Zero, Then Negative

The Congressional Blueprint for Scaling Carbon Removal

MAY 2021

Carbon180

ABOUT CARBON180

Carbon180 is a new breed of climate-focused NGO on a mission to fundamentally rethink carbon.

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Section One

Executive Summary

Executive Summary

The carbon removal field has undergone incredible transformation in the last five years. What began as a highly niche and neglected set of climate solutions has since become a core component of climate action, with growing recognition from an ever-broader coalition of one simple fact: We simply cannot meet our global climate goals without carbon removal. To solve the climate crisis, we must push past zero and get to negative. Building upon recent progress, Congress has a singular opportunity to catalyze the next wave of transformation for carbon removal.

Despite its promise and urgency, carbon removal solutions lag significantly behind other vital approaches such as electric vehicles and renewable energy. The rapid pace of change over the last few years has opened a rare window to double down on our momentum and, with targeted and ambitious investments from the federal government today, far outpace that growth in the coming decades. To do this, we must come together around transformational policies that can address current barriers to full-scale carbon removal.

Current barriers to full-scale carbon removal

1. High costs for nascent carbon removal technologies, compounded by insufficient research, development, and demonstration (RD&D) funding
2. Low demand for removal, associated products, and co-benefits, keeping private sector capital sidelined
3. Inadequate regulations ensuring the safe, sustainable, and equitable deployment of carbon removal projects
4. Insufficient infrastructure to transport and store CO_2 and deploy nature-based restoration solutions
5. Unclear guidelines on carbon monitoring, reporting, and verification for land-based approaches

This report outlines the key actions Congress should take over the next one to three years to rapidly develop and deploy carbon removal. The recommendations in this report focus on how we can realize carbon removal's full potential as a critical climate solution and also deliver on its environmental, economic, and social co-benefits. With the tools at its disposal — RD&D, deployment incentives, infrastructure, and regulations — the federal government is poised to reinvent the US economy, drive forward a new industry, and put our climate and communities first.

LAND-BASED APPROACHES

Land-based carbon removal approaches, many of which are relatively inexpensive and already being deployed, can provide myriad environmental and economic co-benefits. With an integrated approach to assessing and deploying these solutions, Congress can build a durable carbon removal economy that advances environmental justice (EJ), optimizes carbon removal deployment, and supports safe and dignified job creation.

1. Increase and expand RD&D at the Department of Agriculture (USDA) to scale soil carbon storage across US agricultural systems
2. Adjust the federal crop insurance program to encourage the adoption of conservation practices
3. Expand financial and technical assistance to drive adoption of soil carbon practices
4. Pilot a federal land link program at USDA to promote soil carbon storage and support socially disadvantaged producers
5. Expand public forests by improving US Forest Service (USFS) programs
6. Establish dedicated funding at the Department of the Interior (DOI) and USDA to protect and restore existing public forests
7. Establish dedicated funding streams to conserve and restore private forest lands
8. Establish a Civilian Climate Corps to address climate change and provide employment opportunities for US communities
9. Expand the Agricultural Conservation Easement Program-Wetlands Reserve Easements (ACEP-WRE) and Conservation Reserve Program (CRP) to bolster wetland conservation
10. Expand the Forest Inventory and Analysis (FIA) program to improve centralized forest carbon data activities
11. Invest in innovation grants and life cycle assessments (LCAs) to advance durable emerging wood technologies
12. Invest in social science research to identify and reduce barriers to participating in USDA assistance programs
13. Expand research and governance for marine-based carbon removal through federal program creation and international cooperation

TECH-BASED APPROACHES

Technologies that pull carbon out of the atmosphere have the potential to remove gigatons of CO_2, create hundreds of thousands of jobs, and contribute significantly to economic growth. Through the passage of forward-thinking and comprehensive legislation, Congress has the capacity to propel these solutions to realize climate goals and lead the creation of a vibrant market.

1. Utilize federal procurement to drive the deployment of direct air capture (DAC), bioenergy with carbon capture and storage (BECCS), and carbontech
2. Develop comprehensive demonstration and deployment strategies within the Department of Energy (DOE) to complement research and development (R&D) efforts
3. Establish a federal DAC siting research initiative to support equitable and safe deployment
4. Create a DAC market, policy, and people innovation prize
5. Enhance and expand the 45Q tax credit for DAC
6. Create an investment tax credit for DAC
7. Invest in DAC-to-fuel pathways
8. Pre-permit geologic storage on federal land
9. Update the Class VI underground injection well permitting process to enable more rapid development of geologic carbon storage
10. Create a pipeline development task force to site pipelines connecting CO_2 sources to storage facilities
11. Create an RD&D program for enhanced CO_2 mineralization

CROSS-SOLUTION APPROACHES

Carbon removal solutions have traditionally been developed and deployed in silos, but with a host of opportunities and challenges across the industry, it is crucial to develop policy that utilizes expertise across federal agencies.

1. Expand and pass the CREATE Act to ensure a comprehensive, cross-agency carbon removal strategy
2. Codify the Interagency Working Group on Environmental Justice (EJ IWG) and strengthen requirements for the integration of EJ across federal agencies
3. Create an interdisciplinary roadmap for BECCS deployment options
4. Include biomass-based carbon removal products in the Value-Added Producer Grant program

Section Two

Introduction

Introduction

The carbon removal field has undergone incredible transformation in the last five years. What began as a highly niche and neglected set of climate solutions has since become a core component of climate action, with growing recognition from an ever-broader coalition of one simple fact: We simply cannot meet our global climate goals without carbon removal. To solve the climate crisis, we must push past zero and get to negative. Building upon recent progress, Congress has a singular opportunity to catalyze the next wave of transformation for carbon removal.

With 2020's omnibus bill, Congress passed the most substantial climate bill in a decade and delivered historic wins for carbon removal — including the first-ever federal program dedicated to carbon removal research and development, extended tax credits for new projects, and hundreds of millions of dollars in federal appropriations. The first four months of the 117th Congress have produced a string of bipartisan and bicameral bills, such as the SCALE and REPLANT Acts, which promise to accelerate the deployment of land- and tech-based solutions, and the Biden administration has spotlighted carbon removal in its plans to jumpstart climate action.

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For communities across the country, the steps taken on the Hill translate to far more than tons of CO_2 pulled out of the atmosphere. The carbon sequestered by agricultural operations represents a previously untapped source of revenue and productivity, while the growth of new carbon-negative industries means a surge in high-quality jobs for workers and stronger, more competitive local economies. In the business world, capturing and storing CO_2 has become an area of immense interest to high-profile entrepreneurs and the linchpin of corporate strategies to eliminate emissions from operations and supply chains. The recent net-zero and net-negative commitments from Stripe, Shopify, Microsoft, and others underscore an ambition made possible by combining strong policy with solutions that can directly remove CO_2 from the air.

Carbon removal brings a fresh perspective to climate change, and this focus on economic opportunity and community resilience has given it a uniquely bipartisan and cross-sector appeal. In a short period of time, the promise of a carbon-removing future has brought together unlikely collaborators from across party lines and industries, coalitions that will be strategic to the success of long-term climate action.

Despite its promise and urgency, carbon removal solutions lag significantly behind other vital approaches such as electric vehicles and renewable energy. The rapid pace

of change over the last few years has opened a rare window to double down on our momentum and, with targeted and ambitious investments from the federal government today, far outpace that growth in the coming decades. To do this, we must come together around transformational policies that can address current barriers to full-scale carbon removal.

Current barriers to full-scale carbon removal

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This report outlines the key actions Congress should take over the next one to three years to rapidly develop and deploy carbon removal. The recommendations in this report focus on how we can realize carbon removal's full potential as a critical climate solution and also deliver on its environmental, economic, and social co-benefits. With the tools at its disposal — RD&D, deployment incentives, infrastructure, and regulations — the federal government is poised to reinvent the US economy, drive forward a new industry, and put our climate and communities first.

Section Three

Recommendations

INTO THE WOODS

Land-Based Approaches

Land-based carbon removal pathways harness the power of plants and nature — such as forests, wetlands, agricultural fields, and grasslands — to mitigate climate change. Forests are natural carbon removal machines and present the largest opportunity to remove and store carbon dioxide. Agricultural systems also have significant and largely untapped carbon removal potential — farmers and ranchers can implement several land management practices, such as cover crops and conservation tillage, to help increase soil carbon storage. Land-based carbon removal approaches can provide myriad environmental and economic co-benefits — including improved water quality, increased biodiversity, and better crop yields — all of which can help agriculture producers, forest landowners, and their local economies.

Many land-based carbon removal solutions are relatively inexpensive and being deployed today. There is a growing number of private and public sector initiatives that support wide-scale deployment of land-based carbon removal. However, novel policies that 1) improve monitoring, reporting, and verification of carbon in land-based systems, 2) provide equitable financial and technical assistance to land managers and communities, 3) and consider the impacts of climate change on ecosystems are necessary to sustainably scale up carbon removal solutions. The federal government must play a pivotal role in addressing these barriers to help accelerate the adoption of carbon-minded practices and provide long-term revenue streams for rural and urban communities.

An integrated approach to assessing and deploying land-based carbon removal solutions is incredibly important — there are significant environmental, economic, and social implications to consider. This section will include recommendations that strive to buoy carbon removal programs with other co-benefits such as public health, job creation, and ecological integrity. Underlying these efforts is a focus on equity and justice and a concerted effort to redress harms that have excluded economically and socially disadvantaged landowners, producers, and communities from carbon removal solutions and their many benefits.

Congress can build a prosperous and durable carbon removal economy that advances environmental justice (EJ), optimizes carbon removal deployment, and supports safe and dignified job creation. Innovative incentives, increased federal research and development (R&D), and improved assistance programs driven by American leadership and ingenuity are essential to address the climate crisis.

1. Increase and expand RD&D at the Department of Agriculture (USDA) to scale soil carbon storage across US agricultural systems

BY GIANA AMADOR & VANESSA SUAREZ

While many practices that promote soil carbon storage, such as reduced tillage and cover cropping, are already deployed across farms in the US, research is still needed to better assess the effectiveness of the suite of carbon removal agricultural practices across geographies, climates, and operation types. In addition, as farmers, private companies, and governments look to monetize carbon storage, there is a need to improve techniques to monitor and verify carbon storage, better understand the economic and social benefits and barriers to adopting these practices, and develop the next generation of agriculture solutions.

There are several offices within USDA that lead scientific and economic research on agricultural soil carbon storage, including the Economic Research Service (ERS), Agricultural Research Service (ARS), and National Institute of Food and Agriculture (NIFA). Outside USDA, several departments also have related research, including the National Science Foundation (NSF), Department of Energy (DOE), and Department of the Interior (DOI). However, these efforts have historically been siloed, underfunded, and too heavily focused on specific subsets of the US agriculture industry.

Moving forward, additional policy action is needed to:

- Centralize and coordinate existing work
- Expand foundational research around soil carbon sequestration
- Find new technology breakthroughs
- Understand the economic and social science research that can help inform adoption of soil carbon storage practices across different geographies and contexts and aid in developing better policy design

1.A *Recommendation:* Increase, expand, and centralize RD&D on soil carbon across federal agencies

Direct USDA to create an interagency research program focused on soil

carbon, led by USDA in collaboration with DOE, DOI, the National Aeronautics and Space Administration (NASA), and NSF. This program should be funded at $1 billion in total over five years, gradually ramping up as capacity improves. This funding should go toward foundational research around soil carbon science, technologically enhanced crop varieties and soil amendments, improving data networks and integration, developing new tools, methodologies, and protocols for soil carbon monitoring, reporting, and verification (MRV), and economic and social science research.

Leadership and coordination will be a critical component of the success of this research, especially to ensure that findings are rapidly shared and transferred to the real world. USDA should explicitly include soil carbon storage within its Departmental Strategic Plan and prioritize soil carbon in appropriate existing programs across the department. The under secretary for Research, Education, and Economics (REE) should serve as the lead coordinator for all of these research activities to reduce redundancies, evaluate effectiveness, and collaborate across other agencies. USDA should prepare progress reports for Congress at one-, three-, and five-year increments.

RELATED RESOURCES

- Leading with Soil, Carbon180
- Soil Carbon Storage Fact Sheet, Carbon180

2. Adjust the federal crop insurance program to encourage the adoption of conservation practices

BY GIANA AMADOR & VANESSA SUAREZ

Over 290 million acres are covered under the USDA's Federal Crop Insurance Corporation (FCIC), including more than 80% of the acres planted with major US field crops.[1] Crop insurance is an important pillar of the agricultural system, and it inevitably plays an influential role in the types of crops and practices farmers adopt. The premiums are supported partially by farmers but largely by the government.

Today, there are a few main issues with the federal crop insurance program. First, this program currently disincentives the use of conservation practices that may store carbon in soils. In addition, there has been a lack of consistency between the practices pre-approved as "good farming practices" under the FCIC and those endorsed by the Natural Resources Conservation Service (NRCS).[2]

Second, these same practices that store carbon in agricultural soils have

1. Economic Research Service. (2020). *Government Programs & Risk: Major Risk Management Programs.* US Department of Agriculture. https://www.ers.usda.gov/topics/farm-practices-management/risk-management/government-programs-risk/#:~:text=More%20than%20290%20million%20acres,planted%20in%20the%20United%20States
2. Amador, G., Burns, E., Kosar, U., Suarez, V., & Zelikova, J. (2020). *Leading with Soil.* Carbon180. https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/5eaa30d12c3a767e64c3845b/1588211922979/LeadingWithSoil_Final+Text.pdf

also demonstrated the ability to increase resilience and reduce indemnification in the face of worsening climate change. A recent paper found that relatively small increases not only reduced average liabilities under severe drought by 36%, but also increased on-farm yield under these conditions.[3] The current crop insurance structure doesn't take these resilience and financial benefits into account.

Investing in farmer resilience and reducing crop insurance indemnities (which are currently on the rise) will be critical as the frequency of drought, floods, and extreme weather impact the agriculture economy.[4] If improved, the FCIC can be an important lever for promoting soil carbon storage on farms and ranches across the US.

2.A

Recommendation: Adjust the federal crop insurance program to account for increasing climate impacts and encourage the adoption of conservation practices

Congress should direct USDA to revamp the FCIC, aiming to provide a level playing field for conservation practices and to fully incorporate the resilience benefits of these practices.

Specifically, premium rates for farms that undertake particular risk-reducing and soil carbon-bolstering conservation practices should be lowered. Congress can ask subprograms within USDA to share with the Risk Management Agency (RMA) county-level data on conservation practices and their associated resilience benefits. RMA should then conduct a review of this research to determine which practices have the greatest ability to reduce indemnification and in which geographies, incorporating this data into their actuarial tables. RMA should also be directed to disseminate these results to private FCIC insurers to facilitate reduced premiums for farms that adopt these practices. This adjustment would serve the dual benefit of reducing indemnification costs on agricultural yields and American taxpayers, while also sequestering carbon dioxide and mitigating climate change.

In addition, all NRCS-approved conservation practices should be established as "good farming practices" under the FCIC. Finally, Congress could also explore developing a "carbon crops" incentive within the program, similar to the one used for organic practice coverage.[5]

SIMILAR POLICIES

Iowa crop insurance pilot program for planting cover crops

The Iowa Department of Agriculture and Land Stewardship (IDALS) launched a pilot program to reduce crop insurance premiums for farmers who plant cover crops in their systems.

3. Anusewicz, J. (2021, March 22). The Dirt on Crop Insurance. *Yale School of the Environment.* https://environment.yale.edu/news/article/the-dirt-on-crop-insurance-/
4. Smith, P., Adams, J., Beerling, D.J., et al. (2019). Land-Management Options for Greenhouse Gas Removal and Their Impacts on Ecosystem Services and the Sustainable Development Goals. *Annual Review of Environment and Resources,* (44), 255-286. https://doi.org/10.1146/annurev-environ-101718-033129
5. Risk Management Agency. (2019). *Organic Farming Practices* [Fact sheet]. US Department of Agriculture. https://www.rma.usda.gov/Fact-Sheets/National-Fact-Sheets/Organic-Farming-Practices

RELATED RESOURCES

- Leading with Soil, Carbon180
- Transition Book: Priorities for Administrative Action on Carbon Removal in 2021+, Carbon180
- Farm Bill Primer: Federal Crop Insurance, Congressional Research Service
- Iowa Crop Insurance Discount for Cover Crops, Iowa Farm Bureau

3. Expand financial and technical assistance to drive adoption of soil carbon practices

BY GIANA AMADOR

Despite growing interest in soil carbon storage in many states, insufficient technical and financial assistance, among other barriers, significantly hinders the implementation of these agricultural practices. As a result, current adoption continues to fall short of a scale relevant for addressing climate change. The federal government already has several conservation programs that support agricultural producers in maintaining carbon-rich, healthy soils. These programs are significantly oversubscribed, especially as interest in soil carbon and soil health grows. The federal government should increase funding for these programs to allow more farmers and ranchers to receive financial support to adopt new conservation practices that bolster soil health. Landowners and

Despite significant interest, three core barriers continue to impede the scale of soil carbon storage:

EDUCATION

Technical assistance and education resources are critical for farmers and ranchers to implement new practices and capitalize on the value of soil health.

