STORAGE RESOURCES FOR COMMERCIAL DEVELOPMENT

Secure, long-term storage locations must be developed in the United States to support the massive levels of carbon removal that the nation will need by 2050. Stringent monitoring and verification standards must be applied to these sites to garner public and community support for them. Many existing onshore geological storage sites can serve the needs of both CCS and DAC, and DOE should work to ensure their effective use, with an eye toward co-usage.

Developing a long-term monitoring and verification plan for each storage site will ensure that these projects' environmental and social benefits are realized. Broad societal acceptance of CCS and DAC will only be possible if the public has confidence in the long-term viability of storage sites. In addition, as corporate and individual interest in offsetting emissions through CCS and DAC grows, these sites will have to prove that they are, in fact sequestering carbon on geologically significant timescales. Widely sharing the costs and benefits of active carbon management technologies will also be critical to build the necessary public support for large-scale projects. If the costs of carbon management technologies are put only upon the communities in which they are located, while the benefits are received by broader publics, there is a risk that community resistance to project development will increase as more projects are built.

The next frontier of CO_2 storage will be in the world's oceans, which may provide gigatons of cheap and accessible storage to meet climate targets. One study projects the world will need between 10,000 and 14,000 offshore CO_2 injection wells by 2050 to meet a 2-degree target.[2] The United States outer continental shelf represents a particularly appealing location for CO_2 injection for several reasons, and the opportunities are ample.

Offshore CO_2 storage has several key regulatory advantages over onshore CO_2 storage. Most federal and state drilling regulations are in place to ensure safe access to drinking water. These concerns are not present in offshore storage as no freshwater aquifers would be impacted. Therefore, Class VI permitting will not be required. Early-stage efforts to develop offshore geological CO_2 storage have been carried out by the National Energy Technology Laboratory, which has identified as much as 30 million tons of capacity under the Gulf of Mexico. Another benefit of offshore CO_2 sequestration is that it limits, although it does not eliminate, local stakeholder concerns. However, this is still a relatively new area for both industry and government, with only two announced offshore storage projects in Norway. Very little federal guidance is available for offshore projects, and no offshore storage lease program has begun. The federal government should vet and approve projects to help scale the industry quickly. Projects that take advantage of the Gulf Coast's oil and gas infrastructure and labor expertise and utilize large CO_2 reservoirs relatively close to shore may be particularly attractive. Offshore carbon storage offers an opportunity to utilize existing human and infrastructure capital that is currently invested in the multi-billion-dollar offshore oil and gas industry around the world.

TECHNICAL AREA 3: CARBON DIOXIDE PIPELINE INFRASTRUCTURE AT THE REGIONAL & NATIONAL LEVEL

The cost of transporting captured carbon today is estimated to be around $10/ton. This cost must decline to around $2/ton if the industry is to scale up.[3] The existing CO_2 pipeline network is small but has an impressive safety record. It must grow if the United States is to meet the carbon sequestration challenge. This build-out will need to factor in the unique risks in CO_2 transport. CO_2 pipelines are unlike natural gas or oil pipelines.

CO_2 must be pressurized at far greater levels than either oil or natural gas, and it is also much more corrosive. It is unclear whether existing non-CO_2 pipelines can be retrofitted safely and cost-effectively to transport highly pressurized CO_2 over long distances for many years. CO_2 pipeline safety and longevity are critical to both ensure safe operation and win social and community acceptance. Unsafe or dangerous conditions will spur public resistance or backlash to this infrastructure.

DOE must ensure that demonstration projects have in place adequate safety monitoring and verification programs as well as robust safety procedures. The current 6,500 mile CO_2 pipeline system will need to grow to an estimated 65,000 miles if captured carbon is to be transported from where it is produced to where it will be stored or used.[4] Most of this pipeline infrastructure will be located along the Gulf Coast and in areas with existing oil and gas infrastructure. Co-siting and developing these pipelines alongside existing pipeline infrastructure corridors and other rights-of-way will likely lower permitting costs and reduce community opposition. In addition, co-siting facilities and pipeline pathways near and along industrial corridors where the captured CO_2 is most likely to be used in commercial and industrial processes could provide additional revenue to support demonstration projects.

Finally, the threat of climate change is an important consideration for siting CO_2 pipelines along existing infrastructure and pipeline corridors, particularly along the Gulf Coast, where rising sea levels, stronger hurricanes, and more frequent flooding could damage them. Precautions and safety measures should consider these risks when siting, permitting, and building an expanded CO_2 pipeline network to support FECM's carbon capture and DAC pilot projects.

TECHNICAL AREA 4: DIRECT AIR CAPTURE TECHNOLOGIES & REGIONAL DEPLOYMENT OPPORTUNITIES

DAC hubs offer a significant opportunity to scale and learn from applications across diverse industrial and physical settings. DAC facilities can be located to optimize energy resources and market opportunities. Locations near demand centers for captured CO_2 both in traditional applications and in new, yet-to-be-developed use-cases will enhance the prospects of commercial success for next-generation DAC facilities.

