EFI Foundation input to SB005 annotated agenda and related annexes on Article 6.4 mechanism and carbon dioxide removal

900 Seventeenth Street NW, Suite 1100, Washington, D.C., USA, 20006
+1 (202) 688-0010
Joseph S. Hezir, Principal & Executive VP, jshezir@efifoundation.org
Sam F. Savitz, Senior Research Associate, sfsavitz@efifoundation.org
Timothy Steeves, Senior Research Associate, tmsteeves@efifoundation.org [A]

Background Information

The EFI Foundation is a 501(c)(3) non-partisan, nonprofit organization dedicated to educating the public on issues relating to harnessing the power of technology and policy innovation to accelerate the clean energy transition. The EFI Foundation is based in Washington, D.C. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, the EFI Foundation builds on the prior work of the Energy Futures Initiative, a nonprofit organization co-founded by former Secretary Moniz in 2017. Reports by the EFI Foundation and the legacy work of the Energy Futures Initiative are available for download at www.efifoundation.org.

Since 2019, EFI and the EFI Foundation have published seven reports about carbon dioxide removal (CDR) and six additional reports about the broader large-scale carbon management landscape (see Bibliography). EFI's first major CDR report, *Clearing the Air*, outlined a 10-year, $11-billion initiative for CDR research, development, and demonstration (RD&D) across the U.S. federal government. Subsequent work has focused on specific pathways meriting further RD&D and policy attention—including mineralization, marine CDR, and technologically enhanced terrestrial solutions—or on policy concepts such as government procurement of CDR as a public good. Other reports have focused on scaling up carbon transportation, storage, and point-source capture, including investment challenges and labor issues.

This document contains the EFI Foundation's responses to the call for input on the "Information note: Removal activities under the Article 6.4 mechanism." These responses are based on the EFI Foundation's research in public and forthcoming reports, divided into four topics.

Topic 1: Pros and Cons of "Engineering-Based" and "Land-Based" CDR

Reaching net zero and curbing climate change will very likely require a portfolio of CDR options, including a combination of what the Information Note calls "engineering-based" and "land-based" CDR.[B] IPCC's interquartile ranges for CDR include, at minimum, some BECCS in 2050.[1] While the Sixth Assessment Report details some illustrative scenarios that use only forestation for CDR, these require emissions reductions that are deeper and steeper; these scenarios are less feasible, given that current policies lag behind needed mitigation. Land-

[A] This response was also prepared with the assistance of Nicholas Britton.

[B] The Information Note's taxonomy of CDR activities appears inconsistent, such as classifying BECCS as land-based in some cases but engineering-based in others or leaving ocean-based activities out of the discussion in Section 3.2. This response assumes a narrow definition of "land-based" that includes the activities listed as such in Table 4 of the Information Note, with all others considered "engineering-based."

based solutions alone might also prove insufficient to reach the scale required to achieve net zero.

While natural solutions are at much higher technological readiness levels overall, their potential to scale to the level needed is much less definitive. Table 4 of the Information Note shows that the lower bound estimates of all land-based activities sum to 2.3 gigatons per year of CDR (according to the IPCC). In the same report, the median scenario identified by the IPCC utilized 6.0 gigatons of CDR per year by 2050[2] from a combination of natural and technological resources. Without engineering-based activities to complement them, the ability to reach net zero emissions and global temperature targets is uncertain.

International policy that includes varied CDR options can be a crucial driver of innovation. The Information Note contends that engineering-based CDR is "technologically and economically unproven, especially at scale," and compares[c] the current deployment of those solutions to land-based activities.[3] While many engineering-based CDR activities are currently deployed at small scales, deployment and investment (both public and private) totaled more than $4B in public RD&D and $200M between 2020 and 2022.[45] Innovation is also driving down costs and reducing uncertainty. Policy action at the international level can also be a driver of deployment and innovation, providing certainty and a market signal to developers and investors.[6] Current high costs and low deployment are not reasons to exclude a technology from policy frameworks: deep decarbonization will not be possible in any sector with only current technologies.

Land-based and engineering-based activities both have costs and benefits. The Information Note also contrasts land-based and engineering-based activities by saying that the latter entails "unknown environmental and social risks," while the former are "proven and safe."[7] The EFI Foundation's analysis, however, has shown that all types of CDR have both uncertainties and potential benefits.

Many of the land-based solutions listed, such as biochar, are also unproven at large scales for CDR (though they may be more widely used for other purposes, such as agricultural productivity). As acknowledged elsewhere in the Information Note, land-based solutions can also have environmental and social risks (e.g., land use change, methane emissions) if not properly governed. Voluntary carbon markets have demonstrated this, with high-profile cases of low-quality offsets undermining trust in the system. While risks of CDR—both engineered and land-based—are a lively area of research and governance discussions, such concerns are increasingly well understood.[8] Risk mitigation (e.g., reversal, accounting, and additionality guidelines, as detailed in other sections of the Information Note) will be necessary for any version of the Article 6.4 mechanism.