SCIENCE

Practices need to be linked with soil health and soil carbon outcomes in an accessible and reproducible way.

INCENTIVES

New financial incentives and tweaks to existing incentives can reduce barriers to adoption and encourage durable carbon storage.

extension agents are already familiar with NRCS programs, and the programmatic infrastructure for their expansion already exists. A significant increase in funding for carbon removal practices in these programs could meaningfully stimulate the economy and increase agricultural productivity.

3.A

Recommendation: Bolster the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP)

Increase funding for EQIP by $975 million per year for the next five years. Congress should also consider establishing a special initiative under EQIP for carbon sequestration, similar to the existing Organic Initiative. It could also expand advance payments for costs associated with planning, design, materials, equipment, installation, labor, management, maintenance, or training typically reserved for disadvantaged or new farmers.

Increase funding for CSP by $480 million per year for the next five years. To create continuity between programs, reduce administrative burdens for producers, and support the maintenance of carbon storage on working lands, Congress could authorize an "automatic graduation" option that allows EQIP producers to automatically become eligible for CSP.

To provide support for the duration of time required to yield full benefits for producers, EQIP and CSP should provide cost-share contracts on longer timelines, for a minimum of three years (but potentially longer in dryland ecosystems or with forestry approaches). In addition, USDA should give priority to applications:

1. with an explicit focus on carbon storage or the inclusion of practices with higher carbon storage potential (including agroforestry and forestry practices), and
2. from historically underrepresented groups in the agriculture and forestry industries, including first-time farmers, farmers of color, Indigenous land managers, tribes, and young farmers.

3.B

Recommendation: Expand the Conservation Innovation Grant (CIG) soil health demonstration trials

Congress should increase funding to expand the CIG soil health demonstration trials by $100 million per year to establish a minimum of

80 soil health demonstration trials. These trials should cover the full geographic and operational diversity of US agriculture.

These demonstration trials should aim to fill knowledge gaps around certain underexplored practices (especially grazing and soil amendments). New analysis is likely needed to assess existing demonstration projects — including those done by the Long-Term Agroecosystem Research (LTAR) Network and the soil health demonstration trials funded in the 2018 Farm Bill — and identify high-priority gaps. The USDA Climate Hubs may be well positioned to carry out this analysis and make recommendations for where to focus new funding. These trials should also be done in partnership with the USDA's Economic Research Service (ERS) and focus on answering key economic questions about the cost of implementation, financial outcomes, potential yield increases, and on-farm and on-ranch soil health benefits from implementation.

RELATED RESOURCES

- Leading with Soil, Carbon180
- Rooted in Resilience, Carbon180

4. Pilot a federal land link program at USDA to promote soil carbon storage and support socially disadvantaged producers

BY VANESSA SUAREZ

Land link services began in the early 1990s as a way to connect landowners who did not have successors to land seekers, with the aim of extending the reach and networks of owners and seekers, and facilitating introductions between them.[6] The need for land link services continues to grow due to various reasons, including the rising cost of entry to farming as a profession, the declining number of young people getting into farming, the growing consolidation of small and medium farms into larger ones, and land use changes.[7]

In addition to addressing the above issues, land link programs have the potential to provide targeted farming, ranching, and land ownership opportunities and support for beginning and socially disadvantaged agricultural producers, including Black, Indigenous, and People of Color (BIPOC), low-income, and immigrant producers.[8, 9, 10] By doing so, land link programs can address the unequal participation and access to agriculture and agricultural support, as well as redress previous inequities, such as the monumental land loss experienced by Black

6. Valliant, J., Ruhf, K., Gibson, K., Brooks, J. R., & Farmer, J. (2019). Fostering farm transfers from farm owners to unrelated, new farmers: A qualitative assessment of farm link services. *Land Use Policy, 86*, 438-447. https://doi.org/10.1016/j.landusepol.2019.05.004

7. Valliant, J., Ruhf, K., Gibson, K., Brooks, J. R., & Farmer, J. (2019). Fostering farm transfers from farm owners to unrelated, new farmers: A qualitative assessment of farm link services. *Land Use Policy, 86*, 438-447. https://doi.org/10.1016/j.landusepol.2019.05.004

8. Valliant, J., Ruhf, K., Gibson, K., Brooks, J. R., & Farmer. (2019). Fostering farm transfers from farm owners to unrelated, new farmers: A qualitative assessment of farm link services. *Land Use Policy, 86*, 438-447. https://doi.org/10.1016/j.landusepol.2019.05.004

9. National Young Farmers Coalition. (2020). *USDA Programs*. https://www.youngfarmers.org/usda-programs/

10. Tan, R. (2020, January 20). New to the country, veterans of the land. *The Washington Post*. https://www.washingtonpost.com/local/maryland-news/new-to-the-country-veterans-of-the-land/2020/01/21/ee61c13e-3250-11ea-91fd-82d4e04a3fac_story.html

producers across the US over the past century.[11] Land link programs could also support maintenance of soil carbon storage in farms and agricultural systems by helping landowners pass their land to land seekers planning to implement and manage similar conservation practices, as well as assist new producers who want to shift the operations of an existing farm.[12]

Currently, there exists no comprehensive federal land link program within USDA. Most land link programs operate at the state or local level, and are run by community-based organizations, nonprofits, state agencies, and similar entities.[13, 14] These programs often suffer from having more participation from land seekers than current land owners and operators, and they generally are not comprehensive in providing vital technical and financial support systems for producers, nor is there standardization in "best practices" across programs.[15, 16] Establishing a comprehensive program at the national level could provide listings of land sellers and land seekers across the land, facilitate successful land transitions, and provide technical and financial support and capacity-building for socially disadvantaged and beginning producers.

4.A

Recommendation: Establish a pilot federal land link program

USDA should establish a pilot federal land link program to be administered by the Farm Service Agency (FSA) that targets the transfer of both farm and ranch land. The program's purpose should be to connect retiring producers who have implemented conservation practices (including soil carbon storage practices) on their land and non-operator landowners who are looking to sell their land with land seekers who desire to continue implementing and maintaining conservation practices. The program should also support new producers seeking to shift the operations of an existing agricultural operation to be more sustainable. The program should include listing, linking, and matching between producers and land seekers, and it should offer facilitation, technical support, document preparation, educational opportunities, and transaction, financing, and loan navigation assistance to both parties.[17] The program should also coordinate closely with state and local USDA offices, including FSA offices, to ensure comprehensive implementation and support of these services, and to foster regional producer networks. Coordination with local USDA offices should also seek to provide technical, educational, and cooperative assistance opportunities relating to conservation practice implementation for the new landowners. The pilot program should target the Midwest, Central Plains, West Coast, and Southeast regions.

The land link program should target and prioritize BIPOC, immigrant, beginning, and young producers and other historically socially

11. Castro, A., & Willingham, Z. (2019). *Progressive Governance Can Turn the Tide for Black Farmers.* Center for American Progress. https://www.americanprogress.org/issues/economy/reports/2019/04/03/467892/progressive-governance-can-turn-tide-black-farmers/

12. Mulligan, J., Ellison, G., Gasper, R., & Rudee, A. (2018). *Carbon removal in forests and farms in the United States.* World Resources Institute. https://files.wri.org/s3fs-public/carbon-removal-forests-farms-united-states_0.pdf

13. Beginning Farmers. (2017). *Finding land to farm.* https://www.beginningfarmers.org/finding-land-to-farm/

14. National Young Farmers Coalition. (2019). *Land Link Directory.* https://www.youngfarmers.org/wp-content/uploads/2019/10/Land-Link-Directory-2019.pdf

15. Valliant, J., Ruhf, K., Gibson, K., Brooks, J. R., & Farmer, J. (2019). Fostering farm transfers from farm owners to unrelated, new farmers: A qualitative assessment of farm link services. *Land Use Policy, 86,* 438-447. https://doi.org/10.1016/j.landusepol.2019.05.004

16. Ruhf, K. (2019). *Developing and strengthening farm link programs.* Land for Good. https://landforgood.org/wp-content/uploads/LFG-Farm-Link-Guide-Developing-and-Strengthening-Farm-Link-Programs.pdf

17. Valliant, J., Ruhf, K., Gibson, K., Brooks, J. R., & Farmer, J. (2019). Fostering farm transfers from farm owners to unrelated, new farmers: A qualitative assessment of farm link services. *Land Use Policy, 86,* 438-447. https://doi.org/10.1016/j.landusepol.2019.05.004

disadvantaged groups. Similarly, land link prioritization should be given to lands located within BIPOC and low-income communities, where regenerative agriculture and conservation practices could have demonstrable community and environmental health benefits. The FSA should utilize existing assistance mechanisms, including customer service and farm loans, as well as provide educational opportunities to best support socially disadvantaged producers in the land link process, including preferential enrollment and loan rates.

The transfer of working land often takes several years, so impact can best be assessed if the program is reviewed about five years after it is established. Medium-term metrics should be monitored to evaluate the program's efficacy in connecting landowners and seekers and capacity building for socially disadvantaged and beginning producers. After evaluation, the FSA should release recommendations on scaling and improving the program.

RELATED RESOURCES

- Developing and Strengthening Farm Link Programs, Land for Good
- Farmers Seeking Land, USDA

5. Expand public forests by improving US Forest Service (USFS) programs

BY UGBAAD KOSAR & VANESSA SUAREZ

Forests play an important role in addressing climate change as massive carbon sinks that naturally sequester carbon dioxide. The expansion of forests can increase these carbon stocks; reforestation efforts have been identified as the single largest land-based pathway to increasing carbon removal in the US.[18] However, it is incredibly important that expanding public forests does not translate to ad-hoc, mass tree planting, but is instead a science-driven and collaborative effort funded at multiple stages. This includes support for high-quality seed collection and nursery production, strategic planting with safeguards that protect existing carbon-rich and biodiverse lands, and post-planting monitoring.[19] Investment in all stages of holistic tree planting can improve long-term health and productivity of forests.

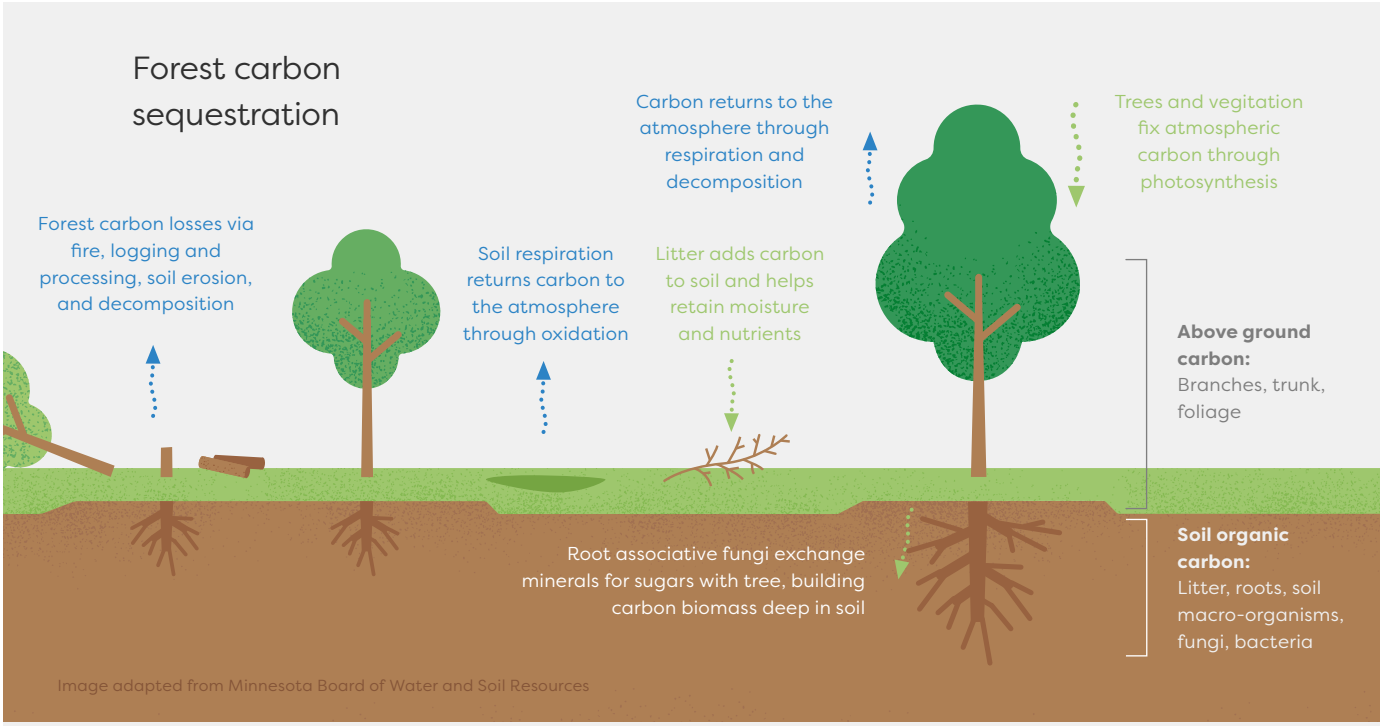
There is growing bipartisan support for large-scale tree-planting initiatives through legislative efforts such as the REPLANT Act.[20] Reforestation on public lands is ready to be deployed today; USFS has a strong grasp on reforestation best practices across geographies. However, financial streams for reforestation on federal lands and technical assistance to support tree planting on community and urban

18. Fargione, J., Bassett, S., Boucher, T., Bridgham, S., Conant, R., Cook-Patton, S., et al. (2018). Natural climate solutions for the United States. *Science Advances. 4*(11), Article eaat1869. https://advances.sciencemag.org/content/4/11/eaat1869

19. Kosar, U., & G. Amador. (2020). *Rooted in Resilience.* Carbon180. https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/5f87b42903dc081162f7caf1/1602729008631/RootedInResilience+WhitePaper+Web.pdf

20. REPLANT Act, S. 866, 117th Congress. (2021). https://www.congress.gov/bill/117th-congress/senate-bill/866/text?r=1&s=1

lands are currently insufficient. Reforestation efforts can be catalyzed by providing grants, expanding existing programs, and establishing a Civilian Climate Corps.



5.A *Recommendation:* Eliminate the cap on the Reforestation Trust Fund

USFS should eliminate the cap on the Reforestation Trust Fund to make more funds available for reforestation efforts. The Reforestation Trust Fund receives funds from tariffs on imported wood products. While removing the cap would not increase tariffs, it would unlock more than $90 million in additional funds.[21]

21. Daley, J. (2020, July 29). *How to Grow More Trees and Jobs in National Forests.* Medium. https://americanforests.medium.com/how-to-grow-more-trees-and-jobs-in-national-forests-97bfa6a4cc33t

5.B *Recommendation:* Establish a reforestation grant matching program

USFS should establish a grant matching program for reforestation projects on federal lands. This program should be made available for states, tribes, and NGOs to implement projects.

5.C *Recommendation:* Increase funding for the Urban and Community Forestry program

USFS should increase funding for the Urban and Community Forestry program, providing an additional $150 million per year over 10 years. The

increases in funding should support the establishment of a matching grant program to plant urban forests, prioritizing underserved communities with low tree canopy coverage, paired with technical assistance provided under the Urban and Community Forestry program's focus areas.[22]

22. US Forest Service. (2020). *Urban and Community Forestry Program.* US Department of Agriculture. https://www.fs.usda.gov/managing-land/urban-forests/ucf

5.C

Recommendation: Establish the Civilian Climate Corps

Read more about this recommendation on page 25.

6. Establish dedicated funding at DOI and USDA to protect and restore existing public forests

BY UGBAAD KOSAR & VANESSA SUAREZ

There are substantial amounts of carbon stored in America's forests, sequestering approximately 12% of US annual emissions.[23] The National Forest System spans 193 million acres, encompassing a quarter of all US forests; another 140 million acres of public forest are community forests in cities and towns.[24, 25] The carbon stored in these systems is at risk of being released back into the atmosphere because of competing land use priorities, frequent natural disasters, and pest and disease outbreaks. In 2020, more than 40% of US forests were at risk from pest and disease invasion, and wildfires released about 200 million tons of CO_2.[26, 27] Climate change is directly linked to worsening wildfires and outbreaks, which increase tree mortality and release more CO_2 into the atmosphere, further perpetuating this cycle. Rapid development along the wildland-urban interface (WUI) increases the likelihood of human-caused wildfires, putting lives and homes at risk.

