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BEFORE THE  
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY  
SUBCOMMITTEE ON ENERGY ON  
MARINE CARBON DIOXIDE REMOVAL RESEARCH AND DEVELOPMENT  
September 19, 2024

Thank you, Chairman Williams and Chairman Miller, Ranking Member Bowman and Ranking Member Ross and distinguished members of the Committee. Thank you for the opportunity to testify today on marine carbon dioxide removal research and development.

## 1. INTRODUCTION

The Intergovernmental Panel on Climate Change is clear that if we are to limit average global temperature increase to 1.5°C, we not only must drastically reduce greenhouse gas emissions, but also must actively remove carbon dioxide from the atmosphere.<sup>1</sup> In line with this scientific consensus, the Department of Energy (DOE) is investing billions of dollars in carbon management and carbon dioxide removal solutions as part of the Biden-Harris Administration's commitment to building a net-zero economy by 2050. The Office of Fossil Energy and Carbon Management plays a central role in funding science and innovation related to a broad portfolio of carbon removal solutions, including marine carbon dioxide removal (mCDR), and we are honored to participate in this hearing on such an important and rapidly advancing field.

Marine Carbon Dioxide Removal, as defined by the White House Ocean Climate Action Plan<sup>2</sup>, refers to deliberate efforts to increase the amount of atmospheric carbon dioxide stored by the ocean, including seawater, marine life, and marine sediments. mCDR is one of the six primary pathways that DOE has prioritized for funding as part of its broader programming for carbon dioxide removal, as directed within the Consolidated Appropriations Act, 2021<sup>3</sup> and coordinated through DOE's Carbon Negative Shot<sup>TM</sup><sup>4</sup>, as one of several Energy Earthshots<sup>5</sup>. The Carbon Negative Shot<sup>TM</sup> initiative has developed a target for a comprehensive portfolio of CDR

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<sup>1</sup> IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647

<sup>2</sup> Ocean Policy Committee. (March 2023). "Ocean Climate Action Plan." The White House. Washington, DC. [https://www.whitehouse.gov/wp-content/uploads/2023/03/Ocean-Climate-Action-Plan\\_Final.pdf](https://www.whitehouse.gov/wp-content/uploads/2023/03/Ocean-Climate-Action-Plan_Final.pdf)

<sup>3</sup> Consolidated Appropriations Act, 2021, Pub. L. No. 116-260 (2020). <https://www.congress.gov/bill/116th-congress/house-bill/133>

<sup>4</sup> Office of Fossil energy and Carbon Management. (January 4, 2024). Carbon Negative Shot. Department of Energy. Washington, DC. <https://www.energy.gov/fecm/carbon-negative-shot>

<sup>5</sup> Department of Energy. (2024). "Energy Earthshot Initiative." U.S. Department of Energy. Washington, DC. <https://www.energy.gov/energy-earthshots-initiative>

approaches to deliver billion-tonne per year net removal capacity at less than \$100 per net tonne of carbon dioxide equivalent removed from the atmosphere. The Carbon Negative Shot™ initiative also prioritizes efforts aimed at increasing the duration of carbon storage and improving measurement, monitoring, reporting, and verification (MMRV) to enable CDR solutions to be compared in an apples-to-apples manner across different pathways.

For mCDR to contribute meaningfully to the Carbon Negative Shot™ goals, significant research and development will be necessary to assess and inform the viability and efficacy of different mCDR pathways.

## **2. THE DEPARTMENT OF ENERGY'S CURRENT ROLE IN MARINE CARBON DIOXIDE REMOVAL EFFORTS**

DOE seeks to build on its core strengths as a science and innovation funding agency to support promising mCDR concepts to move from lab research to field testing to potential commercial scale operations. The DOE at present is a leader in carbon management research, development, and demonstration, and aims to further integrate mCDR into our largely terrestrial-based portfolio, applying our experience and lessons learned from industries like direct air capture and marine energy to expansion of the mCDR field. DOE also has significant analytic capabilities that it plans to leverage to assess the cost and performance of promising mCDR solutions as they mature to successively higher technology readiness levels, to help inform where future public- and private-sector investment would be most valuable and how mCDR can advance in as responsible a manner as possible. Lastly, DOE is investing in the ongoing creation and development of measurement, monitoring, reporting, and verification (MMRV) technologies and methodologies. MMRV tools developed by DOE include a suite of hardware, modeling, and computational approaches to accurately and reliably quantify the comprehensive greenhouse gas benefit of a CDR approach. Strong MMRV is of national security and economic interest, both to ensure that the international community is carrying out mCDR in a responsible manner, and to ensure that mCDR pathways can participate in carbon markets in an effective way.