The four or more DAC hubs funded by the infrastructure bill should be located in areas across the country, including areas with varied ambient temperatures and wind speeds, electric-grid carbon intensities, water and land constraints, and access to storage and CO_2 transportation infrastructure. This approach will test the technology under different conditions to better understand the advantages and drawbacks of diverse stresses. It will also deepen understanding of the non-energy and heat requirements for DAC.

DAC pilot projects should be in areas that can potentially grow beyond the initial project investment. DAC modules can potentially be stacked – or additional units added later to increase capture rates. Project siting should also consider increasing overall size, which may require additional CO_2 transportation or storage capacity.

We suggest that pilot projects be located in the following areas:

- U.S. Southwest region (Nevada, Arizona, New Mexico) to take advantage of low-cost and consistent geothermal and solar electricity and heat,
- Gulf Coast (Texas, Louisiana) to take advantage of existing energy, pipeline, storage, and industrial CO_2 demand markets,
- Midwest (Illinois, Indiana) to take advantage of the low-carbon nuclear electricity and heat and to test DAC in areas of high wind speeds and brown-field sites, and

- A state with high variable renewable energy penetration, such as California, to understand how DAC might operate with variable renewable energy resources.

Finally, DAC can play an essential role in carbon management strategies by providing an upper limit on the cost of offsets and mitigation. As the marginal cost of emissions abatement increases for any sector or source, there will be a point at which an additional ton of abatement costs more than removal via DAC. The lower the cost of DAC, the more likely very-expensive-to-decarbonize sectors such as international airline travel and shipping will find it an appealing option. For example, the estimated abatement cost for an international flight is as high as $2,000 a ton of CO_2.[5] As DAC costs decline, airlines may well prefer to invest in capturing a ton of carbon from the atmosphere rather than eliminating it from engine exhaust.

TECHNICAL AREA 6: OPPORTUNITIES FOR CARBON CONVERSION TECHNOLOGIES & GRANT PROGRAMS

The primary business case for exploring commercial and industrial applications for captured carbon is to provide an additional and potentially robust and sustainable source of revenue for carbon capture and DAC projects. While enhanced oil recovery (EOR) is the predominant use case for captured carbon today, its environmental benefits and total demand are limited. With potentially billions of tons of captured carbon becoming available over the next three decades, industry must find ways to put some of it to commercial use. Beyond EOR, the potential uses for captured carbon include synthetic fuels, polymers and plastics, and cement.

To date, public support for RD&D and the commercialization of value-added carbon products have been lacking. DOE's Carbon Utilization Program, which has funded a number of innovative carbon conversion projects, is a good start and should be continued and expanded to include a broader suite of possible products, such as plastics and polymers.[6] The National Energy Technology Laboratory, with FECM's support, is an ideal early-stage and cross-cutting government program to lead carbon product innovation RD&D.

In addition, a lack of standards and verification for what constitutes a carbon-negative industrial product or a verifiable way to guarantee that a product uses captured carbon in production likely limits the market for these goods. Companies, investors, and individuals interested in selling or buying products that embed captured carbon are uncertain due to this gap. This issue is particularly problematic for government entities interested in procuring low-carbon building products and materials. An effort has emerged to address commercial standards for building materials, particularly cement, but progress in other product fields has been slower.

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Finally, DOE should work closely with other federal agencies including, but not limited to, the Departments of Transportation, Defense, and Commerce, the General Service Administration, and EPA to develop robust testing, verification, and product control standards for products that use captured carbon and to seize opportunities to accelerate markets development through federal procurement.

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1. See IPCC, "2018: Global Warming of 1.5°C.An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels," 2019, https://www.ipcc.ch/sr15/; IEA, "Net Zero by 2050: A Roadmap for the Global Energy Sector," May 2021, https://www.iea.org/reports/net-zero-by-2050.; Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final Report Summary, Princeton University, Princeton, NJ, 29 October 2021. https://netzeroamerica.princeton.edu/the-report.
2. Ringrose, P.S., Meckel, T.A. Maturing global CO2 storage resources on offshore continental margins to achieve 2DS emissions reductions. *Sci Rep* **9,** 17944 (2019). https://doi.org/10.1038/s41598-019-54363-z
3. Smith, Erin, "The cost of CO2 Transport and Storage in Global Integrated Assessment Modeling," MIT, June 2021, https://globalchange.mit.edu/sites/default/files/Smith-TPP-2021.pdf.
4. Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final Report Summary, Princeton University, Princeton, NJ, 29 October 2021. https://netzeroamerica.princeton.edu/the-report.
5. U.S Department of Energy, Office of Energy Efficiency & Renewable Energy, "Sustainable Aviation Fuel: Review of Technical Pathways," September 2020, https://www.energy.gov/sites/prod/files/2020/09/f78/beto-sust-aviation-fuel-sep-2020.pdf
6. U.S. DOE, "DOE Invests $17 Million to Advance Carbon Utilization Projects," June 16, 2020, https://www.energy.gov/articles/doe-invests-17-million-advance-carbon-utilization-projects#:~:text=%E2%80%9CDOE's%20Carbon%20Utilization%20Program%20is,like%20plastics%20and%20carbon%20fibers.%E2%80%9D.