A significant portion of existing forest carbon stocks can be found in old-growth forests on federal lands.[28] There is also a backlog of forest restoration projects that needs to be addressed to rehabilitate forest ecosystems damaged by natural disasters. Avoided forest conversion, proforestation, and forest restoration are relatively low-cost pathways that are shovel-ready for deployment. These efforts can protect watersheds, help combat invasive species, minimize risk to nearby communities and firefighters, create jobs, and could save millions of dollars over the long term from avoided wildfires and outbreaks.

23. Hoover, K., & Riddle, A. (2020). *US Forest Carbon Data: In Brief.* Congressional Research Service. https://fas.org/sgp/crs/misc/R46313.pdf

24. Hoover, K., & Riddle, A. (2019). *National Forest System Management: Overview, Appropriations, and Issues for Congress.* Congressional Research Service. https://crsreports.congress.gov/product/pdf/R/R43872

25. US Forest Service. (2020). *Urban and Community Forestry Program.* US Department of Agriculture. https://www.fs.usda.gov/managing-land/urban-forests/ucf

26. Fei, S., Morin, R. S., Oswalt, C. M., & Liebhold, A. M. (2019). Biomass losses resulting from insect and disease invasions in US forests. *Proceedings of the National Academy of Sciences. 116*(35), 17371-17376. https://doi.org/10.1073/pnas.1820601116

27. Lombrana, L., & Rathi, A. (2020, September 16). California Fires Are Emitting Record Amounts of Carbon Dioxide. *Bloomberg Green.* https://www.bloomberg.com/news/articles/2020-09-16/california-fires-are-emitting-record-amounts-of-carbon-dioxide

28. Moomaw, W. R., Masino, S. A., & Faison, E. K. (2019). Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good. *Frontiers in Forests and Global Change, 2*(27). https://doi.org/10.3389/ffgc.2019.00027

6 . A

Recommendation: Invest in holistic forest restoration on federal lands that protects existing carbon stocks and increases ecological resilience

- Provide an additional $20 million per year over five years for the Forest Health Management Program on Cooperative Lands to improve and protect the health of federal forests. Technical assistance and outreach from this program should prioritize providing direct assistance to federal forest land managers on biological evaluations, site visits, and training.
- Provide an additional $40 million per year over five years for the Collaborative Forest Landscape Restoration Program (CFLRP). This program leverages local resources that provide jobs and sustain rural economies. Projects that participate in CFLRP should target high-priority activities that fall within the WUI and have demonstrable carbon storage benefits.
- Provide an additional $80 million per year over the next five years for the Vegetation and Watershed Management program to fund forest restoration projects, targeting those with demonstrable carbon sequestration and resilience benefits.
- Expand capacity of nurseries and seed extractories to meet growing reforestation efforts. A new study highlights seed nursery capacity must be more than doubled to reforest over 66 million acres of available land by 2040.[29] Nursery infrastructure can be expanded by removing the cap on the Reforestation Trust Fund or leveraging USDA Rural Development business loan guarantees.

READ MORE

Read more about removing the cap on the Reforestation Trust Fund on page 20.

6 . B

Recommendation: Invest in responsible, science-driven wildfire management and post-fire rehabilitation to reduce wildfire impact and support natural regeneration efforts of federal forests

- Provide an additional $100 million per year over five years for the USDA Hazardous Fuels program and an additional $60 million per year over five years for the DOI Hazardous Fuels Management program.

GLOSSARY

Wildland-urban interface (WUI)
A zone of transition where buildings, homes, and other developments meet or intermingle with undeveloped wildland vegetation.

Proforestation
Growing an existing forest intact to reach its full ecological potential.

29. Fargione, J., et al. (2021). Challenges to the Reforestation Pipeline in the United States. *Frontiers in Forests and Global Change*. https://www.frontiersin.org/articles/10.3389/ffgc.2021.629198/full

Congress should direct USDA and DOI to ensure that any thinning or silvicultural practices aimed at minimizing fuel loads are targeting highest priority regions (such as WUIs) and are applied sustainably, aiming to optimize carbon storage and maintain ecological integrity. USDA and DOI programs should aim to remove small-diameter branches and underbrush, avoiding the removal of mature trees or those found in backcountry regions whenever possible.

- Provide an additional $10 million per year over five years for the USDA Burned Area Emergency Response program. In addition to increased funding, this program should be expanded to incorporate longer-term (a minimum of five years) post-fire rehabilitation activities on federal lands, modeled after the DOI's Burned Area Rehabilitation program.
- The Federal Emergency Management Agency (FEMA) should establish a community wildfire defense grant program to improve community resilience and land-use planning along the WUI. Grants should prioritize state, local, or tribal governments that can support low-income communities in fire-prone areas. USFS should develop and publish a map depicting at-risk communities.

GLOSSARY

Silvicultural practices
Any practices involving the growing or cultivation of trees.

6.C

Recommendation: Strengthen forest conservation efforts to protect existing carbon stocks on public lands

USDA and DOI should establish a national forest carbon reserve that aims to identify, protect, and restore carbon-rich forest ecosystems. This reserve can extend protections for high-priority, primary forests that can both protect existing carbon stores and keep ecological integrity of forest ecosystems intact.

SIMILAR POLICIES

Wildfire Disaster Funding Act of 2017
Ensures that wildfires are funded as natural disasters and protects agencies' fire prevention budgets by putting a freeze on the rising budget costs of the 10-year average.

Wildfire Defense Act of 2020
Would set aside $1 billion each year to pay for better infrastructure, land-use, and evacuation route planning in fire-prone communities.

RELATED RESOURCE

Forest Carbon Reserve, Sierra Club

7. Establish dedicated funding streams to conserve and restore private forest lands

BY UGBAAD KOSAR

Forests cover one-third of US lands, and nearly two-thirds of those forests are privately owned.[30] Most opportunities to protect and restore carbon stocks in US trees are on private lands.[31] However, this opportunity remains largely untapped and underexplored. There is increasing pressure to develop private forestland and inadequate federal assistance options for private forestland owners interested in remaining engaged and financially incentivized to protect and sustainably manage their forestlands.

Improving financial and technical assistance can help retain existing private forestland and incentivize management practices that store carbon. Reforestation and restoration are shovel-ready, low-cost carbon removal solutions that present significant opportunities to remove and store carbon dioxide today.[32] There are also significant social, economic, and environmental co-benefits to conserving and restoring private forestlands for both owners and surrounding communities. Despite this, existing programs are not sufficient to address both the demand and needs of private forest landowners under a changing climate.

30. Alvares, M. (2018). *The State of America's Forests.* US Endowment for Forestry and Communities. https://www.arcgis.com/apps/Cascade/index.wappid=d80a4ffed7e044219bbd973a77bea8e6

31. Mulligan, J., Rudee, A., Lebling, K., Levin, K., Anderson, J., & Christensen, B. (2020, January). *Carbonshot: Federal Policy Options for Carbon Removal in the United States.* World Resources Institute. https://www.wri.org/publication/carbonshot-federal-policy-options-for-carbon-removal-in-the-united-states

32. Mulligan, J., Rudee, A., Lebling, K., Levin, K., Anderson, J., & Christensen, B. (2020, January). *Carbonshot: Federal Policy Options for Carbon Removal in the United States.* World Resources Institute. https://www.wri.org/publication/carbonshot-federal-policy-options-for-carbon-removal-in-the-united-states

7.A *Recommendation:* Establish dedicated funding streams to better address the financial burden on private forest landowners to conserve and restore trees

- Increase EQIP funding streams dedicated to expand forest management practices covering invasive species treatment, agroforestry expansion, tree planting and monitoring, and other practices. NRCS should also cover more upfront costs required to prepare lands for tree restoration activities.
- Increase the enrollment acreage threshold by 15 million acres to expand eligibility for the Conservation Reserve Program (CRP) program. This would allow for the inclusion of forestation practices on historically forested lands that are now classified as unproductive or abandoned farmland.
- Direct Congress to guarantee dedicated funding streams to support the Forest Legacy Program (currently funded by the Land and Water Conservation Fund) and the Healthy Forests Reserve Program (discretionary funding administered by NRCS). Both of these programs

are significantly under-resourced but provide critical financial support to landowners looking to conserve and protect their forestlands.

- Establish a federal subsidy for forest restoration through a practice-based tax credit.

RELATED RESOURCES

- Achieving the Mid-Century Strategy Goals for Deep Decarbonization in Agriculture and Forestry, The Nicholas Institute for Environmental Policy Solutions
- Natural Carbon Solutions in US Farms and Forests: Building a Policy Agenda for Congressional Action, Bipartisan Policy Center

8. Establish a Civilian Climate Corps to address climate change and provide employment opportunities for US communities

BY UGBAAD KOSAR & VANESSA SUAREZ

The Civilian Conservation Corps (CCC) was a voluntary public work relief program established as part of Roosevelt's New Deal programs. The CCC was a cross-agency effort, including the National Park Service (NPS), USDA, USFS, and DOI. Program activities encompassed firefighting, tree planting, and roads construction and maintenance. Over the course of the program, more than 3 billion trees were planted, and trails and shelters were constructed in more than 800 parks.[33]

The COVID-19 pandemic and subsequent economic fallout resulted in similar impacts seen during the Great Depression, including significant food, housing, and unemployment hardships across the US. In April 2020, the unemployment rate jumped to a level not seen since the 1930s — and still stood at 6.7% in December 2020.[34] In addition to these hardships, record wildfires, hurricanes, and other natural disasters exacerbated by climate change have devastated all parts of the US, releasing unprecedented amounts of carbon dioxide into the atmosphere.[35] BIPOC and low-income communities have borne disproportionate burdens of both COVID-19 and climate change.

Building on the recent executive order released by President Biden and previous legislative efforts, the CCC from the New Deal era should be re-established as the Civilian Climate Corps with updated priorities, roles, responsibilities, and project components to promote community resilience, preparedness, and leadership.[36]

33. History. (2019). *Civilian Conservation Corps*. https://www.history.com/topics/great-depression/civilian-conservation-corps
34. Center on Budget and Policy Priorities. (2021, April 22). *Tracking the COVID-19 Recession's Effects on Food, Housing, and Employment Hardships*. https://www.cbpp.org/research/poverty-and-inequality/tracking-the-covid-19-recessions-effects-on-food-housing-and
35. National Centers for Environmental Information. (2021). *Billion-Dollar Weather and Climate Disasters*. National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/billions/
36. The White House (2021, January 27). *President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government* [Fact sheet]. https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/

8.A

Recommendation: Establish the Civilian Climate Corps

USDA and DOI should establish the Civilian Climate Corps as a cross-agency program, with additional program coordination with the Department of Labor, the National Ocean and Atmospheric Administration (NOAA), Environmental Protection Agency (EPA), and other federal agencies relevant to land-based carbon removal solutions.

The Civilian Climate Corps program's priority areas should strive to address climate change by:

- conserving and restoring public lands and watersheds,
- bolstering reforestation and post-planting monitoring efforts,
- increasing wetland restoration efforts,
- improving community resilience,
- increasing soil carbon storage on farms and ranches,
- promoting urban agriculture and urban forestry,
- protecting biodiversity, and
- improving access to recreational opportunities on public lands.

USDA and DOI should ensure recruitment efforts, program design, and implementation to address the needs of BIPOC and low-income communities. In doing so, the program should provide well-paying union jobs that meet strong labor standards. The Corps can also provide robust vocational opportunities in communities, partnering with local community-based organizations, nonprofits, community colleges, and related organizations whenever possible.

RELATED RESOURCES

– Biden's Civilian Climate Corps, Grist

– Grant Program Highlights, Corporation for National and Community Service

9. Expand the Agricultural Conservation Easement Program-Wetlands Reserve Easements (ACEP-WRE) and CRP to bolster wetland conservation

BY MAYA GLICKSMAN & VANESSA SUAREZ

Wetlands can be a powerful climate tool, acting as natural carbon sinks that can store carbon for hundreds to thousands of years. US wetlands alone store nearly 34 billion tons of carbon, primarily in deep soils.[37]

37. Kolka, R., Trettin, C., Tang, W., Krauss, K., Bansal, S., Drexler, J., Wickland, K., Chimner, R., Hogan, D., Pindilli, E. J., Benscoter, B., Tangen, B., Kane, E., Bridgham, S., & Richardson, C. (2018). *Second State of the Carbon Cycle Report: Terrestrial Wetlands).* US Global Change Research Program. Chapter 13, 507-567. https://doi.org/10.7930/SOCCR2.2018.

However, when natural wetlands are converted to other land uses or are subjected to disturbances, they release the stored carbon back into the atmosphere.[38] Protecting and restoring natural wetlands in the US pose a large opportunity to scale up land-based carbon removal.

In addition to enhancing natural carbon removal, wetland conservation can provide myriad co-benefits for coastal communities. Wetlands can mitigate natural hazards (e.g., protection from powerful waves), restore fisheries, enhance biodiversity, bolster community climate resilience, increase community adaptive capabilities to natural disasters (e.g., floods, droughts, and storm runoff), improve local water quality, and provide new job and economic opportunities.[39, 40]

Past policies have focused on net wetland acreage alone, incentivizing creation of new wetlands to "offset" losses elsewhere, rather than conserving and restoring natural wetlands.[41] Based on acreage numbers alone, net wetland loss has slowed dramatically in recent decades. However, these numbers fail to account for losses in carbon stocks, ecological integrity, and ecosystem services when natural wetlands are destroyed. If expanded and improved, the ACEP-WRE and CRP could significantly increase the US land carbon sink by protecting and restoring wetlands.

9.A

Recommendation: Improve and expand ACEP-WRE

In fiscal year (FY) 2019, ACEP-WRE enrolled only 9% of the lands it received applications for, leaving approximately 372,000 acres unfunded.[42] NRCS should increase program funding to $100 million per year over four years to increase enrollment and expand services. Rather than focusing solely on acreage as past policies have, NRCS should provide expanded technical assistance to landowners to create long-term conservation plans that explicitly promote carbon storage and resiliency benefits. The program should prioritize enrollment of lands with high carbon sequestration potential and significant climate resilience benefits for coastal communities.

9.B

Recommendation: Improve and expand CRP

Under the current Farm Bill, the CRP provides funds for wetland protection and restoration, but the majority of the program's funds are spent on upland habitats.[43] The FSA should increase the acreage enrollment cap from 27.5 million to 32 million acres and increase funding for the program overall by an additional $800 million per year. The FSA should prioritize enrollment of lands with high carbon sequestration and climate resilience potential and prioritize planting native species to bolster natural carbon accumulation.

38. Minnesota Board of Water and Soil Resources. (n.d.). *Carbon Sequestration in Wetlands.* http://bwsr.state.mn.us/carbon-sequestration-wetlands#:~:text=All%20wetlands%20sequester%20carbon%20from,instances%2C%20over%20thousands%20of%20years

39. State of Washington Department of Ecology. (n.d.). *Wetlands & climate change.* https://ecology.wa.gov/Water-Shorelines/Wetlands/Tools-resources/Wetlands-climate-change#:~:text=Wetlands%20can%20reduce%20the%20effects,species%20move%20to%20better%20areas

40. US Environmental Protection Agency. (2015). *Connectivity of Streams and Wetlands To Downstream Waters: A Review and Synthesis of the Scientific Evidence (Final Report).* https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=296414

41. Dahl, T. E. (2011). *Status and Trends of Wetlands in the Conterminous United States 2004 to 2009.* US Department of the Interior, US Fish and Wildlife Service. https://www.fws.gov/wetlands/Documents/Status-and-Trends-of-Wetlands-in-the-Conterminous-United-States-2004-to-2009.pdf

42. Stubbs, M. (2020). *Agricultural Conservation: A Guide to Programs.* Congressional Research Service. https://fas.org/sgp/crs/misc/R40763.pdf

43. Sibbing, J. M. (2004). *Nowhere Near No Net Loss.* National Wildlife Federation. https://www.nwf.org/~/media/PDFs/Wildlife/Nowhere_Near_No-Net-Loss.pdf

GLOSSARY

Upland habitats
High, dry, non-wetland habitats.

RELATED RESOURCES

- Wetlands: An Overview of Issues, Congressional Research Service
- Wetlands In a Changing Climate: Science, Policy and Management, Mark Brinson Review

10. Expand the Forest Inventory and Analysis (FIA) program to improve centralized forest carbon data activities

BY MAYA GLICKSMAN & UGBAAD KOSAR

The FIA program, housed within USFS, is the primary data source on the status, conditions, and trends of US forests and forest resources.[44] This data is essential in revising land management plans under the National Forest Management Act (NFMA). Currently, the FIA cannot keep up with demand.