Specifically, DOE is supporting safe and responsible research and potential commercialization of advancing a range of mCDR approaches through:

- (1) foundational research and development,
- (2) lab-scale design and prototype,
- (3) analysis and community engagement,
- (4) field pilot and validation, and
- (5) CDR credit market development.

### ***Foundational research and development:***

Foundational research and development are necessary to inform decisions regarding the progression of applied mCDR research to technology development, and if appropriate, the

potential scaling of these mCDR techniques.<sup>6</sup> The goal of DOE's mCDR research and development portfolio is to identify, assess, and validate innovative approaches, consistent with the best available science.

To achieve that goal, DOE is collaborating with the National Oceanic and Atmospheric Administration (NOAA), through our involvement in the NOAA-managed National Oceanographic Partnership Program (NOPP) in fiscal years 2022 and 2023 to support several mCDR projects. In FY22, this effort supported DOE's Pacific Northwest National Laboratory (PNNL) to collaborate with NOAA's Pacific Marine Environmental Lab, and Ebb Carbon, Inc., an industry partner, to advance Ebb Carbon's ocean alkalinity enhancement method.<sup>7</sup> In FY23, this partnership provided funding for two projects focused on ocean alkalinity enhancement. The Office of Energy Efficiency and Renewable Energy's (EERE) Water Power Technologies Office (WPTO) is funding additional work at PNNL with Ebb Carbon, specifically on investigating potential uses for the acidic product stream from the Ebb Carbon system, in an effort to lower the costs and carbon footprint of the overall process<sup>8</sup>.

### ***Lab-scale design and prototype:***

The goal of DOE's lab-scale design and prototyping work is to understand whether mCDR systems can operate effectively on a path to climatically relevant and cost-effective scale.

To achieve this goal, FECM issued a funding solicitation for mCDR projects,<sup>9</sup> and awarded eight projects to carry out conceptual design studies on abiotic direct ocean capture (DOC) systems.

In addition, DOE's Advanced Research Projects Agency (ARPA-E) is funding a \$36 million portfolio of projects focused on improving mCDR MMRV through their Sensing Exports of Anthropogenic Carbon through Ocean Observations (SEA-CO<sub>2</sub>) program.<sup>10</sup> This program is funding eleven projects across eight states that focus on researching and developing novel efforts for mCDR MMRV in order to identify cost-effective and energy efficient carbon dioxide removal solutions. The knowledge gained from these projects will play a critical role in creating new and appropriately scaled sensors and models that will quantify the effectiveness and impacts of mCDR techniques.

### ***Analysis and Engagement:***

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<sup>6</sup> National Academies of Sciences, Engineering, and Medicine. (2022). "A Research Strategy for Ocean Carbon Dioxide Removal and Sequestration." National Academies Press. Washington, DC. <https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration>

<sup>7</sup> Water Power Technologies Office. (March 14, 2024). "First-of-its-Kind Marine Carbon Dioxide Removal Device Deployed in Washington State." Department of Energy. Washington, DC. <https://www.energy.gov/eere/water/articles/first-of-its-kind-marine-carbon-dioxide-removal-device-deployed-washington-state>

<sup>8</sup> Ibid

<sup>9</sup> Office of Fossil Energy and Carbon Management (2024). "Project Selections for FOA 2614: Carbon Management (Round 2)." Department of Energy. Washington, DC. <https://www.energy.gov/fecm/project-selections-foa-2614-carbon-management-round-2>

<sup>10</sup> Advanced Research Projects Agency - Energy. (2023). "DOE Announces \$36 Million To Advance Marine Carbon Dioxide Removal Techniques and Slash Harmful Greenhouse Gas Pollution." Department of Energy. Washington, DC. <https://www.energy.gov/articles/doe-announces-36-million-advance-marine-carbon-dioxide-removal-techniques-and-slash>

It is imperative for the success of mCDR efforts that research, scaling, and potential implementation occur in a responsible manner that stewards taxpayer funding effectively, minimizes harm, and provides benefits to ecosystems, local communities, and others that rely on the ocean economically and culturally.

To ensure investment flows to the projects with the greatest potential, DOE is leveraging its analytic capabilities to assess the cost and performance of mCDR pathways.

To align with Administration priorities like the Justice40 initiative,<sup>11</sup> and to maximize the effectiveness and efficiency of its carbon management activities, the FECM recently released the Responsible Carbon Management Initiative (RCMI) Principles<sup>12</sup> to encourage project developers, researchers, and others in the carbon management industry to pursue the highest levels of safety, environmental stewardship, accountability, workforce development and quality jobs, community engagement, and societal benefits in carbon management projects. Through the RCMI process, FECM is engaging with the broader community around key guardrails and guidance for responsible research, development, and demonstration of carbon management technologies and will leverage the principles laid out within this effort to guide our future mCDR activities. DOE is, and will continue to be, a leader in ensuring that carbon management practices mitigate risks and provide global climate benefits alongside local and regional community benefits and economic development opportunities.