Conversely, engineering-based solutions have benefits beyond what is listed in the Information Note—i.e., the ability to store carbon permanently. These include ancillary

[C] The numbers cited in Table 3 may not portray the complete picture since the number cited for engineering-based activities includes only direct air capture and because anthropogenic forestry and land use remains a net *source* of emissions globally, rather than a sink, according to IPCC.

benefits to the climate (e.g., BECCS displacing fossil-based energy), ecosystems (e.g., marine CDR decreasing local hypoxia and acidification), economies, and social equity (e.g., carbon management employing workers displaced by the energy transition).[9] [10] [11] These pathways can support sustainable development goals, including clean energy, industrialization/innovation/infrastructure, and ecosystem restoration or preservation.

Engineering-based CDR can help lower the costs of decarbonization. The IPCC is clear that CDR may be necessary to compensate for "hard-to-abate" emissions from sectors like industry, agriculture, and aviation—in addition to, not instead of, deep cuts to emissions elsewhere.[12] In many cases, engineering-based CDR may be lower-cost than alternative options for mitigation, such as fuel-switching or electrifying these sectors, or the only viable option. It can also serve as a bridge, lowering CO_2 concentrations in the atmosphere while emissions-abatement solutions are developed through innovation. In some cases, engineered CDR pathways may compare favorably to land-based CDR options because of better local suitability, permanence, or economically valuable products and co-benefits. Different options for CDR also need not compete (with each other or with emissions reduction measures): multiple strategies could be deployed in parallel and every tenth of a degree—and therefore every megaton of CO_2 removed—matters.[13] Facilitating flexibility and diversification through technology-agnostic policy can lower overall costs, reduce risks, and ensure adaptability to changing global realities and local conditions.[14]

Topic 2: CDR and Carbon Disposal Permanence

Both higher- and lower-permanence activities can be part of the CDR portfolio. Permanence is a core question for any large-scale carbon management technology. Ideally, carbon removed by CDR should be permanently separated from the atmospheric carbon cycle, but any real-world solution risks leakage or reversal. This possibility needs to be evaluated and included in accounting and policy development. The current language in the Information Note accurately identifies that land-based activities that store carbon in "ecosystem reservoirs" hold carbon for shorter timespans (decades to centuries, rather than millennia or longer for geologic storage) and face a greater risk of premature reversal (i.e., released back into the atmosphere), making their carbon removals entirely reversible.[15] This could be a huge problem when these removals are commoditized, as the integrity of these traded removals will rightfully be called into question if they literally or figuratively go up in flames.

This does not mean these efforts or options should be discounted; in fact, it means that nature-based solutions likely need greater attention regarding long-term stewardship. Any solution in which carbon is stored underground has a massive advantage in terms of permanence. However, this is counterbalanced by other factors that advantage more temporary land-based solutions, such as cost. **No single pathway will likely be sufficient to meet global CDR needs, and different pathways have strengths and weaknesses with no single "winner."**[16] Limiting Article 6.4 mechanism eligibility may box out certain solutions that could significantly contribute to carbon mitigation efforts.

Engineered solutions still have some (small) potential for reversal.[17][18] Carbon stored in geologic formations or minerals could also be released from these systems through natural processes or human intervention. The risk is lesser with these solutions, but protocols for the eventuality of reversal are still necessary.

In a previous report on a U.S. program for government procurement of CDR, the EFI Foundation identified permanence as a critical requirement for potentially purchased CDR and called for evaluation on the scale of decades and centuries.[19] **For Article 6.4, a similar liability-based approach could be pursued, and the potential issues facing nature- and land-based solutions should be given more attention.** Liability solutions can take many forms, including MRV requirements, buffer credits, and "tiers" of CDR credits based on the degree of permanence.

Similarly, CO_2 sequestered in products should similarly be evaluated for permanence and maintain the possibility of eligibility. For example, CO_2 captured from DAC and sequestered in concrete has little risk of returning to the atmosphere[20] and could be eligible for Article 6.4, just as with other carbon storage methods. Rather than a blanket exclusion of products, different product categories could be evaluated based on permanence (as well as other criteria, such as environmental sustainability).