Standard FIA plots are too spread out in many regions to meet analysis needs, and many regional offices must intensify data sampling if resources allow. Current FIA plot remeasurement is also too infrequent — occurring every five years, at most — to document drastic changes that occur from year to year, including disturbances such as wildfires, insect and disease outbreaks, and extreme weather events. The complexity of the database and supporting tools makes it challenging for non-expert users to access data beyond that included in standard reports.

To accurately compare the carbon impacts of different forest management practices and improve land management planning under a changing climate, the FIA must strengthen data collection, analysis, and reporting capacity.

44. US Forest Service. (n.d.). *Forest Inventory and Analysis National Program: FIA Contributions to National and Global Reporting.* US Department of Agriculture, US Forest Service. https://www.fia.fs.fed.us/program-features/NationalGlobal_Reporting/

10 . A *Recommendation:* Expand the FIA plot network

FIA must intensify baseline sampling resolution based on regional needs to provide data that is both complete and useful to local land managers. This expansion is necessary to fill massive gaps in current FIA data.

10 . B *Recommendation:* Accelerate data collection and enhance data quality

FIA should require plot remeasurement every three years to account for and accurately represent short-term disturbances and ecological

changes. FIA should also utilize advanced aboveground and belowground monitoring tools, including lidar, to improve data quality and models while reducing ground sampling costs.

45. Hoover, C., Bush, R., Palmer, M., & Treasure, E. (2020). Using Forest Inventory and Analysis Data to Support National Forest Management: Regional Case Studies. *Journal of Forestry, 118*(3), 313–323. https://doi.org/10.1093/jofore/fvz073

10 . C

Recommendation: Improve accessibility of FIA data

Many land and natural resource managers must partner with data scientists (e.g., USFS R&D scientists) to obtain and use FIA data.[45] FIA should create new comprehensive support tools for navigating databases, creating custom analysis reports, and interpreting data to make this information accessible to those without technical data expertise.

RELATED RESOURCES

- Carbon Removal in Forests and Farms in the United States, World Resources Institute
- Using Forest Inventory and Analysis Data to Support National Forest Management: Regional Case Studies, Journal of Forestry

11. Invest in innovation grants and life cycle assessments (LCAs) to advance durable emerging wood technologies

BY MAYA GLICKSMAN & UGBAAD KOSAR

Conventional building materials (e.g., concrete and steel) are emissions-intensive products. The production of cement, a key ingredient in conventional concrete, accounts for about 8% of total global CO_2 emissions annually.[46] Substituting a portion of these materials with emerging wood technologies, such as cross-laminated timber, can both avoid emissions associated with the production of traditional building materials and also store carbon long term. However, more RD&D is needed to understand the definitive role of innovative wood technology as a climate mitigation tool.

Future incentives for wood products must be tied to robust environmental safeguards and LCAs that require sustainable forest management practices. Investing in RD&D of burgeoning and innovative wood technologies can play an important role in incentivizing landowners to invest in and maintain private forests and create

46. Lehne, J., & Preston, F. (2018, June). *Making Concrete Change: Innovation in Low-Carbon Cement and Concrete.* Chatham House, The Royal Institute of International Affairs. https://www.chathamhouse.org/2018/06/making-concrete-change-innovation-low-carbon-cement-and-concrete

diversified economic opportunities in rural areas. The 2018 Farm Bill established a research, development, education, and technical assistance program, including a competitive Wood Innovation Grant program, to facilitate the use of wood products for building and construction. Although this program is a strong first step, the federal government must continue to expand RD&D efforts to understand the carbon benefits, substitution potential, and life cycle impacts of emerging wood products.

11 . A

Recommendation: Provide an additional $10 million over the next five years for USFS Wood Innovation Grants

Wood Innovation Grants fund projects exploring wood as a construction material in commercial buildings to stimulate and ultimately expand wood markets. Congress should direct USDA to enhance coordination with compatible programs at DOI and DOE to identify opportunities to advance sustainable wood product innovation. USFS should prioritize projects to demonstrate real-world durability of innovative wood products as building materials to address concerns among construction professionals. Projects should also work to identify best maintenance practices to ensure that emerging wood building materials are long-lasting, resilient, and safe.

11 . B

Recommendation: USFS should collaborate with EPA to develop and conduct LCAs of engineered wood products

USFS should draw from the EPA's National Risk Management Research Laboratory (NRMRL) guidelines for LCAs and develop guidelines specific to emerging wood technologies.[47] Many cradle-to-gate LCAs exist for various wood products,[48] but USFS and EPA should prioritize full cradle-to-grave assessments. Cradle-to-grave LCAs should integrate analyses of net greenhouse gas (GHG) balances, required land, and social, economic, and ecosystem costs, as well as how innovative wood products compare with incumbent building materials.[49] LCAs should explore how different forest management practices impact life cycle carbon emissions of wood products and whether or how these products can be reclaimed at the end of life. Careful evaluation of permanence, additionality, and leakage concerns should also be included.

47. Scientific Applications International Corporation. (2006). *Life Cycle Assessment: Principles and Practice.* National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi/P1000L86.PDF?Dockey=P1000L86.PDF

48. Consortium for Research on Renewable Industrial Materials. (2021). *Library of LCAs on Wood Products.* https://corrim.org/lcas-on-wood-products-library/

49. National Academies of Sciences, Engineering, and Medicine. (2019). *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.* Washington, DC: The National Academies Press. https://www.nap.edu/read/25259/chapter/5#126

GLOSSARY

Cross-laminated timber
A type of prefabricated solid wood panel, which consists of several layers of dimension lumber stacked crosswise at right angles.

Cradle-to-gate life cycle assessments (LCAs)
Analyses that incorporate the impacts of any processes between extraction of a resource and production of a finished product.

Cradle-to-grave life cycle assessments (LCAs)
Analyses that extend beyond cradle-to-gate analyses, incorporating the impacts of any processes from extraction of resources to the production, use, and disposal of a finished product.

RELATED RESOURCES

- LCA as an assessment tool, CDR Primer
- Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, National Academies of Sciences, Engineering, and Medicine

12. Invest in social science research to identify and reduce barriers to participating in USDA assistance programs

BY MAYA GLICKSMAN & UGBAAD KOSAR

Incentive and assistance programs are instrumental tools to help scale up soil and forest carbon storage. Increasing program participation is critical to support land managers looking to adopt practices that store carbon. In particular, identifying the unique barriers that underserved forest landowners and agriculture producers face in accessing USDA programs can help address their disproportionately low participation rates.[50] A lack of research about the unique values, interests, and barriers of underserved forest landowners and farmers leaves a critical knowledge gap for making forest and agriculture assistance programs accessible and inclusive.

Robust economic and social science research can provide the baseline information needed to understand the economic, social, and cultural factors that affect land managers' decision-making, paving the way for equitable and accessible policy design.

50. Butler, S. M., Schelhas, J. & Butler, B. J. (2019). Minority Family Forest Owners in the United States. *Journal of Forestry, 118*(1), 70–85. https://doi.org/10.1093/jofore/fvz060

12 . A *Recommendation:* Invest in social science research to increase program enrollment

USFS research stations should receive an additional $3 million per year over five years to administer new research projects regionally. To understand barriers faced by agriculture producers, ERS should receive an additional $5 million per year over five years to address the below research areas, taking into consideration the diversity of agricultural operations across the US.

Research in respective agencies should collect qualitative and quantitative data along with landowner recommendations for improvement in the following focus areas:

- Administrative barriers include paperwork, online interfaces, and general accessibility of the program enrollment process.

- Cost analysis can quantify variation in the cost of implementing carbon-minded management practices that may affect adoption and inform future incentive design. Costs may vary by region, social landscape, and management practice.
- Technical assistance barriers and needs may vary by region, social landscape, and management practices. Studies should examine how landowners perceive the types, effectiveness, and accessibility of technical assistance offered.
- Social, behavioral, and cultural factors may affect participation, land ownership, and management strategies along regional or demographic lines. Such factors may include social norms, perception of risk, and environmental consciousness, among others.
- Barriers specific to underserved land managers may contribute to historically low participation in forestry and agriculture assistance programs within these communities. Studies should offer unrestricted, open-ended space for landowners to share their experiences, thoughts, and recommendations candidly.
- Regional trends show how a variety of factors influence participation at-large. All research should include detailed spatial analysis to guide region-specific improvements to assistance programs.

RELATED RESOURCES

– Carbon Removal in Forests and Farms in the United States, World Resources Institute

– Minority Family Forest Owners in US, Journal of Forestry

13. Expand research and governance for marine-based carbon removal through federal program creation and international cooperation

BY VANESSA SUAREZ

Oceans play a key role in the climate system, acting as massive heat and carbon sinks and naturally capturing carbon and storing it on a medium- to long-term basis.[51] Climate change has already begun to have adverse effects on oceans and marine environments. Through increased concentrations of carbon in the ocean, marine ecosystems are

51. Carnegie Climate Governance Initiative. (2019). *Governing Marine Carbon Dioxide Removal and Solar Radiation Modification.* https://www.c2g2.net/wp-content/uploads/c2g_evidencebrief_marine.pdf

experiencing ocean acidification, ocean warming, and deoxygenation.[52, 53] Marine carbon removal, which enhances the ocean's uptake and storage of carbon, is an important piece of the carbon removal portfolio and can aid in addressing the impacts of climate on ocean ecosystems.[54]

At scale, marine-based carbon removal can sequester billions of tons of carbon dioxide due to the sheer size of oceans, the absence of land-use complications, and the wide variety of approaches.[55] This portfolio of solutions spans ocean fertilization, micro- and macro-algae cultivation, coastal blue carbon, up- and down-welling, ocean alkalinization, and seawater carbon extraction.[56, 57] In addition to enhancing natural carbon removal, marine approaches can provide myriad co-benefits, including reducing ocean acidification, improving fishery yields, producing feedstocks for a variety of products, and increasing biodiversity.[58, 59]

However, many of these technologies and practices are not technologically ready, and they will require large investments in RD&D to advance and equitably commercialize the leading approaches.[60, 61] Moreover, marine carbon removal will require appropriate governance frameworks at the national and international levels, as oceans are considered global commons.[62, 63] Policy support is necessary to advance RD&D efforts, establish a new program dedicated to marine carbon removal, and foster and support international collaboration.

13 . A

Recommendation: Bolster RD&D efforts to spur dedicated support for marine carbon removal innovation

Congress should authorize a new cross-agency program, led by NOAA, in collaboration with DOE, the Department of Defense (DOD), and NSF, dedicated to marine carbon removal methods. The program should take inventory of the various marine carbon removal approaches and their differing readiness levels, carbon removal potentials, potential adverse impacts, potential co-benefits, and key needs for advancement. The program should be funded at $2 billion over the next 10 years.[64]

13 . B

Recommendation: Establish and promote appropriate national and international governance frameworks

The cross-agency marine carbon removal program led by NOAA should establish robust frameworks for public engagement and support, and ensure inclusion of the public in decision-making surrounding research, development, and demonstration of marine carbon removal

52. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

53. Lebling, K., & Northrop, E. (2020). *Leveraging the Ocean's Carbon Removal Potential.* World Resources Institute. https://www.wri.org/blog/2020/10/ocean-carbon-dioxide-sequestration

54. Carnegie Climate Governance Initiative. (2019). *Governing Marine Carbon Dioxide Removal and Solar Radiation Modification.* https://www.c2g2.net/wp-content/uploads/c2g_evidencebrief_marine.pdf

55. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

56. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

57. Carnegie Climate Governance Initiative. (2019). *Governing Marine Carbon Dioxide Removal and Solar Radiation Modification.* https://www.c2g2.net/wp-content/uploads/c2g_evidencebrief_marine.pdf

58. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

59. Lebling, K., & Northrop, E. (2020). *Leveraging the Ocean's Carbon Removal Potential.* World Resources Institute. https://www.wri.org/blog/2020/10/ocean-carbon-dioxide-sequestration

60. Carnegie Climate Governance Initiative. (2019). *Governing Marine Carbon Dioxide Removal and Solar Radiation Modification.* https://www.c2g2.net/wp-content/uploads/c2g_evidencebrief_marine.pdf

61. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

62. Lebling, K., & Northrop, E. (2020). *Leveraging the Ocean's Carbon Removal Potential.* World Resources Institute. https://www.wri.org/blog/2020/10/ocean-carbon-dioxide-sequestration

approaches. Specifically, the program should actively seek community engagement and acceptance from coastal communities, including fishing, low-income, and BIPOC communities. The program should also ensure the best and most up-to-date scientific data is available, promote scientific coordination and collaboration, and incorporate scientific findings into decision-making processes. Lastly, the program should establish an advisory board with membership from the groups and communities mentioned above.

The US should also lead in the development and creation of new international agreements that meaningfully incorporate marine carbon removal. These agreements should do their best to promote environmental safeguards; transparency; robust accounting and reporting methods; mechanisms for technology, monetary, and information transfer between Global North and Global South countries; meaningful participation from Global South countries; cooperative RD&D efforts; frameworks for ethical responsibility in technology implementation; and robust methodologies for public and stakeholder engagement.

RELATED RESOURCES

- Governing Marine CDR and SRM, C2G
- Leveraging the Ocean's Carbon Removal Potential, World Resources Institute
- Uncharted Waters, Energy Futures Initiative

63. Carnegie Climate Governance Initiative. (2019). *Governing Marine Carbon Dioxide Removal and Solar Radiation Modification.* https://www.c2g2.net/wp-content/uploads/c2g_evidencebrief_marine.pdf

64. Energy Futures Initiative. (2020). *Uncharted Waters: Expanding the Options for Carbon Dioxide Removal in Coastal and Ocean Environments.* https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/6011a63f65321405af54681f/16117 69420810/Uncharted+Waters.pdf

TECH ON DECK

Tech-Based Approaches

The deployment of innovative technologies that pull CO_2 from the atmosphere, paired with utilization or storage, will play a critical role in reaching mid-century emissions targets.[65] While the portfolio of tech-based carbon removal can include an array of promising technologies, this section focuses on policies relevant to direct air capture (DAC)[66] and applications for the captured carbon.

DAC technologies have significant potential for scale-up; projections indicate that they could remove as much as 5 gigatons of CO_2 by 2050[67] with a relatively small land use footprint,[68] create hundreds of thousands of jobs,[69] and contribute significantly to economic growth.[70] At present, one of the major barriers to scaling these technologies is cost; since CO_2 is relatively dilute in the air, the separation process is energy-intensive and expensive. However, a recent surge of federal funding for RD&D has begun to change things, driving significant private sector interest and investment in these technologies. Additional federal support to develop and deploy these solutions can capitalize on this momentum to drive down technology costs and launch these emerging technologies beyond the demonstration phase.

Equitable, durable, and timely scale-up of carbon removal technologies will require a holistic strategy for deployment that includes social, environmental, and labor considerations. The economic and employment opportunities associated with these technologies can support historically disadvantaged communities and transitioning industries, but only with the appropriate policies in place. To this end, recommendations in this section include broadening the scope of federal RD&D, encouraging infrastructure development, enhancing and modifying relevant regulations, and emphasizing public engagement and community-led initiatives.

Through the passage of forward-thinking and comprehensive legislation promoting carbon removal technologies and their deployment, Congress has the unique capacity to propel these solutions in a direction that both enables the realization of climate goals and leads to the creation of a vibrant market that will benefit society, the environment, and the economy far into the future.

65. National Academies of Science, Engineering, and Medicine. (2019) *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda.* Washington, DC: The National Academies Press. https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda

66. Carbon180. (2020). *Direct Air Capture.* https://static1.squarespace.com/static/5b9362d89d5abb8c51d474f8/t/602b5c61fcd7254f1bd13f9f/1613454437930/Carbon180+Ed+Packet+DAC.pdf

67. Larsen, J., Herndon, W., Grant, M., & Marsters, J. (2019). *Capturing Leadership: Policies for the US To Advance Direct Air Capture Technology. Rhodium Group.* https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

68. Energy Futures Initiative. (2019). *Clearing the Air.* https://energyfuturesinitiative.org/efi-reports#:~:text=%E2%80%9CClearing%20the%20Air%3A%20A%20Federal,carbon%20dioxide%20removal%20(CDR).