### ***Field pilot and validation:***

The goal of DOE's field validation and pilot-scale work is to leverage our expertise in technoeconomic, environmental health and safety, and life cycle assessment to identify and demonstrate the mCDR approaches that are most likely to perform efficiently, cost-effectively, verifiably, and safely in field environments. Field research activities will require permits issued under the appropriate regulatory authorities of the *Marine Protection, Research and Sanctuaries Act*, *Clean Water Act*, and other relevant laws.

To achieve this goal, FECM will select two projects from a funding opportunity announcement to carry out pilot project field validation, with expected DOE cost-share up to \$4 million per project to develop and test direct ocean capture technologies in representative environments.<sup>13</sup> Ongoing projects selected for Phase 2 participation will test their technology in an integrated system and field conditions to accelerate ocean processes that remove carbon dioxide from the atmosphere. Projects supported under this program should develop techno-economic analyses that demonstrate

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<sup>11</sup>Office of Energy Justice and Equity. (2024). "Justice40 Initiative." Department of Energy. Washington DC. <https://www.energy.gov/justice/justice40-initiative>

<sup>12</sup> Office of Fossil Energy and Carbon Management. (August 6, 2024). "Responsible Carbon Management Principles Resources." Department of Energy. Washington, DC. <https://www.energy.gov/fecm/responsible-carbon-management-principles-resources>

<sup>13</sup> Ibid.

meaningful progress towards achieving DOE’s Carbon Negative Shot™ target of less than \$100 per net tonne of carbon dioxide equivalent removed.

### ***CDR Credit Market Development:***

The Department of Energy recognizes that if carbon dioxide removal efforts are to be implemented at the scale necessary to achieve a net-zero economy and remove legacy emissions from the atmosphere, a strong and science-driven market for carbon credits may be necessary. FECM’s CDR Purchase Pilot Prize is supporting a range of CDR projects, including three mCDR companies in the semifinalist stage of this Prize.<sup>14</sup> DOE recognizes that the Prize is insufficient to drive mCDR projects to scale alone, and so has designed the Prize to crowd in additional voluntary private sector support through identifying projects that have demonstrated the potential for effective field-scale validation and testing, in a way that catalyzes innovation in the field and incorporates rigorous MMRV. These efforts are in pursuit of the Biden-Harris Administration priority to drive forward a high-quality carbon credit market, as outlined in the Principles for Responsible Participation in Voluntary Carbon Markets policy statement, co-signed by the Energy Secretary Jennifer Granholm and Treasury Secretary Janet Yellen, among others.<sup>15</sup> Specifically, the CDR Purchase Pilot Prize is designed to support the broader CDR field as it navigates the challenges of this emerging market to identify and develop high-quality credits. The inclusion of mCDR approaches as semifinalists within the CDR Purchase Pilot Prize provides an opportunity to leverage the research performed and expertise available across the U.S government to rigorously assess the quality, efficacy, and safety of these pathways and their corresponding CDR credits, within the context of voluntary markets.

### **3. THE DEPARTMENT OF ENERGY’S ROLE IN ADVANCING MARINE CARBON DIOXIDE REMOVAL INTO THE FUTURE**

Looking to the future, to maximize complementary capacities and minimize duplication of efforts, we have embarked on a formal collaboration with NOAA, the Agency that leads U.S. efforts in oceanography, atmospheric composition, and ocean observations. A five-year Memorandum of Agreement (MOA) was signed in June 2024 by DOE’s Under Secretary for Science and Innovation, Dr. Geraldine Richmond, and NOAA’s Under Secretary of Commerce for Oceans and Atmosphere, Dr. Richard Spinrad.<sup>16</sup> This interagency partnership on mCDR formalizes engagement between NOAA and DOE’s FECM, EERE, and Office of Science. Activities under

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<sup>14</sup> Office of Fossil Energy and Carbon Management. (May 28, 2024). "Carbon Dioxide Removal Purchase Pilot Prize Phase 1 Semifinalists." Department of Energy. Washington, DC. <https://www.energy.gov/fecm/carbon-dioxide-removal-purchase-pilot-prize-phase-1-semifinalists>

<sup>15</sup> U.S. Department of the Treasury. (2024). "Voluntary Carbon Markets Joint Policy Statement and Principles." Department of the Treasury. Washington, DC. <https://home.treasury.gov/system/files/136/VCM-Joint-Policy-Statement-and-Principles.pdf>

