JULY 2017

CARBON REMOVAL POLICY: *Opportunities for Federal Action*

CENTER FOR CARBON REMOVAL

DEAR READERS,

Since the industrial revolution, the global economy has released about two trillion tons of carbon dioxide (CO_2) into the atmosphere, largely from burning fossil fuels. While continuing to add to this total is risky business, historical CO_2 emissions do not have to remain a permanent liability.

In fact, carbon removal innovators have already begun to explore how to transform those trillions of tons of excess CO_2 in the atmosphere into trillions of dollars of valuable products and services—and, in turn, create new jobs, investment opportunities, and strategies for environmental protection. For example, better forestry and agricultural practices can harness the power of photosynthesis to capture CO_2 from the air and lock carbon away in soils and plants—and, in the process, make our food system more efficient, resilient, and profitable. New industrial technologies are also being developed to capture CO_2 directly from air and use it to manufacture cleaner chemicals and stronger building materials, or store it underground as an atmospheric cleanup service.

Like all new enterprises, carbon removal businesses face numerous challenges that policymakers are well suited to address. Established companies and investors hesitate to invest in technology development when markets and regulations are uncertain, and land managers operating on thin margins are often averse to adopting new practices. As a result, policymakers hold great power to unlock the potential of carbon removal strategies today. While some smart policies related to carbon removal have already been written and vetted by U.S. federal policymakers, there have been few policies enacted that support the development of carbon removal strategies.

This report equips policymakers with the information needed to make smart and robust policies that accelerate the progress of carbon-removing enterprises. If enacted, these strategies could unlock investment in targeted research and innovation, create incentives for early deployments of promising solutions, and provide regulatory clarity for project developers. The ideas in this report are by no means limited to the U.S. federal context, and we hope this report can spark dialogues and action in city, state and national governments around the world.

What the report also shows is that the time for leadership on carbon removal policy is now. The opportunity to clean up CO_2 from the air and catalyze trillions of dollars in value creation, new jobs, and a stronger environment is simply too large to leave on the sidelines any longer.

Thank you in advance for pioneering the carbon removal policy frontier with us!

Noah Deich

Executive Director, Center for Carbon Removal

TABLE OF CONTENTS

LIST OF ACRONYMS

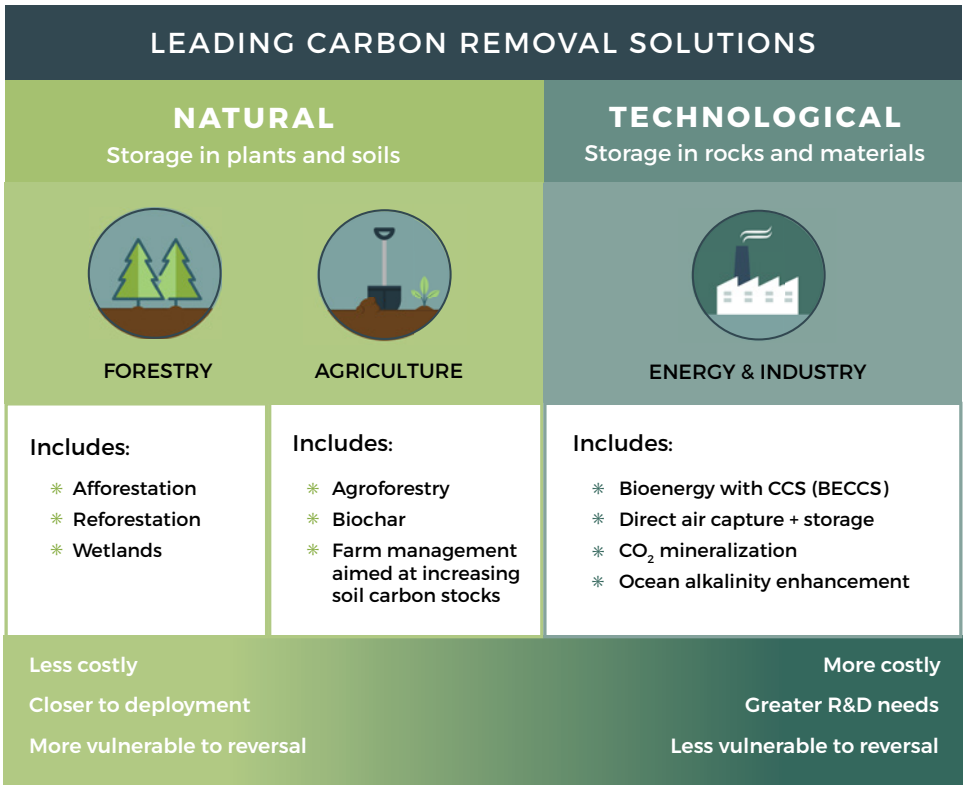
AFRI	USDA National Institute of Food and Agriculture's Agriculture and Food Research Initiative
ARPA-E	Department of Energy Advanced Research Project Agency - Energy
ARS	USDA Agriculture Research Service
CCS	Carbon Capture, Utilization, and Storage
CDR	Carbon Dioxide Removal
CO_2	Carbon Dioxide
COMET	Carbon Management Evaluation Tool
DAC	Direct Air Capture
DOE	Department of Energy
DOI	Department of Interior
EERE	DOE Office of Energy Efficiency and Renewable Energy
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
FE	Fossil Energy
FWS	Fish and Wildlife Service
GHG	Greenhouse Gas
LCA	Lifecycle Carbon Assessment
MLP	Master Limited Partnership
NAWCA	FWS North American Wetlands Conservation Grant
NETL	National Energy and Technology Laboratory
NRCS	Natural Resource Conservation Service
NWCA	National Wetlands Conservation Assessment
OAR	EPA Office of Air and Radiation
ORD	EPA Office of Research and Development
PAB	Public Activity Bond
REIT	Real Estate Investment Trusts
USDA	United States Department of Agriculture
USFS	United States Forestry Service
USGS	United States Geological Survey