69. Larsen, J., Herndon, W., & Hiltbrand, G. (2020). *Capturing New Jobs. Rhodium Group.* https://rhg.com/wp-content/uploads/2020/06/Capturing-New-Jobs-Employment-Opportunities-from-DAC-Scale-Up.pdf

70. Larsen, J., Herndon, W., & Hiltbrand, G. (2020). *Capturing Business. Rhodium Group.* https://rhg.com/wp-content/uploads/2020/06/Capturing-New-Business-Market-Opportunities-from-DAC-Scale-Up.pdf

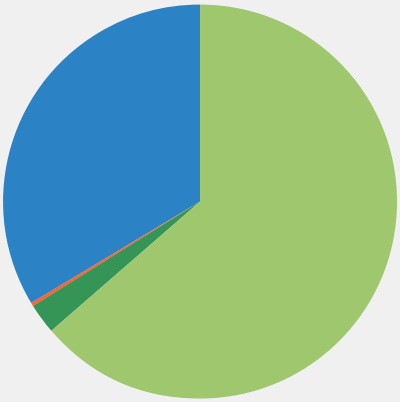
1. Utilize federal procurement to drive the deployment of DAC, bioenergy with carbon capture and storage (BECCS), and carbontech

BY COURTNI HOLNESS, LUCIA SIMONELLI, PHD, TIM STEEVES, PHD, & MERON TESFAYE, PHD

In 2019, the federal government was responsible for emitting a total of 83 million tons CO_2-equivalent from both standard and non-standard operations.[71] During the same year, the US government spent more than $568 billion on products and services.[72] Using this purchasing power to procure carbon removal services and related products, Congress can set federal agencies on the path to reach net-negative by 2050 and build strong early markets for nascent technologies.

The benefits of federal procurement of carbon removal and related products extend beyond reducing the carbon footprint of the US government. Market penetration of renewables such as solar and wind is in part attributed to the purchasing power of the federal government.[73] A Congressional mandate would provide marketplace certainty for carbon removal and promote the emergence of diverse technologies

Greenhouse gas emissions of the US federal government (FY2019)



Heat and Electricity 33.4%
Fuel and Mobile Emission 63.8%
Fugitive Emission 2.5 %
Industrial Processes 0.3%

SOURCE:
US Department of Energy. (2019). *Comprehensive Annual Energy Data and Sustainability Performance.* Retrieved from https://ctsedwweb.ee.doe.gov/Annual/Report/ComprehensiveGreenhouseGasGHGInventoriesByAgencyAndFiscalYear.aspx

71. US Department of Energy. (2019). *Comprehensive Annual Energy Data and Sustainability Performance.* Retrieved from https://ctsedwweb.ee.doe.gov/Annual/Report/ComprehensiveGreenhouseGasGHGInventoriesByAgencyAndFiscalYear.aspx

72. US Government Accountability Office. (2020, May 26). *A Snapshot of Government-wide Contracting for FY 2019 (infographic).* https://blog.gao.gov/2020/05/26/a-snapshot-of-government-wide-contracting-for-fy-2019-infographic/

73. Kutak Rock LLP and Scully Capital Services. (2018). *Examination of Federal Financial Assistance in the Renewable Energy Market.* US Department of Energy, Office of Nuclear Energy. https://www.energy.gov/ne/downloads/report-examination-federal-financial-assistance-renewable-energy-market

and businesses as carbon removal continues to develop and mature.[74] Use of the federal government's purchasing power for sustainable products has broad public support and can serve to drive momentum in fighting climate change.[75] A long-term federal procurement strategy can also create a framework for carbon removal deployment that includes parameters such as preservation of environmental integrity, protection of frontline communities, public engagement, and labor justice.

The federal government should take the following actions to launch federal procurement of carbon removal and carbontech to support building early and strong markets for low-carbon pathways.

GLOSSARY

Bioenergy with carbon capture and storage (BECCS) A form of energy production that utilizes plant biomass to create electricity, hydrogen, heat, and/or liquid fuel. This process simultaneously captures and sequesters some portion of the carbon from the biomass for storage.

1.A

Recommendation: Adopt a federal net-negative goal

As part of the larger goal of global decarbonization, the US federal government should commit to achieving net-negative emissions by 2030, establishing and tracking separate targets for emissions reductions and carbon removal efforts. A plan to do so should be mandated by Congress and subsequently developed and finalized by federal agencies. Meeting negative emissions targets will necessitate accelerating renewable energy purchasing, continuing energy efficiency improvements, and procuring carbon removal solutions to tackle hard-to-abate and historical emissions by federal agencies. Congress can achieve the latter by procuring carbon removal directly, purchasing carbon-negative fuels, and building materials as described below.

1.B

Recommendation: Procure high-quality carbon removal offsets

In line with net-zero emissions efforts, Congress can require the US government to purchase an amount of carbon removal equivalent to a target percentage of annual emissions. Only carbon removal that is verifiable, additional, and permanent must be considered for purchase. A procurement program similar to the Federal Energy Management Program (FEMP) can be established within the newly authorized carbon removal program at DOE, to help agencies with offset procurement strategies for DAC and BECCS. Initial purchases could be made through both competitive and noncompetitive procurement processes. In the early years, to spur market diversity and penetration, non-competitive procurement targets can be set for DAC and high-cost BECCS; a model similar to the former Energy Research and Development Administration (ERDA) Block Buy program for solar could be beneficial in order to pre-negotiate contracts based on removal targets before initiating the formal procurement process.[76] Federal procurement of DAC offsets

74. Larsen, J., Herndon, W., Grant, M., & Marsters, J. (2019). *Capturing Leadership: Policies for the US To Advance Direct Air Capture Technology. Rhodium Group.* https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

75. Data for Progress. (2020). *Voters Support Using the Government's Procurement Power to Take on Climate Change.* Retrieved from https://www.filesforprogress.org/datasets/2021/1/dfp_green_procurement.pdf

76. Nemet, G. F. (2019). *How Solar Became Cheap: A model for low-carbon innovation.* Routledge.

should aim to ramp up to at least 9 million tons of CO_2 by 2030. Additional procurement can be awarded to competitive carbon removal offsets for carbon-negative energy via BECCS.

1.C *Recommendation:* Procure low-carbon and carbon-negative fuels

The largest portion of emissions from the federal government originate from fuels and mobile emissions largely from non-standard operations (such as emergency response, relief operations, and combat and law enforcement activities). These emissions could be tackled through various carbon removal and low-carbon fuel procurement options, and DAC-to-fuels specifically could provide a low-carbon alternative to conventional fuel. Congress could anticipate the need for procurement of these synthetic fuels by establishing a minimum carbon intensity requirement for all fuels purchased by federal agencies. Existing federal procurement regulation already stipulates that procurement of alternative fuels has to be less than or equal to emissions from an equivalent conventional fuel.[77] In addition, low-carbon fuel standards in California and Oregon are driving down the cost of low-carbon intensity fuels across the nation.[78] The federal government can leverage existing structures and marketplaces to further drive down emissions associated with the transportation sector. Congress can also instruct specific federal agencies responsible for high emissions such as DOD, DOE, and USDA to set production volume and price targets and make matching funds available for purchase of carbon-negative fuels via DAC and BECCS.[79]

READ MORE

Read more about DAC-to-fuels on page 48.

1.D *Recommendation:* Procure low-carbon and carbon-negative building materials for public projects through a competitive bidding process

Governments are often the largest buyers of building materials. In the US, DOD is the primary agency purchasing construction materials and transportation equipment, and the General Services Administration (GSA) issues procurements for about 44 construction projects a year.[80] Building materials such as cement, iron, and steel have high GHG intensities and account for a large share of global GHG emissions, but they are not typically a part of procurement programs. At the same time, new companies are innovating around low-carbon and carbon-

GLOSSARY

DAC-to-fuels
Synthetic fuels produced by using the CO_2 obtained from direct air capture (DAC).

77. Procurement and acquisition of alternative fuels. 42 U.S.C. § 17142 (2013).

78. Fuels Institute. (2020). *Impact of Transportation-Related Environmental Initiatives.* https://www.fuelsinstitute.org/CMSPages/GetFile.aspx?guid=1d06a94b-0ce2-4d3d-9f75-bdff8ab77f84

79. Environmental and Energy Study Institute. (2014, September 26). *Government Agencies Award Annual Contracts for 100 Million Gallons of Drop-In Biofuels.* https://www.eesi.org/articles/view/government-agencies-award-annual-contracts-for-100-million-gallons-of-drop-

80. Krupnick, A. (2020, November). *Green Public Procurement for Natural Gas, Cement, and Steel.* Resources for the Future. https://media.rff.org/documents/RFF_WP_20-17_Green_Public_Procurement_for_Natural_Gas_Cement_and_Steel.pdf

negative building materials made from CO_2 from DAC, BECCS or traditional carbon capture and storage (CCS).

Congress should direct agencies to procure low-carbon and carbon-negative building materials for public projects through a competitive bidding process. Top performers, or those with low global warming potential (GWP), would earn discounts applied to their price, allowing them to be more competitive and provide better value. These procuring agencies should also create an industry-wide standard for measuring efficiency, emissions intensity, and embodied carbon and require reliable CO_2 footprint labeling. Industry-wide standards increase communication about the life cycle environmental impact of products in a transparent and comparable manner. Finally, procuring agencies should coordinate and establish target dates for achieving net-zero carbon emissions in building materials production. Addressing embodied carbon provides an opportunity to reduce the carbon footprint of building materials production and accelerate the development of a market for building materials with low embodied carbon in the US.

SIMILAR POLICY

The Low Embodied Carbon Concrete Leadership Act
Passed in NY and NJ, this legislation establishes a climate impact procurement standard for state construction projects and aims to drive carbon reduction through market-based incentives. Read more in *Paving the Way for Low-Carbon Concrete.*

RELATED RESOURCES

- Paving the Way for Low-Carbon Concrete: Recommendations for a Federal Procurement Strategy, Carbon180
- Green Public Procurement for Natural Gas, Cement, and Steel, Resources for the Future

ON THE MARKET TODAY

Companies such as CarbonCure and Solidia use CO_2 during the curing process, where it improves the strength of the material and lowers carbon intensity.

GLOSSARY

Bioenergy with carbon capture and storage (BECCS)
A form of energy production that utilizes plant biomass to create electricity, hydrogen, heat, and/or liquid fuel. This process simultaneously captures and sequesters some portion of the carbon from the biomass for storage.

Global warming potential (GWP)
A ratio of how much energy the atmospheric emission of 1 ton of a gas will absorb over a given period of time (typically 100 years), relative to the emissions of 1 ton of carbon dioxide.

2. Develop comprehensive demonstration and deployment strategies within DOE to complement R&D efforts

BY GIANA AMADOR, ERIN BURNS, & LUCIA SIMONELLI, PHD

While there is growing support for carbon removal innovation, it is essential that early stage R&D be met with forward-thinking policies to ensure durable and equitable deployment at the necessary scale.[81] Building on the momentum of the Energy Act of 2020 and other recent boosts to federal R&D for technological carbon removal, especially DAC, Congress should anticipate the need for bold and comprehensive demonstration and deployment strategies as technologies mature.

81. Data For Progress. (2020). *A Progressive Climate Innovation Agenda.* https://www.filesforprogress.org/memos/climate-innovation-agenda-report.pdf

Planning ahead for the demonstration and deployment phase of technologies arising from federal R&D will ensure that the proper structures are in place for the creation of a healthy market. In the context of technological carbon removal, DOE should incorporate metrics into demonstration projects that include environmental, social, and labor justice, and that lead to a more diverse deployment landscape that favors small businesses and entrepreneurs.

Technological carbon removal funding has primarily gone through DOE, and specifically to the Office of Fossil Energy, but building a resilient future for these technologies will require robust coordination both within the government — between offices, programs, and agencies — as well as internationally. Congress has an opportunity to lead in charting this path forward.

2.A

Recommendation: Prioritize community-driven initiatives and inclusion of public engagement and EJ considerations in demonstration project selection processes

Congress should direct DOE to prioritize community-driven initiatives when evaluating proposals for demonstration project awards. In addition, the directive should include establishing coordination between the Carbon Removal Program, staff offices such as the Office of Legacy Management,[82] EPA, and NSF to determine the appropriate metrics to ensure that EJ[83] is a key consideration in the selection process. These metrics should include preservation of environmental integrity as well as protection of frontline communities. Robust public engagement strategies should also be considered during selection processes, including language justice initiatives when applicable. This work can be done in partnership with the new deputy director for energy justice and deputy assistant secretary for public engagement.

READ MORE

Read more about siting DAC facilities on page 42.

2.B

Recommendation: Increase funding for the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs with directives to prioritize carbon removal proposals

To diversify the portfolio of small businesses and startups engaging in

82. Office of Legacy Management. *Community Engagement Initiatives.* US Department of Energy. https://www.energy.gov/lm/community-engagement-initiatives

83. Office of Legacy Management. *What Is Environmental Justice?* US Department of Energy. https://www.energy.gov/lm/services/environmental-justice/what-environmental-justice#:~:text=Environmental%20justice%20is%20the%20fair,laws%2C%20regulations%2C%20and%20policies

carbon removal, Congress should increase DOE R&D funding specifically for the SBIR and STTR[84] carbon removal awards. Across the SBIR and STTR programs, Congress should explore ways for DOE to lower the barriers for small businesses and early entrepreneurs in accessing support.

2.C *Recommendation:* Establish a new Loan Programs Office subprogram for carbon removal solutions

Congress should establish a new Loan Guarantee Program under DOE's Loan Program Office to support demonstration and deployment for projects in early stages of development. This program should expand beyond DAC and BECCS to also support enhanced mineralization, ocean capture, and carbon utilization. Such a program would be housed in the Title 17 Innovative Energy Loan Guarantee Program and financed in a structure similar to the Advanced Fossil Energy and Renewable Energy & Efficient Energy Loan Guarantees. Across the loan program office, Congress should explore ways for DOE to lower the barriers for small businesses and early entrepreneurs in accessing loan program funding.

2.D *Recommendation:* Emphasize integration of carbon removal technology into a broad range of sectors

Congress should direct DOE to emphasize novel applications of carbon removal technologies such as integration into industrial processes. For example, it should promote the accelerated development of DAC applications for cement through research, development, demonstration, and deployment (RDD&D) funding.[85] This directive should include applications of small-scale technologies that remove less than 1,000 metric tons of CO_2 per year.

2.E *Recommendation:* Include technological carbon removal in formal international coordination and collaboration

Congress should direct DOE to explore the inclusion of technological carbon removal into existing international collaborative frameworks such as the Fossil Energy Bilateral Agreements,[86] the Carbon Sequestration Leadership Forum,[87] and Mission Innovation.[88]

84. Office of Science. *Small Business Innovation Research and Small Business Technology Transfer programs office.* US Department of Energy. https://www.energy.gov/science/sbir/small-business-innovation-research-and-small-business-technology-transfer

85. Talati, S., Merchant, N., & Neidl, C. (2020). *Paving the Way for Low-Carbon Concrete: Recommendations for a Federal Procurement Strategy.* Carbon180. https://carbon180.org/s/Paving-the-Way-for-Low-Carbon-Concrete

86. US Department of Energy. *Fossil Energy Bilateral Agreements.* https://fossil.energy.gov/international/International_Partners/International_Partners.html

87. Carbon Sequestration Leadership Forum. https://www.cslforum.org/cslf/

88. US Department of Energy. *Mission Innovation.* https://www.energy.gov/mission-innovation/mission-innovation-doe

REINVESTING FOSSIL FUEL SUBSIDIES

A recent Biden executive order includes a call to end federal fossil fuels subsidies. Should Congress codify this order, almost $20 billion annually could be reinvested into environmental justice and decarbonization initiatives, including carbon removal projects.

RELATED RESOURCES

- Paving the Way for Low-Carbon Concrete: Recommendations for a Federal Procurement Strategy, Carbon180
- A Progressive Climate Innovation Agenda, Data for Progress
- Community Engagement Initiatives, DOE Office of Legacy Management
- Environmental Justice Initiatives, DOE Office of Legacy Management
- SBIR/STTR Programs Office, DOE Office of Science

3. Establish a federal DAC siting research initiative to support equitable and safe deployment

BY COURTNI HOLNESS

Early DAC deployments will need to minimize stress on water, land, and energy resources while providing long-term and high-paying jobs, among other community benefits. In some instances, DAC facilities may be sizable industrial facilities (up to 2 km^2 per 1 million tons CO_2 removed), and at the global scale could remove gigatons of CO_2 from ambient air.[89] Research on how to site DAC facilities in a just, equitable, and economical manner will be necessary for near-term pilot and commercial facilities to ensure that the infrastructure has climate benefits and ensure safety. Siting studies can also improve the quality, timeliness, and public acceptance of projects.

The Carbon Dioxide Removal Primer, and numerous other recent efforts, includes an ongoing effort to map locations optimal for siting carbon removal solutions.[90, 91, 92] However, there is still not a mapping resource that integrates social and EJ considerations with energy sources and sequestration potential.