Topic 3: Biomass-Based, Marine, and Mineralization CDR

There are advantages to BECCS and other CDR pathways that use sustainable forest and waste feedstocks. Biomass-based CDR pathways—including bioenergy with carbon capture and storage (BECCS)—could be an essential part of the global CDR portfolio. BECCS makes up the second-largest share of CDR in IPCC's median scenario for 2050 (after forestation).[21] BECCS is one of the only CDR options that produce (clean) energy rather than consuming it, combines relatively low cost with high permanence, builds on known technologies with opportunity for innovation, and offers the potential for significant social and environmental co-benefits.[22]

The Information Note's proposed definitions for the "Temporal boundary for removals" and "Removals versus avoided emissions" would seemingly exclude biomass-based CDR that uses specific feedstock categories from eligibility under the Article 6.4 mechanism.[23] In particular, these rules could exclude many sources of forest biomass and all or most waste biomass.

There is a substantial body of literature on the emissions benefits of BECCS from these sources, including their ability to achieve net-negative emissions.[24] BECCS using urban wastes, agricultural wastes, logging residues, and industrial wood waste can have several advantages over alternative feedstocks: they can cost less, achieve larger life cycle emissions benefits, use fewer resources, and result in less land use change.[25] These feedstocks can have distinct co-benefits, such as reducing wildfire risk.[26] Excluding forest and waste feedstocks could take much of the CDR potential (e.g., as estimated by the IPCC or the U.S. National Academies of Science, Engineering, and Medicine) off the table. Alternative feedstocks, such as dedicated bioenergy crops, face higher social barriers and uncertainties.[27] Policy guardrails can ensure that BECCS and other CDR pathways may take advantage of these feedstocks while maintaining additionality and preventing detrimental effects on ecosystems or other land uses.

The definition of CDR should include ocean-based pathways as an essential complement to reducing CO_2 levels in the atmosphere. Altering the definition of CDR to include capture from both the "atmosphere and oceans," as proposed in the Information Note, could help clarify the eligibility of various marine CDR pathways.[D] Such pathways can capture and sequester CO_2 at gigaton scale, given the oceans' size, carbon sequestration capacity, and lack of land use complications. Oceans already absorb about 25 percent of net anthropogenic CO_2 emissions, primarily stored temporarily in the upper layers. Without corresponding enhanced marine CDR, reducing atmospheric CO_2 levels will cause oceans to release some of this absorbed CO_2 back into the atmosphere. Both biological and non-biological marine pathways can capture and store CO2 in ways that provide co-benefits, such as reduced anthropogenic ocean acidification, improved fishery yields, and feedstock production for food and durable products. [28]

Measurement and monitoring protocols for marine CDR and mineralization have already been demonstrated at small scales, so these technologies should continue to be considered in policy. Mineralization presents another promising pathway for near-permanent CDR, given that about one gigaton of CO_2 is already stored annually via natural carbon mineralization; technologically enhanced mineralization (at the surface or underground) could accelerate these removals five to tenfold.[29]

The Information Note's discussion of "Methodological issues related to engineering-based removal activities" suggests that no known monitoring methods exist for enhanced rock weathering and ocean-related CDR activities. While monitoring, reporting, and verification (MRV) technologies are not yet well-developed, there is existing proof of concept research and policy proposals for both technology areas that could be used as the foundation for MRV.[30,31] As with other pathways discussed above, these solutions need not be taken off the table for global policy—and action that could stunt innovation and investment.

Bibliography of EFI Foundation Reports on Large-Scale Carbon Management

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

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

"Building to Net-Zero: A U.S. Policy Blueprint for Gigaton-Scale CO_2 Transport and Storage Infrastructure." Labor Energy Partnership, September 2021. https://energyfuturesinitiative.org/reports/building-to-net-zero/.

"Carbon Removal: Comparing Historical Federal Research Investments with the National Academies' Recommended Future Funding Levels." Bipartisan Policy Center and Energy Futures Initiative, April 2019. https://energyfuturesinitiative.org/reports/carbon-removal/.

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

[D] The EFI Foundation already uses such a definition in CDR reports.

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

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

"From the Ground Up: Cutting-Edge Approaches for Land-Based Carbon Dioxide Removal." Frontiers of CDR. Energy Futures Initiative, December 2020. https://energyfuturesinitiative.org/reports/from-the-ground-up/.

"Ohio River Valley Hydrogen and CCS Hub Market Formation." From Kilograms to Gigatons: Pathways for Hydrogen Market Formation in the United States. Energy Futures Initiative, September 2021. https://energyfuturesinitiative.org/reports/ohio-river-valley-hydrogen-and-ccs-hub-market-formation/.

"Rock Solid: Harnessing Mineralization for Large-Scale Carbon Management." Frontiers of CDR. Energy Futures Initiative, December 2020. https://energyfuturesinitiative.org/reports/rock-solid/.

"Surveying the BECCS Landscape." Bioenergy with Carbon Capture and Storage: Sowing the Seeds of a Negative-Carbon Future. Energy Futures Initiative, January 2022. https://energyfuturesinitiative.org/reports/surveying-the-beccs-landscape/.