INTRODUCTION

BACKGROUND

"Carbon removal" describes the capture and reliable storage of CO_2 from the atmosphere. Carbon removal strategies enable businesses to transform CO_2 in the air into valuable products and services, while cleaning the air in the process. For example, agriculture companies can turn atmospheric CO_2 into healthier soils and more resilient food systems, and manufacturing companies can use atmospheric CO_2 to make stronger building materials and cleaner fuels and chemicals. The new jobs and investments offered by carbon removal can help communities in all geographies prosper from reducing risks related to climate change.[1]

Leading carbon removal strategies fall under two broad categories: natural (such as forests and agriculture) and technological (such as energy, manufacturing, and mining).[2]



Negative-emissions approaches can include use of natural systems (e.g., forest or other ecosystem restoration, agricultural soil carbon sequestration) and technological systems (e.g., bioenergy, direct air capture coupled with storage in long-lived materials or geologic formations, accelerated CO_2 mineralization processes).

[1]See Appendix II for a discussion of the climate math and the importance of carbon removal for meeting Paris Agreement targets.

[2]Numerous other carbon removal solutions besides those listed here have been proposed, but have not yet advanced past a concept stage of development. While further research into these solutions would be valuable, this report focuses on policy recommendations for the more developed approaches that could benefit from a wider range of policy action today.

Now is the time for Federal policy makers to unlock the economic, job creation, and climate change stopping potential of carbon removal.

WHY IS CARBON REMOVAL POLICY IMPORTANT TODAY?

A number of barriers hinder the scale-up of promising carbon removal strategies, including:

- Insufficient information about the technical, economic, social, and environmental aspects of leading carbon removal solutions.
- Lack of funding for innovation to drive down solutions costs.
- Inconsistent regulations and incentives that hinder project development and private-sector commercialization.
- Patchwork quantification standards and regulations for ensuring carbon storage is measured in a consistent, fair, robust, and cost-effective manner, and for protecting health and safety of communities from any unintended negative effects of carbon removal solutions.

Better policy can overcome these barriers.

WHY THE U.S. FEDERAL GOVERNMENT?

Federal action on carbon removal policy is important for a number of reasons. First, the U.S. federal research enterprise, including the National Labs and National Science Foundation, is unparalleled in its scientific capabilities, and offers a unique opportunity to advance carbon removal innovation at a swift pace. Second, interstate commerce, environmental, and agricultural regulations oversee the markets that carbon removal innovators are pursuing. Lastly, federal tax and finance policy can accelerate early market adoption of carbon removal approaches.

KEY POLICY LEVERS

"Today, federal policymakers can take action in four key areas to reduce or remove the barriers holding back carbon removal strategies."

INVESTMENT IN RESEARCH AND INNOVATION

Federal investment in research and innovation can reduce costs, improve reliability, and mitigate the environmental and social risks of carbon removal. However, today, there are only small and loosely coordinated research and innovation efforts directed to carbon removal. Increasing federal investment in research and innovation around carbon removal to match investment in other leading energy and agriculture technologies will speed up the development of emerging carbon removal strategies.