The US federal government has the capability to perform domestic DAC siting research with interagency resources, authority over federal lands, and expertise in broader infrastructure and resource considerations, as well as social, environmental, and economic justice. Federal reporting can provide a baseline of information for DAC developers to commence projects within the US. The federal government manages roughly 28% of land in the US for the purposes of preservation, recreation, and development of natural resources — some of which could be suitable for DAC construction.[93] Federal lands that have been degraded, present few

89. Lebling, K., McQueen, N., Pisciotta, M. & Wilcox, J. (2021). *Direct Air Capture: Resource Considerations and Costs for Carbon Removal.* World Resources Institute. https://www.wri.org/blog/2021/01/direct-air-capture-definition-cost-considerations

90. Pilorgé, H., Kolosz, B., Wu, G., C., &Freeman, J. (2021). "Global Mapping of CDR Opportunities." *CDR Primer.* https://cdrprimer.org/read/chapter-3

91. McQueen, N., Psarras, P., Pilorgé, H., et al. (2020). Cost Analysis of Direct Air Capture and Sequestration Coupled to Low-Carbon Thermal Energy in the United States. *Environmental Science & Technology, 54*(12), 7542-7551. https://doi.org/10.1021/acs.est.0c00476

92. Williams, J. H., Jones, R. A., Haley, B., Kwok, G., Hargreaves, J., Farbes, J., & Torn, M. S. (2021). Carbon-Neutral Pathways for the United States. *AGU Advances, 2*(1), e2020AV000284. https://doi.org/10.1029/2020AV000284

93. Congressional Research Service. (2020). *Federal Land Ownership: Overview and Data.* https://fas.org/sgp/crs/misc/R42346.pdf

ecological disruptions, and are far removed from communities may be suitable for DAC siting research.

3.A

Recommendation: Direct DOE, the US Army Corps of Engineers, Council on Environmental Quality, EPA, DOI, National Institute of Standards and Technology, and NSF to create a DAC siting research and reporting task force

Task this new entity with 1) conducting studies to assess optimal locations for DAC, 2) preparing a formal report on assessment findings, and 3) creating a database with information and guidelines for developers and the government to reference. This report should be made available no later than two years after the creation of the task force. This task force may be developed in a manner parallel to the previous Interagency Task Force on Carbon Capture and Storage, but it would focus on the specific resource and social considerations associated with DAC.

3.B

Recommendation: Conduct DAC siting assessments

DAC siting studies should identify optimal sites for deployment, with consideration of co-location with low-carbon energy sources and geologic storage, ecological impacts, natural resource protection, community consultation, and potential co-benefits. The studies should be conducted on local or regional scales to contextualize existing global studies and create more accurate and granular data for local land in the US. Siting studies should also include frequent and robust public engagement to identify 1) communities open to information and discussion of DAC facilities, 2) risk perception and mitigation, and 3) the equitable distribution of potential benefits from DAC deployment.

DAC developers will likely require permits to achieve regulatory compliance with environmental laws such as the Safe Drinking Water Act (SDWA), National Environmental Policy Act (NEPA), Clean Water Act (CWA), and the Clean Air Act (CAA).[94] The federal government may offer categorical exclusions for projects by pre-screening DAC sites under environmental laws and predefining those projects as benign when appropriate. Screening can establish a streamlined regulatory process by predetermining if DAC construction would have any adverse environmental or social impacts, with respect to criteria such as available energy, storage capacity, water consumption, and ecological harms. The process would not allow circumvention of procedures, but rather increase efficiency by permitting sites with relatively limited risk.

94. Hester, T. (2018). Legal Pathways to Negative Emissions Technologies and Direct Air Capture of Greenhouse Gases. *Environmental Law Reporter, 48*(5),10413-10432.

Pre-screening during the siting stage of projects is likely to save time and help determine if a project will need to make a full environmental impact statement.

3.A

Recommendation: Publish DAC siting report and database

The task force should present and publish the findings from the siting studies in a formal report and create a database to organize the studies' information and status of all projects. The database shall also include a public input interface to increase accessibility and transparency of the full project cycle and allow for public commenting periods.

The database shall serve as a tool for managing, tracking, and accelerating appropriate DAC projects in the US with the potential to envelop other carbon removal solutions. The database should also include 1) site maps with geologic and environmental characteristics, 2) public participation comments and considerations, 3) answers to related EJ questions on whether development may exacerbate or redress any existing disproportionate impacts to minority and low-income communities, and 4) public health and environmental threats or concerns.

RELATED RESOURCE

– Global Mapping of CDR Opportunities, CDR Primer

4. Create a DAC market, policy, and people innovation prize

BY CHRIS NEIDL & LUCIA SIMONELLI, PHD

Prize competitions for novel solutions and products have long been used to foster innovation by both private philanthropies and the public sector alike. By combining financial incentives with open and transparent selection and eligibility criteria, well-structured and widely promoted prize competitions can both catalyze breakthroughs and foster new forms of collaboration in high-impact ways that markets alone often cannot.

The transformative potential of prizes can play a critical role in accelerating carbon removal innovation. In the Energy Act of 2020, Congress authorized two DAC-specific innovation prizes that would support multiple demonstration and commercial scale deployments. The recent announcement of the $100 million carbon removal XPRIZE, funded by Elon Musk, further confirms that this idea is gaining traction.

The substantial technical and cost barriers to scaling DAC are particularly well suited to this type of intervention.

However, the constraints surrounding DAC deployment transcend technological challenges. Reaching gigaton capacity will require creative strategies to promote both durable and equitable markets. This necessitates new approaches to implementing public policy and regulation by leveraging and cultivating public, private, and human resources, and building meaningful public engagement, participation, and ownership. State, municipal, and tribal governments, other public sector agencies, civil society organizations, academic institutions, and the private sector all have a role to play in discovering, implementing, and replicating the conditions necessary to ensure a future in which DAC is widespread, sustainable, equitable, and locally anchored.

We propose a federal DAC market, policy, and people innovation prize competition that aims to rapidly foster policy and commercial innovation at the state and municipal scale, on the ground, where DAC infrastructure will ultimately be realized.

4.A

Recommendation: Create and fund a DAC market, policy and people innovation prize

Congress should authorize a DAC market, policy, and people innovation prize competition within the DOE Carbon Removal Program. This prize builds on the need for technological development (covered by the existing prizes) by including provisions to encourage innovation around building markets and creating policies:

- focusing on locally based (state, tribal, and municipal), novel models for DAC project development, deployment strategies, financing options, and incentivization policies,
- soliciting ideas for innovative ideas to create local or regional markets for DAC technologies,
- prioritizing public engagement and community-based initiatives,
- building multi-stakeholder visioning and planning into processes, ensuring bottom-up innovation and equity,
- emphasizing regional equity when creating awards, and
- ensuring broad eligibility, including and prioritizing public, private, and institutional coalitions.

RELATED RESOURCE

– "And the winner is..." Capturing the promise of philanthropic prizes, McKinsey & Company report

5. Enhance and expand the 45Q tax credit for DAC

BY ERIN BURNS & RORY JACOBSON

In 2018, the 45Q tax credit was updated to include DAC for the first time, which has arguably been the single most significant federal incentive for engineered carbon removal. In fact, as a result of this and other state level incentives, we've seen the first-ever megaton scale plant announced.[95] While this is an enormous victory, the current credit level was developed for point source carbon capture, a far more mature technology, and will not be sufficient to deploy DAC at the levels and in the timeframe needed to meet climate goals. Updates to 45Q that take into account the unique needs of DAC are the next critical step.

At the time of the 2018 45Q tax credit updates, DAC was even more nascent and a climate solution new to most policymakers. Getting it included in 45Q was a major achievement. Since then, interest in and support for the technology has skyrocketed, and there have been more detailed analyses of what policies are needed to scale DAC, including further updates to 45Q. In response to the 2018 amendments to the 45Q credit, significant economic research has been done on the capacity of the credit to drive economically viable DAC projects. Most notably, the Rhodium Group published an analysis that estimated the cost gap (for a facility to break even) with the current 45Q credit values on a per-ton basis.[96]

95. Geman, B. (2020, August 19). Occidental Petroleum teams with private equity firm to deploy carbon capture tech in US. *Axios*. https://www.axios.com/occidental-petroleum-carbon-capture-rusheen-ca90b907-aa84-4d03-848e-46b964da285a.html

96. Larsen, J., Herdon, W., Grant, M., & Marsters, P. (2019). *Capturing Leadership Policies for the US to Advance Direct Air Capture Technology. Rhodium Group*. https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

5.A *Recommendation:* Update and expand the 45Q tax credit to support DAC deployment

- The value of the credit should be raised from the current level of $50 per ton in 2026 to $180 per ton upon enactment for saline storage, and the value for carbontech should be raised from $35 per ton to $130 per ton. The current values were set for point source carbon capture and enhanced oil recovery — both significantly more commercially mature than DAC and carbontech.
- Minimum annual capture thresholds for qualified facilities should be eliminated. Current DAC pilot projects operate at the scale of several thousand tons per year, yielding a significant finance and infrastructure gap to achieving the current 100,000-ton threshold. Moreover, the elimination capture thresholds would enable all DAC technologies to compete equally, while enabling greater and more rapid learnings and cost reductions with less project finance risk.
- The commence construction deadline should be extended to at least 2030 to enable a pipeline of projects that will benefit from near-term deployment experience.

- Direct pay should be enacted. Providing direct pay would allow project developers to more easily and effectively cash the 45Q credit.
- A checks and balances system between EPA and the Internal Revenue Service should be implemented, such that 45Q credits are only awarded to projects that demonstrate validated and confirmed compliance with EPA Class VI underground injection control (UIC) protocols.

Many of these recommendations, including eliminating thresholds, direct pay, and extending the commence construction deadline could also spur more point source carbon capture projects and receive wide support from CCS advocates. Importantly, increasing the value for 45Q for point source industrial projects, particularly those where deployment costs are far higher than $50 per ton, could help reduce emissions in hard-to-decarbonize sectors such as steel.

RELATED RESOURCES

– Capturing Leadership: Policies for the US to Advance Direct Air Capture Technology, Rhodium Group

97. National Academy of Engineering and National Research Council. (2010). *The Power of Renewables: Opportunities and Challenges for China and the United States.* Washington, DC: The National Academies Press. https://doi.org/10.17226/12987

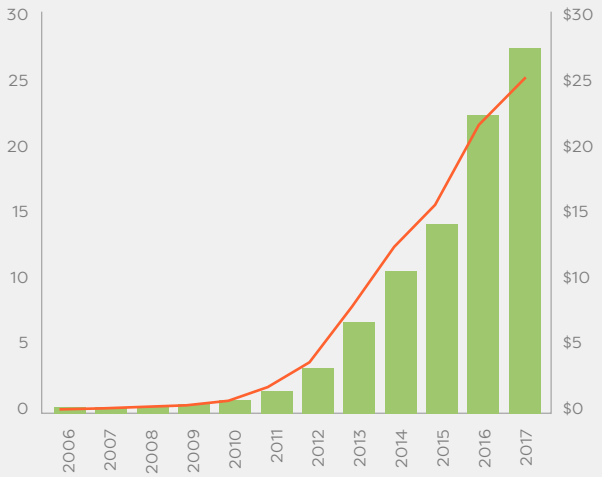
6. Create an investment tax credit for DAC

BY ERIN BURNS, RORY JACOBSON, & LUCIA SIMONELLI, PHD

Investment tax credits (ITC) have been one of the most powerful forces in scaling renewable energy in the US; the solar ITC in particular played a fundamental role in launching and sustaining a strong deployment trajectory, creating a solid foundation for growing private sector interest and investment.[97]

Federal policy support and solar deployment

Cumulative solar capacity, GW (LHS); Cumulative tax support, $2017 billions (RHS)



SOURCE:
Larsen, J., Herdon, W., Grant, M., & Marsters, P. (2019). *Capturing Leadership Policies for the US to Advance Direct Air Capture Technology. Rhodium Group.* https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

Investment tax credits can be invaluable to emerging technologies such as DAC that have not yet reached economies of scale or reaped the benefits of learning by doing. The few deployment incentives for DAC within the US are currently not of sufficient value to attract the investment necessary to finance multiple commercial facilities. To this end, we propose an ITC for DAC that 1) would cover a significant portion of the upfront capital costs, 2) could be stacked with the performance-based tax credit, 45Q, in the case of permanent, geologic storage, 3) does not require a minimum capture capacity for eligibility, and 4) remains applicable for a long enough period to create market certainty and ensure that we reach an adequate level of cost reduction.

6.A

Recommendation: Create an ITC for DAC

This ITC for DAC should include the following specifications:

- Secures deductions of at least 40% of capital costs in order to significantly offset the investment necessary to finance DAC plants. This percentage is higher than the solar ITC, reflecting the difference in maturity of the markets for carbon and energy.
- Ensures stackability with other policies such as 45Q when paired with permanent, geologic storage. This pathway in particular ensures permanent carbon removal and cannot benefit from utilization markets.
- Has no minimum capture threshold so as to align with the current state of the technology, increase diversity of technologies and market players, and ensure that DAC can benefit from niche market applications.
- Does not expire or ramp down until DAC deployment capacity in the US reaches at least the equivalent of 1% of 2021 absolute US emissions.

RELATED RESOURCE

– The Power of Renewables, National Academy of Engineering and National Research Council

98. US Environmental Protection Agency. (2019). *Sources of Greenhouse Gas Emissions.* https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

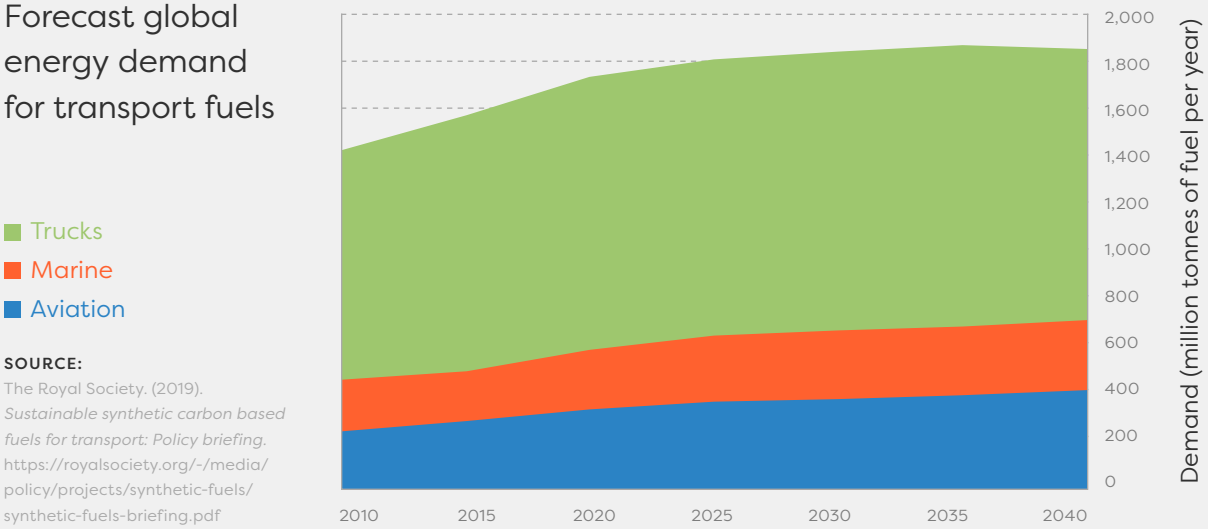
99. The Royal Society. (2019). *Sustainable synthetic carbon based fuels for transport: Policy briefing.* https://royalsociety.org/-/media/policy/projects/synthetic-fuels/synthetic-fuels-briefing.pdf

7. Invest in DAC-to-fuel pathways

BY ERIN BURNS & LUCIA SIMONELLI, PHD

Transportation is responsible for more than a quarter of US emissions.[98] It is predicted that energy demand for transport will increase in the coming decades, including for the hardest-to-decarbonize sectors such as aviation, shipping, and long-haul trucking.[99] While innovation

Forecast global energy demand for transport fuels



SOURCE:
The Royal Society. (2019). *Sustainable synthetic carbon based fuels for transport: Policy briefing.* https://royalsociety.org/-/media/policy/projects/synthetic-fuels/synthetic-fuels-briefing.pdf

continues in the direction of increased efficiency, improvements to energy storage, and development of electric and hybrid vehicles, low-carbon fuels will be essential to meet mid-century climate goals.

Fuels synthesized from CO_2 obtained from DAC can be lower carbon intensity than conventional diesel and some biofuels;[100] are drop-in compatible with refineries, infrastructure, and engines;[101] are cleaner burning — meaning no sulfur and low particulate matter; have virtually unlimited feedstock; and require less water and land use than most biofuels. In addition, they provide an opportunity to produce fuels on-site, which is especially beneficial in the context of national security.

Improvements to the fuel synthesis process are being actively developed,[102] but synthetic fuels, especially jet fuels, remain significantly more expensive than their fossil fuel-based counterparts. While there is some movement in the private and public sectors, robust federal policy incentives, regulation, and funding for RD&D[103] are imperative.