<sup>16</sup> Office of Fossil Energy and Carbon Management. (2024). "NOAA, DOE Sign Agreement to Advance Marine Carbon Dioxide Removal." Department of Energy. Washington, DC. <https://www.energy.gov/fecm/articles/noaa-doe-sign-agreement-advance-marine-carbon-dioxide-removal>

the MOA will advance four key responsibilities: (1) coordination and collaboration, (2) acceleration of research and development infrastructure, including facilities, data management, and feasibility studies, (3) development of protocols for accountable and science-based mCDR for ecosystem safety, social benefit, and economic viability, and (4) the potential for future additional collaboration between both agencies. Activities carried out under this partnership will be in line with recommendations that will be included in an interagency Research Strategy that will be put forth by the White House Fast Track Action Committee on Marine Carbon Dioxide Removal (MCDR-FTAC),<sup>17</sup> of which DOE is a member. Together, NOAA and DOE will build on our strengths to advance mCDR technology that can contribute meaningfully to climate goals while protecting communities that rely on the ocean, ecosystems, and U.S. national security and economic interests. DOE houses extensive expertise, capabilities, and facilities that have direct applications to the transfer of mCDR efforts from foundational and fundamental research into the prototype and pilot phases, and as appropriate, potential large-scale demonstration. The collaborations and programs summarized above indicate DOE's strong potential to advance research and development of mCDR approaches and technologies. Our Department supports pilot projects, provides leadership on principles regarding social governance and community benefits, improves MMRV hardware and software development to enable research through large scale implementation, and is actively assessing the potential role of market mechanisms to enable a responsible net-zero emissions economy. We aim to support the mCDR field as technologies and research expand in scale and scope.

Additionally, DOE has a number of programs and expertise that can offer lessons applicable to the expansion of the mCDR field. Through FECM's direct air capture programs,<sup>18</sup> we have rapidly expanded carbon dioxide removal efforts in the United States, building capacity in bringing cutting edge climate solutions from modeling and lab-based studies, into pilot projects and commercial-scale operation. Through these efforts, FECM has established rigorous technical and community engagement standards for demonstrations including appropriate permitting and environmental assessment, engineering studies, life cycle analyses, and techno-economic assessments. We look forward to applying this expertise to the mCDR field, as science and interagency coordination lead our programming.

Separately, through efforts advanced by WPTO, DOE is the leader in marine energy research and development. WPTO's Testing Expertise and Access for Marine Energy Research (TEAMER)<sup>19</sup>

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<sup>17</sup> Scott Doney. (2023). "Marine Carbon Dioxide Removal: Potential Ways to Harness the Ocean to Mitigate Climate Change." The White House. <https://www.whitehouse.gov/ostp/news-updates/2023/10/06/marine-carbon-dioxide-removal-potential-ways-to-harness-the-ocean-to-mitigate-climate-change/>

<sup>18</sup> DOE is currently implementing multiple programs on direct air capture technologies supported through the Infrastructure Investment and Jobs Act, including the Regional Direct Air Capture (DAC) Hubs Program, the Commercial DAC Prize, and the Precommercial DAC Prize.

<sup>19</sup> Water Power Technologies Office. (2024). "The U.S. Testing Expertise and Access to Marine Energy Research Program (TEAMER)." Office of Energy Efficiency and Renewable Energy. Washington, DC. <https://www.energy.gov/eere/water/us-testing-expertise-and-access-marine-energy-research-program-teamer>

program and PacWave<sup>20</sup> program facilitate marine and wave energy research and development through government-supported testbeds. The mCDR research community has expressed that a lack of mCDR testing infrastructure creates time and financial burden on individual projects that are already financially constrained. The government-supported establishment of mCDR testbeds would greatly support mCDR research and development in this critical stage of the field, when all efforts to scale climate solutions must be safe, responsible, and expeditious. Complementary to the applied offices, the Office of Science conducts large scale climate and environmental modeling that includes marine environments and biogeochemistry throughout the earth system. These capabilities have not yet been applied to mCDR, but could be augmented to do so, allowing simulation and projection of carbon removal in the ocean and carbon fluxes across the earth system as well as study of impacts on ocean dynamics and ecosystems. WPTO's in-house expertise on marine-based research hubs, Office of Science's climate and environmental modeling capabilities, and FECM's expertise on building world-class carbon management testing centers and pilot projects, could collectively be applied to advance the mCDR field into the next stage of necessary testing and development.

#### **4. CONCLUSION**

The Department of Energy recognizes that mCDR research and development is a critical part of the current carbon dioxide removal research landscape and demonstrates potential to scale to be a significant part of overall United States carbon dioxide removal efforts. We are not only actively funding areas of research and development in this field but also look forward to leveraging our relevant knowledge as active participants in the field, in our partnership with NOAA, and a whole of government approach in the future.

We thank the Committee for the opportunity to testify on this important topic.

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<sup>20</sup> Water Power Technologies Office. (2024). "PacWave: Offshore Wave Energy Test Site." Office of Energy Efficiency and Renewable Energy. Washington, DC. <https://www.energy.gov/eere/water/pacwave-offshore-wave-energy-test-site>