The largest federal research and innovation investment opportunities include: (1) basic and applied research; and (2) pilot projects and demonstrations.

Basic and applied research

Research will illuminate how carbon cycles through ecosystems and industries (life cycle assessments), and guide improvements in technologies and practices for measuring and verifying carbon storage. Applied research can help develop materials and processes to reduce the costs of CO_2 capture, transportation, and utilization. Finally, research can highlight the social, economic, and environmental impacts of proposed carbon removal solutions.

Pilot projects and demonstrations

Carbon removal solutions must be demonstrated in real-world applications to improve technical performance and reliability and to identify any unforeseen challenges for larger-scale deployment. Demonstration will address public health and safety concerns and draw in risk-averse private sector capital. Demonstrations must occur in a range of environmental conditions and markets because different settings affect the financial viability and ecological implications of carbon removal strategies.

U.S. DEPARTMENT OF ENERGY

Demonstration investments by the U.S. DOE were critical for the launch of this bioenergy carbon capture project in Decatur, IL, and will likely prove important for other first-of-a-kind carbon removal projects.

MARKETS AND INCENTIVES

To overcome barriers to commercializing carbon removal in the near-term, there are a range of tax and financial instruments that federal policymakers can deploy to spur adoption of promising carbon removal solutions. Expansion of a number of existing tax incentive programs in the energy and agricultural sectors will give carbon removal projects a fair chance to compete, drive innovation, and unlock private capital. In the future, carbon removal can be a strong complement to most of the leading proposals for comprehensive, market-based climate policy, such as a carbon tax or fee-and-dividend.

The Treasury Department provides a number of tax-advantaged financing structures across the energy, manufacturing, and land management sectors. If finance tools like Master Limited Partnerships, Private Activity Bonds, and Real Estate Investment Trusts were extended to carbon removal, they could help shovel ready projects move private money off the sidelines and into these investments.

The adoption of carbon sequestering agricultural practices could be accelerated with targeted financial support from policymakers. No or low-till practices, cover crop planting, or mulching can increase soil fertility, yields, and carbon storage.

While carbon accounting protocols already exist for forest expansion, it will be critical to harmonize these efforts with other carbon removal solutions and improve the efficacy and cost of measurement and verification.

ENCOURAGING PUBLIC-PRIVATE PARTNERSHIPS

The federal government can "crowd-in" private sector capital to carbon removal in a number of ways. First, it can leverage its research capabilities to analyze and share information about the opportunities and challenges facing carbon removal solutions. Second, it can bring key stakeholders across industry and civil society together to catalyze project development. Third, it can collaborate with industry and civil society to accelerate the buildout of carbon removal infrastructure projects.

CLIMEWORKS

The world's first commercial direct air capture plant benefited from public and private sector funding.

REGULATIONS AND STANDARDS

Streamlined regulations and updated standards can also help accelerate the development and deployment of carbon removal solutions.

Promote a common measuring stick for carbon storage

An "apples-to-apples" strategy for measuring carbon uptake, verifying its secure storage, and accommodating the upstream carbon impacts will ensure that each ton of carbon sequestered is legitimate and counted fairly across natural and technological solutions. Policymakers can harmonize existing lifecycle carbon assessment (LCA) protocols for specific solutions to ensure that all carbon removal initiatives can account for their carbon impacts in a transparent, publicly available, user-friendly, inexpensive, and consistent manner across all agencies. Common LCA frameworks also must leverage affordable and accessible instrumentation for measuring carbon removal and must be recognized by other regulatory and voluntary carbon pricing schemes at the state, national, and international levels.