7.A

Recommendation:
Ensure robust funding for RD&D in existing utilization programs

Building on the momentum of the SEA FUEL Act, the USE IT Act, and the newly reauthorized Carbon Utilization Program in the Energy Act of 2020, continued funding for RD&D of synthesizing fuels, especially aviation fuels,[104] from captured CO_2 is necessary to improve processes and catalysts used for the reactions in order to increase efficiency and ultimately drive down cost.

100. Liu, C. M., Sandhu, N., McCoy, S. T., & Bergerson, J. (2020). A life cycle assessment of greenhouse gas emissions from direct air capture and Fischer–Tropsch fuel production. *Sustainable Energy & Fuels, 6.* https://pubs.rsc.org/en/Content/ArticleLanding/2020/SE/C9SE00479C#!divAbstract

101. Carbon Engineering. *Air to Fuels.* https://carbonengineering.com/air-to-fuels/

102. Yao, B., Xiao, T., et al. (2020). Transforming carbon dioxide into jet fuel using an organic combustion-synthesized Fe-Mn-K catalyst. *Nature Communications, 11,* Article 6395. https://www.nature.com/articles/s41467-020-20214-z

103. National Academies of Science, Engineering, and Medicine. *Gaseous Carbon Waste Streams Utilization.* Chapter 11. (2019). https://www.nap.edu/catalog/25232/gaseous-carbon-waste-streams-utilization-status-and-research-needs

CURRENT INITIATIVES

Examples of initiatives underway to use recycled CO_2 in the production of aviation fuels:

- **Lanzatech and Virgin Atlantic**
- **Opus 12 and the US Air Force**
- **Carbon Engineering and Aerion Supersonic**

7 . B

Recommendation: Mandate federal procurement of DAC-to-fuels

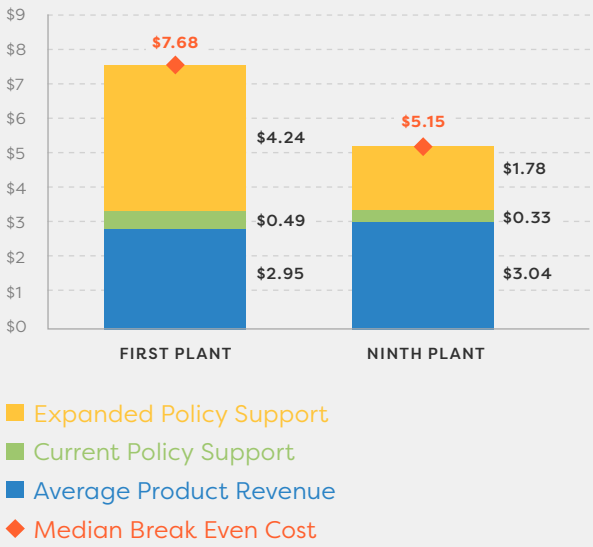
While efforts to fully electrify the federal fleet should be prioritized, it will take many years to realize this goal. In the interim, Congress should direct agencies to purchase synthetic, low-carbon fuels; according to an analysis by Rhodium Group,[105] DOD could ramp up competitive procurement of DAC-based fuels from 95 million gallons in 2023 to 850 million gallons in 2030.

READ MORE

Read more about federal procurement strategies on page 36.

Expanded RFS policy support and cost of DAC-to-fuels estimates

30-year levelized $2018/gallon



SOURCE:
Larsen, J., Herdon, W., Grant, M., & Marsters, P. (2019). *Capturing Leadership Policies for the US to Advance Direct Air Capture Technology. Rhodium Group.* https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

7 . B

Recommendation: Establish DAC-to-fuels pathways through modification of the Renewable Fuel Standard (RFS) or the creation of a federal Low Carbon Fuel Standard (LCFS)

Congress should restructure the RFS to include DAC-to-fuel eligibility, directing EPA to approve a pathway for these fuels.

Although ambitious, one of the most effective strategies for incentivizing the use of DAC-to-fuel would be for Congress to implement a federal version of California's LCFS. One additional benefit of this direction is that credits could be established for other forms of carbon removal such as DAC to carbon storage and stacked with other incentives such as the 45Q tax credit.

104. Scheelhaase, J., Maertens, S., & Grimme, W. (2019). Synthetic fuels in aviation – Current barriers and potential political measures. *Transportation Research Procedia, 43.* https://www.sciencedirect.com/science/article/pii/S2352146519305824

105. Larsen, J., Herndon, W., Grant, M., & Marsters, P. (2019). *Capturing Leadership: Policies for the US to Advance Direct Air Capture Technology.* Rhodium Group. https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/

8. Pre-permit geologic storage on federal land

BY COURTNI HOLNESS & TIM STEEVES, PHD

Geologic saline storage refers to permanently storing CO_2 from the atmosphere underground and is the final step in many carbon capture and carbon removal systems. Developers of carbon removal solutions like DAC need technical assistance to locate suitable geologic storage reservoirs and build CO_2 injection well infrastructure. It is critical to identify and assess different geologic storage resources so that developers have access to safe and permanent CO_2 storage. Pre-permitting Class VI wells on federal lands can help bolster support for carbon removal and allow developers a more structured path to storing carbon dioxide. By 2018, DOI had permitted and leased 12.8 million acres with 96,000 wells for oil and gas leasing, which has been crucial for the scaling of natural gas and crude extraction.[106] Cooperation among several departments and agencies could facilitate a similar process for the purpose of carbon dioxide removal.

The US has billions of tons of deep saline storage widespread in both onshore and offshore formations, yet there are only two active Class VI wells in use today.[107] Federal R&D efforts over the past decade have shifted from small demonstrations to understanding the technical and commercial viability of large commercial-scale projects.[108] R&D efforts can be amplified with increased agency capacity to assess, report, and prepare Class VI well infrastructure. DOE, EPA, USDA, and DOI have the resources and expertise to pre-permit Class VI wells on federal lands to accelerate the deployment of large-scale carbon removal solutions like DAC and keep the US on track to meet climate goals.

READ MORE

Read more about Class VI improvements on page 53.

The 117th Congress has introduced a few bills to support geologic sequestration. S. 799/H.R. 1992, the SCALE Act, would increase the capacity of EPA to review and grant geologic sequestration permits, and extend those powers to states, fund cost-share for CO_2 transport infrastructure, and provide grants for state and local governments to procure CO_2 utilization products for infrastructure projects. H.R. 1512, the CLEAN Future Act, increases funding for geologic storage by increasing the authorization for activities related to permitting Class VI wells and providing grants for states to establish their own geologic storage permitting programs.

106. US Bureau of Land Management. (n.d.). *About the BLM Oil and Gas Program.* US Department of Interior. https://www.blm.gov/programs/energy-and-minerals/oil-and-gas/about

107. National Energy Technology Laboratory. (2014, November). *CO_2 Storage Resource Methodology.* US Department of Energy. https://www.netl.doe.gov/node/5964

108. Congressional Research Service. (2020, February 21). *Carbon Sequestration Legislation in the 116th Congress.* https://crsreports.congress.gov/product/pdf/IF/IF11345

FY 2021 appropriations also continued support for geologic sequestration by allocating $3 million to the UIC Class VI well program to expand EPA's expertise and capacity to ensure safe and secure geologic storage of CO_2.

8.A

Recommendation: Direct DOE, EPA, US Geological Survey (USGS), USDA, and DOI to collaborate and fund an interagency program to support the pre-permitting of Class VI UIC wells on federal lands

The pre-permitting process should assess the social, environmental, and economic impacts of injecting CO_2 into deep saline storage reservoirs across the US. The federal government should perform environmental impact assessments for sites with deep saline storage that 1) are or able to be co-located with low-carbon energy and carbon removal solutions such as DAC, 2) include community and tribal government consultation, 3) address and monitor the ecological and environmental impacts of injecting CO_2 below the surface, 4) pre-screen for relevant environmental laws including SDWA, NEPA, Endangered Species Act, and CWA, and 5) comply with the appropriate EPA guidance for the UIC program for safe and durable storage of CO_2 in saline formations (Class VI Permit).

READ MORE

Read more about siting DAC facilities on page 42.

8.B

Recommendation: DOI should pre-permit and lease federal land for permanent, saline geologic carbon storage to help project developers effectively navigate current inefficiencies in the Class VI UIC program, while maintaining environmental and public health standards

The pre-permitting assessments should be comprehensive and result in the creation of a database that includes assessment information such as 1) site maps with geologic and environmental characteristics, 2) public participation comments and considerations, and 3) answers to related EJ questions about whether sites may exacerbate any existing disproportionate impacts to minority and low-income communities. DOI should work with EPA to ensure permits are processed expediently and in compliance with UIC regulations, prioritizing sites near retired oil and

gas industries to facilitate new employment opportunities. Finally, EPA and DOI should work closely with the Internal Revenue Service to ensure that projects eligible for 45Q tax credit comply with all EPA provisions before credits are provided.

RELATED RESOURCE

- Geologic Carbon Storage, Carbon180
- Geologic Storage Is Permanent: An FAQ with Bruce Hill, Clean Air Task Force
- Storing CO_2: Planning Tomorrow's Net-Zero Infrastructure, Clean Air Task Force
- Injection and Geologic Sequestration of Carbon Dioxide: Federal Role and Issues for Congress, Congressional Research Service

GLOSSARY

Class VI wells
Class VI wells are used to inject CO_2 into deep rock formations, resulting in long-term geologic carbon storage. The Class VI well program facilitates safe geologic storage and protects underground sources of drinking water. Class VI wells face a different set of regulations than those used for oil and gas-related injection (Class II wells).

9. Update the Class VI underground injection well permitting process to enable more rapid development of geologic carbon storage

BY TIM STEEVES, PHD

Carbon removal at scale requires not only methods for capturing CO_2 but also storing it. Geologic formations in the US have the capacity to store an estimated 3,000 Gt of CO_2, which is more than enough to meet our needs — but there remain barriers to accessing this storage potential.[109]

Geologic storage of CO_2 is facilitated by underground injection wells that pump CO_2 deep underground, where it is permanently stored. EPA permits injection wells for geologic storage (Class VI), but only six permits have ever been issued, four of which expired before the project could begin.

To access the massive potential of geologic storage — and concurrently accelerate technological carbon removal solutions — we need to improve the permitting process for Class VI wells.

109. US Geological Survey Geologic Carbon Dioxide Storage Resources Assessment Team. (2013). *National Assessment of Geologic Carbon Dioxide Storage Resource — Results*. US Geological Survey. https://pubs.usgs.gov/circ/1386/

9.A *Recommendation:* Increase funding for the EPA's UIC program and direct funds directly to Class VI permitting

Due to the speed at which Class VI wells will need to be built and brought online, expansion of permitting capacity is an urgent goal. In addition to near-term appropriations to the UIC program for Class VI

permitting capacity, additional funds should be specifically appropriated to build human capital over the next several years. Technical expertise and computer model licensing is a large part of the analysis required for class VI permitting, and technical talent for this work will need to be recruited and cultivated. At least $10 million per year should be put toward this specific goal over the next 10 years.

9.B *Recommendation:* Review permitting procedure and amend the process to allow for more rapid permitting

Currently, applications for Class VI are so intensive and cumbersome that they are a bottleneck for project development. Preparing and reviewing applications is time-consuming. To ameliorate this, Congress should mandate a review and refresh of the standard permitting process that allows for both rapid (less than six months) turnaround on applications, while still exercising an abundance of caution for natural resources and prioritizing the health and safety of frontline communities. Pre-permitting sites on federal land in collaboration with DOE RD&D projects can also enable rapid deployment of projects.

READ MORE

Read more about pre-permitting geologic storage on page 51.

9.C *Recommendation:* Direct some of the additional funds for the UIC permitting program to review and process state primacy applications

Additional agility may be accessed by allowing more state governments to issue permits. Wyoming and North Dakota have already been granted this ability, which is referred to as primacy. Primacy for this process allows states that have already retained talent and resources for geologic permitting in their regulatory structure to utilize those resources for Class VI permitting. These primacy applications are intensive and have taken years for EPA to review, and additional funding for the UIC program can be used to increase the capacity for primacy application review. Increasing federal funding for these state programs via grants is another way to increase overall capacity for Class VI permitting.

RELATED RESOURCE

– Injection and Geologic Sequestration of Carbon Dioxide: Federal Role and Issues for Congress, Congressional Research Service

10. Create a pipeline development task force to site pipelines connecting CO2 sources to storage facilities

BY TIM STEEVES, PHD

In many proposed carbon capture and carbon removal projects, the facilities that perform capture and storage, respectively, are located directly next to one another, or co-located (e.g., establishing a DAC plant on the same site as a geologic storage well). However, in practice it may be more common that these sites are separated by distances that will require transportation infrastructure. This is a product of the energy and land use requirements associated with DAC technologies and the current placement of many emitting facilities compatible with CCS retrofits.

In some cases, relatively small volumes of CO_2 can be transported economically by train or truck, but eventually the scale of carbon removal will require a more robust transportation system in the form of pipelines. Thousands of miles of CO_2 pipelines are already in use supporting enhanced oil recovery (EOR) and other applications.[110] Some of these existing pipelines and new ones built specifically to connect carbon removal and CCS projects could be utilized to effectively network pilot and demonstration plants to appropriate geological sequestration sites. (Many small DAC projects are being routed to one larger geological storage site via pipeline.)

Furthermore, decarbonizing other heavy emissions industries such as concrete or steel does not allow for co-location unless the industrial site is already on a suitable site for another form of storage. A strategically placed pipeline will allow for many different decarbonization projects to funnel into several larger geological storage sites.

110. Dooley, J. J., Dahowski, R. T. & Davidson, C. L. (2008). Comparing Existing Pipeline Networks with the Potential Scale of Future US CO_2 Pipeline Networks. Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-17381.pdf

10 . A *Recommendation:* Establish a CO2 transport pipeline task force at the federal level

Create an interagency task force (including DOE, EPA, DOI, and others) in collaboration with industry, civil society stakeholders, and current carbon removal and CCS efforts to assess where pipelines might be ideally sited, how public participation would function, and to understand the

economic and labor impacts of a large-scale pipeline network. Connection to proposed RD&D will enable scale-up by integrating multiple smaller sites into one storage facility. This task force should prioritize current and proposed geological storage sites and DAC facilities.

RELATED RESOURCES

- Infrastructure to Enable Deployment of Carbon Capture, Utilization, and Storage in the United States, Proceedings of the National Academy of Sciences
- Review of the CO_2 Pipeline Infrastructure in the US, DOE Office of Fossil Energy

11. Create an RD&D program for enhanced CO2 mineralization

BY COURTNI HOLNESS

CO_2 storage achieved via mineralization is long term, and engineers can enhance the rate of mineralization reactions for carbon removal applications in climate change mitigation.[111]

Mineralization may be enhanced in three ways: 1) ex situ, which involves extracting and grinding minerals for reaction with CO_2 at the surface, 2) in situ, where CO_2 is injected below the surface into reactive rocks, and 3) surficial, which uses mine tailings and alkaline industrial wastes for ambient weathering, since these materials are already present at the surface.[112] Additionally, solid industrial alkaline wastes require resources to be treated and managed, and mineralization can aid this process and serve dual purposes. Methods to enhance mineralization are gaining popularity as an alternative in places where there is no long-term reservoir for CO_2.

Ex-situ methods are the most expensive and time-intensive, and they can be carbon neutral or carbon negative depending on the CO_2 source. In-situ methods require a relatively short timeframe to achieve mineralization — potentially making it a more straightforward approach to socialize. Surficial mineralization methods can be carbon neutral or carbon negative depending on each system framework. Increased RD&D support is needed to understand the different enhancement pathways' 1) applications for geologic storage, industrial waste feedstocks, soil amendments, and other developing applications, and 2) social, environmental, and economic impacts.