"Taking Root: A Policy Blueprint for Responsible BECCS Development in the United States." Bioenergy with Carbon Capture and Storage: Sowing the Seeds of a Negative-Carbon Future. EFI Foundation, [Unpublished].

"Turning CCS Projects in Heavy Industry and Power into Blue Chip Financial Investments." Energy Futures Finance Forum. EFI Foundation, February 2023. https://energyfuturesinitiative.org/reports/turning-ccs-projects-in-heavy-industry-into-blue-chip-financial-investments/.

"Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments." Frontiers of CDR. Energy Futures Initiative, December 2020. https://energyfuturesinitiative.org/reports/uncharted-waters/.

References

[1] "Climate Change 2022: Mitigation of Climate Change," Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2022, https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf. P. 114.
[2] "Mitigation of Climate Change (WGIII)." P. 1261.
[3] Information note, p. 18.
[4] "Direct Air Capture – Analysis," IEA, accessed May 25, 2023, https://www.iea.org/reports/direct-air-capture.
[5] S. M. Smith et al., "The State of Carbon Dioxide Removal – 1st Edition," 2023, https://static1.squarespace.com/static/633458017a1ae214f3772c76/t/63e3d4d4f8731c5a13e5aaa4/1675875543418/SoCDR-Exec-Summary-1st+edition.pdf.
[6] "Turning CCS Projects in Heavy Industry and Power into Blue Chip Financial Investments," Energy Futures Finance Forum (EFI Foundation, February 2023), https://energyfuturesinitiative.org/reports/turning-ccs-projects-in-heavy-industry-into-blue-chip-financial-investments/. P. 23-24.
[7] Information note, p. 18-19.
[8] "Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies" (Energy Futures Initiative, September 2019), https://energyfuturesinitiative.org/reports/clearing-the-air/. P. 129-130.
[9] "Surveying the BECCS Landscape," Bioenergy with Carbon Capture and Storage: Sowing the Seeds of a Negative-Carbon Future (Energy Futures Initiative, January 2022), https://energyfuturesinitiative.org/reports/surveying-the-beccs-landscape/. P. 1-2.

[10] "Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments," Frontiers of CDR (Energy Futures Initiative, December 2020), https://energyfuturesinitiative.org/reports/uncharted-waters/. P. 29.
[11] "Building to Net-Zero: A U.S. Policy Blueprint for Gigaton-Scale CO2 Transport and Storage Infrastructure" (Labor Energy Partnership, September 2021), https://energyfuturesinitiative.org/reports/building-to-net-zero/. P. 60-64.
[12] "Mitigation of Climate Change (WGIII)." P. 36.
[13] *Remarks on CO2-Secure: A National Program to Deploy Carbon Removal at Gigaton Scale*, 2022, https://www.youtube.com/watch?v=Wd6FzzuJBnw.
[14] "CO2-Secure: A National Program to Deploy Carbon Removal at Gigaton Scale" (Energy Futures Initiative, December 2022), https://energyfuturesinitiative.org/reports/co2-secure-a-national-program-to-deploy-carbon-removal-at-gigaton-scale/. P. 25.
[15] David M. Cooley et al., "Managing Dependencies in Forest Offset Projects: Toward a More Complete Evaluation of Reversal Risk," *Mitigation and Adaptation Strategies for Global Change* 17, no. 1 (January 2012): 17–24, https://doi.org/10.1007/s11027-011-9306-x.
[16] "CO2-Secure." p. 25
[17] Juan Alcalde et al., "Estimating Geological CO2 Storage Security to Deliver on Climate Mitigation," *Nature Communications* 9, no. 1 (June 12, 2018): 2201, https://doi.org/10.1038/s41467-018-04423-1.
[18] Alcalde et al.
[19] "CO2-Secure." P. 26
[20] Johannes Tiefenthaler et al., "Technological Demonstration and Life Cycle Assessment of a Negative Emission Value Chain in the Swiss Concrete Sector," *Frontiers in Climate* 3 (2021), https://www.frontiersin.org/articles/10.3389/fclim.2021.729259.
[21] "Mitigation of Climate Change (WGIII)." P. 114.
[22] "Taking Root: A Policy Blueprint for Responsible BECCS Development in the United States," Bioenergy with Carbon Capture and Storage: Sowing the Seeds of a Negative-Carbon Future (EFI Foundation, [Unpublished]).
[23] Information note, p. 10-12.
[24] "Surveying the BECCS Landscape." P. 60-62.
[25] "Surveying the BECCS Landscape." P. 15, 27-28, 60-62.
[26] "Surveying the BECCS Landscape." P. 78-79.
[27] "Mitigation of Climate Change (WGIII)." P. 643, 646.
[28] "Uncharted Waters," p. 6.
[29] "Rock Solid," p. 6.
[30] "Rock Solid," p. 33.
[31] "Uncharted Water," p. 30.