For example, CarbFix has been innovating geologic carbon storage through in-situ mineralization since 2007 and recently launched CarbFix2, designed to make the methodology economically viable and

111. Dipple, G., Kelemen, P., & Woodall, C. M. (2021). "The Building Blocks of CDR Systems." *CDR Primer.* https://cdrprimer.org/read/chapter-2#sec-2-1

112. Dipple, G., Kelemen, P., & Woodall, C. M. (2021). "The Building Blocks of CDR Systems." *CDR Primer.* https://cdrprimer.org/read/chapter-2#sec-2-1

integrated into carbon capture and sequestration (CCS) technologies.[113] De Beers Group has a program called CarbonVault to research surficial mineralization methods.[114] Similarly, Project Vesta is piloting enhanced weathering in coastal regions to assess the safety, effectiveness, and other implications of adding olivine to beaches for mineralization purposes. The costs of mineralization can be reduced by selling carbonate products for use in the construction industry.[115] CarbonCure, a low-carbon concrete company, innovated a carbon removal technology that integrates CO_2 mineralization infrastructure and permanently embeds CO_2 into their concrete.[116]

113. Carbfix. (2021). *Carbfix 2.* https://www.carbfix.com/carbfix2

114. De Beers Group. (n.d.). *CarbonVault.* https://www.debeersgroup.com/sustainability-and-ethics/protecting-the-natural-world/carbon-vault

115. Dipple, G., Kelemen, P., & Woodall, C. M. (2021). "The Building Blocks of CDR Systems." *CDR Primer.* https://cdrprimer.org/read/chapter-2#sec-2-1

116 CarbonCure. (2021). *About.* https://www.carboncure.com/about/

11 . A

Recommendation: Authorize and fund a new RD&D program for early and mid-stage enhanced CO2 mineralization for geologic storage, industrial waste feedstocks, soil amendments, and other nascent applications

The federal government has access to national laboratories and the financial resources to lead RD&D efforts for enhanced CO_2 mineralization. The program should be funded at $70 million per year over 10 years, with the proposed CO_2 mineralization RD&D agenda responsibilities as follows:

Direct DOE's Office of Fossil Energy to:

- coordinate with NSF Directorate for Geosciences (GEO) and carry out pilot studies of in situ-enhanced CO_2 mineralization,
- coordinate with EPA Office of Research and Development (ORD), USGS, and relevant national laboratories to carry out pilot studies of ex situ-enhanced CO_2 mineralization,
- coordinate with DOI USGS for resource assessments involving mapping and assessing geologic resources, mine tailings, and other alkaline industrial wastes for mineralization, and
- develop a public database for carbon mineralization to track projects and data. With regard to the second point, USGS, EPA, and the Office of Fossil Energy should also coordinate with USDA agencies, including the Agricultural Research Service (ARS) and National Institute of Food and Agriculture (NIFA), to perform or fund intramural and extramural research on enhanced mineralizing applications in croplands.

GLOSSARY

CO_2 mineralization
A process that occurs naturally in the environment when CO_2 from the atmosphere reacts with rocks and forms inert minerals that pose little groundwater contamination risk.

Carbonate products
Products made from CO_2 that has been converted into solid mineral form. These products can augment and/or substitute traditional concrete components such as cement and aggregates.

11 . B

Recommendation: Direct EPA ORD and DOI USGS to conduct studies identifying environmental impacts of mineral additions to terrestrial, coastal, and marine environments and disturbing piles of mine tailings

Potential environmental risks associated with carbon mineralization include large water requirements, water contamination risk from mining activities, local air pollution, management of waste rocks, and heavy metal pollution in soils.[117] Other environmental concerns include the disruption and distribution of piles of mine tailings, which can affect local environments and biodiversity. Further research is needed to identify parameters and measurement capabilities, and standards for environmentally acceptable disruption.

11 . C

Recommendation: Direct NSF GEO and DOI USGS to conduct studies identifying social impacts of an expanded mining industry for the purpose of enhanced CO2 mineralization

Some environmental concerns include dispersing mine tailings on coastlines or shallow seafloors, seismic activity due to injecting CO_2, and expanding the mining industry for the purpose of carbon removal. Further research is needed to identify and measure social factors and to determine a threshold for social acceptance.

RELATED RESOURCES

- Clearing The Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies, Energy Futures Initiative
- Mineralization Technology for Carbon Capture, Utilization, and Storage, Frontiers in Energy Research
- Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, National Academies of Sciences, Engineering, and Medicine

117. EFI and EJM Associates. (2019). *Clearing the Air.* Energy Futures Initiative. https://www.dropbox.com/s/2y36ngfrcbpv37f/EFI%20Clearing%20the%20Air%20Full%20Report.pdf?dl=0

GLOSSARY

CO_2 mineralization
A process that occurs naturally in the environment when CO_2 from the atmosphere reacts with rocks and forms inert minerals that pose little groundwater contamination risk.

COME TOGETHER

Cross-Solution Approaches

The diversity of carbon removal solutions — spanning the energy, forestry, agriculture, and mining sectors — provides both obstacles and opportunities. No one solution can solve the challenges presented by the climate crisis; alongside emissions reductions, we must aim to develop and deploy these solutions in tandem. At the same time, each solution has a series of co-benefits that can drive healthy, resilient, and economically thriving communities across the US. From formerly fossil-centered communities in West Virginia to farmers adapting to climate change in California, carbon removal can provide us with an opportunity to actively create the low-carbon future we need.

Historically, carbon removal solutions have been developed in siloes. This has slowed progress and prevented the field from creatively finding synergies around solution development and deployment. Perhaps surprisingly, the myriad carbon removal solutions face a number of similar challenges, including:

- need for innovation to improve technological certainty and decrease costs,
- insufficient infrastructure to deploy solutions at scale, and
- few robust markets that would drive equitable deployment.

Because of these common obstacles, the field would benefit from policy action that unites these solutions under a single umbrella and encourages consistency and collaboration across federal investments in carbon removal. Additionally, some carbon removal solutions like bioenergy with carbon capture and storage (BECCS) straddle the land and tech sectors, making it even more critical to develop federal policy that takes into consideration how to best develop these solutions utilizing expertise across federal agencies.

1. Expand and pass the CREATE Act to ensure a comprehensive, cross-agency carbon removal strategy

BY GIANA AMADOR & LUCIA SIMONELLI, PHD

Carbon removal solutions are technical and varied, and it is imperative that the diversity of the carbon removal portfolio be reflected in formal coordination across federal agencies. At present, federal carbon removal projects have been initiated in disjoint programs, but their growth and success depends on the implementation of a more comprehensive strategy. The Energy Act of 2020 established a much needed Carbon Removal Program within DOE with coordination from other agencies including USDA, but the breadth of carbon removal solutions requires an even broader governance structure.

The introduction of the bipartisan CREATE Act heralded a shift toward a more holistic vision for the government's role in carbon removal. This legislation includes the creation of a large-scale carbon management committee, a federal carbon removal initiative, and working groups tasked with the development of various categories of carbon removal solutions.

While the CREATE Act in its current form provides the potential for the most comprehensive policy for federal carbon removal to date, it does not include provisions for EJ or international coordination — considerations that are crucial for the development of a durable and equitable carbon removal future. To lay the foundation for a robust and effective federal carbon removal strategy, Congress should prioritize passage of an expanded CREATE Act.

1.A *Recommendation:* Prioritize passing an expanded CREATE Act that includes the following provisions and modifications

- Expand the executive committee to include one senior official from each of the following agences: DOI, EPA, Department of Commerce, and NSF.

- Additions to section (b) (2) under duties of committee should include a governance subsection:

  (G) incorporating appropriate governance structures and metrics,

  (i) engaging a comprehensive array of stakeholders across all carbon removal solutions,

  (ii) ensuring that public participation is prioritized through all phases of carbon removal development and deployment, and

  (iii) evaluating federal carbon removal initiatives across the portfolio using the metrics developed by the EJ working group.

- Establish a working group for EJ to identify metrics for environmental, social, and labor considerations across the carbon removal portfolio. These metrics should include preservation of environmental integrity, protection of frontline communities, and transition opportunities for fossil fuel workers.

1.B

Recommendation: Establish a working group for international coordination

The working group for international coordination should be tasked with coordinating carbon removal technology transfer, collaborating with other countries to facilitate equitable and durable carbon removal development and deployment, especially in the Global South, and creating a framework for formal collaboration in cross-solution carbon removal development, similar to Mission Innovation or the Carbon Sequestration Leadership Forum.

RELATED RESOURCES

- IC3 Innovation Action Plan on Carbon Capture, Mission Innovation
- Policy Group, Carbon Sequestration Leadership Forum

2. Codify the Interagency Working Group on Environmental Justice (EJ IWG) and strengthen requirements for the integration of EJ across federal agencies

BY UGBAAD KOSAR & VANESSA SUAREZ

A whole-of-government approach is critical to address the scope, scale, and urgency of the impending climate crisis. However, equity and justice must underpin all efforts to ensure that nobody is left behind.

In 1994, the EJ IWG was established to coordinate and advance EJ principles across the government. Each federal agency within the EJ IWG has a strategy to integrate EJ into programmatic efforts; however, these strategies are outdated and insufficient, and they must expand in scope and reach. An equitable and sustainable scale-up of carbon removal will require a stronger effort to advance EJ priorities into all federal programs and activities, especially those that impact carbon removal RDD&D.

2.A

Recommendation: Codify and expand the EJ IWG to improve the integration of EJ principles in all federal activities

The working group should be housed in EPA and ensure representation from every federal agency. The scope of the EJ IWG should include:

- strengthening the coordination across federal agencies and advising agencies in identifying and addressing any disproportionate burdens or environmental impacts of federal policies or programs on underserved communities,
- promoting meaningful involvement and due process in decision-making and the development, implementation, and enforcement of new and existing environmental laws,
- coordinating with and providing technical assistance to frontline communities to bolster self-determination of EJ communities, and
- identifying areas to improve direct public engagement by federal agencies with frontline communities.

The EJ IWG should submit a report to Congress no later than two years after establishing detailed outcomes and findings of the task force.

SIMILAR POLICIES

Bill Clinton's Executive Order 12898
Directs federal agencies to identify and address the disproportionate public and environmental health impacts their actions may have on socially disadvantaged communities, develop an EJ strategy, and promote nondiscrimination in federal programs.

Joe Biden's Executive Order 14008
Directs federal agencies to incorporate EJ into their programs, policies, and activities, establishes a White House Environmental Justice Interagency Council, creates a Justice40 Initiative, and orders development of a Climate and Justice Screening Tool.

CURRENT INITIATIVES

The Justice40 Initiative
A government-wide effort established through a Biden executive order, the Justice40 Initiative would deliver 40% of the overall benefits of relevant federal investments to disadvantaged communities. This is an important step in promoting distributive justice and should consider investments for carbon removal projects.

Grijalva-McEachin/Ruiz-Booker Environmental Justice for All Act

Would establish several EJ requirements, advisory bodies, and programs to address the disproportionate adverse human health or environmental effects of federal laws or programs on communities of color, low-income communities, or tribal and Indigenous communities.

RELATED RESOURCES

- Cumulative Environmental Impacts: Science and Policy to Protect Communities, Annual Review of Public Health
- Federal Agency EJ Strategies & Annual Implementation Progress Reports, EPA

3. Create an interdisciplinary roadmap for BECCS deployment options

BY MERON TESFAYE, PHD

Estimates around the capacity for BECCS to contribute to global climate change mitigation vary widely. For example, integrated assessment model (IAM) scenarios propose US annual carbon removal from BECCS to be as high as 1 gigaton of CO_2 by 2050, while the World Resources Institute estimates this number to be only 0.3 gigatons or less.[118, 119] This variability reflects uncertainty around sustainable biomass production, scale of deployment, impact on land use change and food prices, ability of electricity generation from biomass to compete with renewables, and potential impacts of large-scale BECCS on community economic and social wellbeing. BECCS and biomass-based carbon removal possess significant potential for combating climate change, as they offer low-cost carbon removal, revenue streams for farmers, and the potential for displacing fossil fuels in various energy and industry sectors. However, concerns around sustainable biomass sources and lack of infrastructure and effective governance structures continue to hinder the potential benefits. BECCS deployment can have implications on food, water, energy, biodiversity, economy, and social systems in the US. As a result, the role it plays in US climate mitigation efforts should be assessed in an integrated manner that takes the cross-cutting impact of BECCS into account.

118. Peters, G., & Geden, O. (2017). Catalysing a political shift from low to negative carbon. *Nature Climate Change 7*, 619–621. https://doi.org/10.1038/nclimate3369

119. Mulligan, J., Rudee, A., Lebling, K., Levin, K., Anderson, J., & Christensen, B. (2020). *CarbonShot: Federal Policy Options for Carbon Removal in the United States*. World Resources Institute. https://www.wri.org/publication/carbonshot-federal-policy-options-for-carbon-removal-in-the-united-states

3 . A

Recommendation: Develop a deployment roadmap for BECCS that ensures climate and social good

Congress should direct DOE's Bioenergy Technology Office (BETO) to develop a roadmap that lays out opportunities and risks associated with deployment scenarios for BECCS and biomass-based carbon removal in the US, in partnership with DOE's Office of Fossil Energy and USDA. BETO should assemble an interdisciplinary team to advise Congress on policy and US investment options including:

- realizable carbon removal pathways for biomass resources in the US, prioritizing waste biomass or biomass with minimal environmental impacts,
- improvement of life cycle assessment tools and standards of practice for biomass carbon removal,
- role of biomass in energy, transportation, hard-to-abate and biomass utilization sectors,
- job and revenue potential associated with different deployment scenarios,
- impact of international biomass-carbon marketplace on US, and
- socioeconomic consequences and EJ considerations for different deployment scenarios and multi-decade national goals.

RELATED RESOURCE

– 2020 Roadmap: Biomass Carbon Removal and Storage, Innovation for Cool Earth Forum

GLOSSARY

Bioenergy with carbon capture and storage (BECCS)
A form of energy production that utilizes plant biomass to create electricity, hydrogen, heat, and/or liquid fuel. This process simultaneously captures and sequesters some portion of the carbon from the biomass for storage.

4. Include biomass-based carbon removal products in the Value-Added Producer Grant program

BY MERON TESFAYE, PHD

According to the 2016 Billion-Ton report, agricultural waste and residues such as stalks, husks, cobs, and other biomass accounts for more than 30% of all dry biomass feedstock available in the US.[120] While some residues should be left on the ground to protect against soil erosion and loss of soil carbon, a large quantity of biomass remains underutilized in leaves and stalks after harvest. Current practice of crop residue disposal (leaving excess residue on the field and burning it in open air) can result in increased greenhouse gas emissions and local air pollution.[121] Farmers and agricultural producers can reap climate and financial benefits by

120. Langholtz, M. H., Stokes, B. J., & Eaton, L. M. (2016). *2016 Billion-Ton report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1.* US Department of Energy. https://www.energy.gov/eere/bioenergy/downloads/2016-billion-ton-report-advancing-domestic-resources-thriving-bioeconomy

121. Tripathi, N., Hills, C. D., Singh, R. S. & Atkinson, C. J.I. (2019). Biomass waste utilisation in low-carbon products: harnessing a major potential resource. *npj Climate and Atmospheric Science, 2*(35). https://doi.org/10.1038/s41612-019-0093-5

producing high-value products that also have significant carbon removal benefits using ag crop residue.

Small, individualized, modular pyrolysis units can be used on farms to produce bio-oil and biochar.[122] Biochar can be used as a soil amendment to improve crop yield, soil fertility, and nutrient and water-holding capacity, while serving as a carbon sequestration sink. Other carbon-negative higher-value products such as compost, consumer products, energy storage products, adsorbents, and catalysts can be derived from biochar. Bio-oil can be utilized to provide energy and substitute fossil fuel sources or store CO_2 below ground via direct bio-oil injection and disposal.[123] These routes can provide revenue streams for agricultural producers through value-added products. Inclusion of bio-oil and biochar for carbon-negative products in the Value-Added Producer Grant program can stimulate distributed utility of biomass for carbon removal, lower the cost of pyrolysis units, and provide direct environmental and financial benefit to agricultural producers.

4.A

Recommendation: Modify the Value-Added Producer Grant program to enable modular carbon removal

Congress should direct USDA to modify the Value-Added Producer Grant program to include biomass-based carbon-negative products such as bio-oil and biochar and expand working capital expense eligibility to include conversion technologies. For sustainable production and maximal environmental benefit, USDA should limit projects to producers that utilize crop residue and other on-farm waste. Along with regular financial performance reports received from grant recipients, USDA should facilitate life cycle assessments of these products for producers and require periodic carbon reporting and transparency to collect data as well as develop a standard of practice and certification process in the near future.

122. Wu, P., Ata-Ul-Karim, S. T., Singh, B. P., et al. (2019). A scientometric review of biochar research in the past 20 years (1998–2018). *Biochar, 1*(1), 23-43. https://doi.org/10.1007/s42773-019-00002-9

123. Sandalow, D., Aines, R., Friedmann, J., McCormick, C., & Sanchez, D. (2020). *Biomass Carbon Removal and Storage (BiCRS) Roadmap.* Innovation for Cool Earth Forum. https://www.icef-forum.org/roadmap/

GLOSSARY

Pyrolysis
Breakdown of biomass (plants, residue, or organic material) under moderate to high temperature and anaerobic conditions to produce heat, bio-oil, gas, and biochar.

Bio-oil
Liquid fuel produced from the breakdown of biomass through pyrolysis.

Biochar
A long-lived, carbon-rich charcoal-like product used as soil additive and produced from the breakdown of biomass through pyrolysis.

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