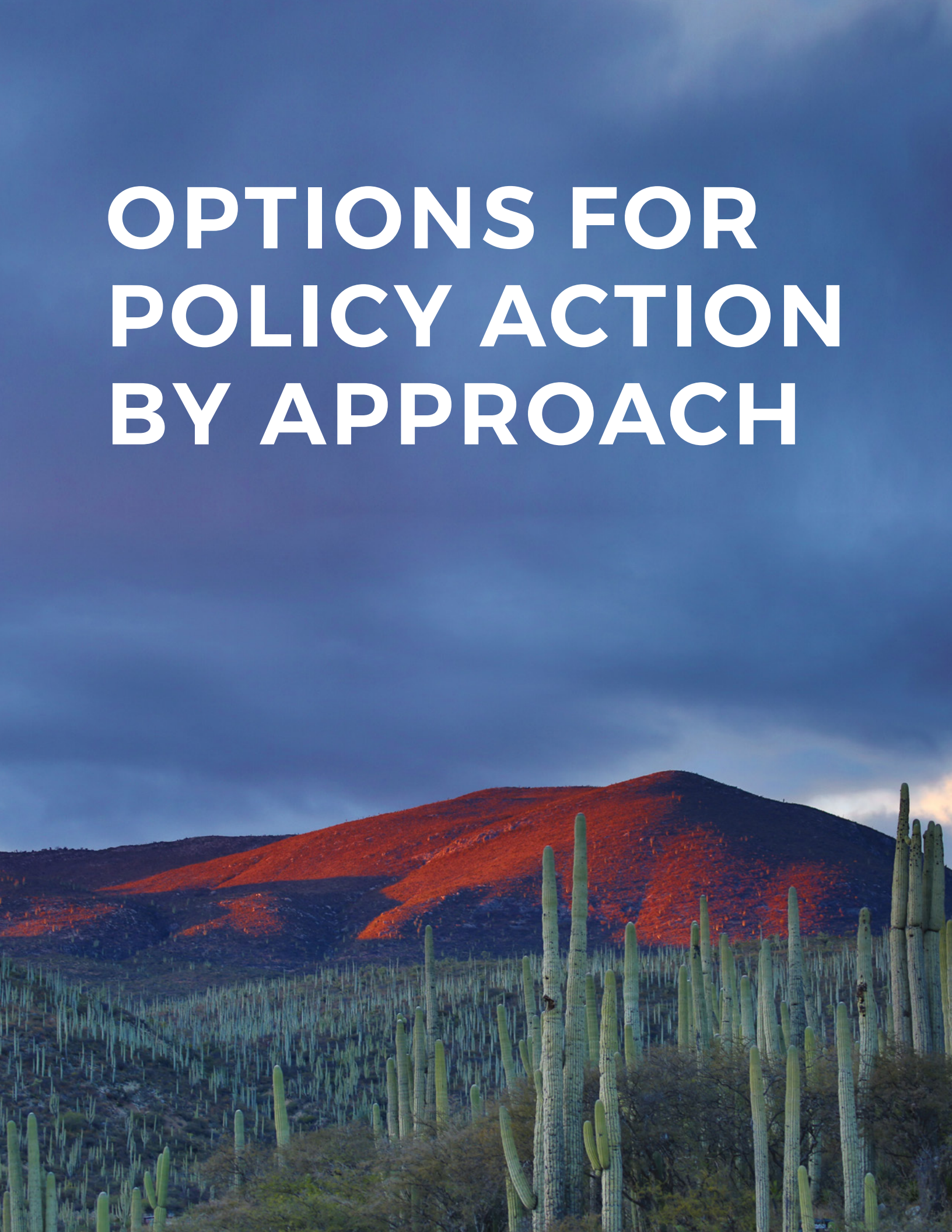
Clean up regulations pertaining to carbon removal

A clearer and more workable regulatory landscape will help innovators scale up their nascent carbon removal initiatives. At the same time, communities and stakeholders must know that they will be protected from any negative unintended externalities from carbon removal projects. To achieve these dual goals, Congress and federal agencies must clarify uncertain regulations relating to carbon removal projects, work swiftly to review project submissions under existing rules, and ensure any updated regulations are developed with broad stakeholder input.

A note on the role of economy-wide climate policy for carbon removal:

In the long run, comprehensive climate policy that prices CO2 fairly, consistently, and transparently can greatly accelerate the development and deployment of carbon removal solutions. When comprehensive climate action is seriously considered—be it as a carbon tax, cap-and-trade, or other regulatory approach, it will be critical to ensure that pathways for carbon removal can compete on a level playing field. In particular, robust carbon measurement and verification standards can enable carbon removal solutions to participate in economy-wide climate policy. However, an economy-wide climate policy is far from the only way to advance carbon removal solutions in the near term, so we need not wait to start taking action on carbon removal.

OPTIONS FOR POLICY ACTION BY APPROACH



CARBON ENGINEERING

Innovative companies like Carbon Engineering are manufacturing direct air capture technologies that have the ability to remove CO_2 from ambient air and recycle it for use in other valuable products.

CCS SHOVEL READY POLICIES[3]

S.3179 - Carbon Capture Utilization and Storage Act

Amending Section 45(Q) of the Tax Code to expand and enhance credits for CO_2 utilization and storage. In July 2016, Senators Heidi Heitkamp (D-ND) and Sheldon Whitehouse (D-RI) introduced legislation to extend and expand the 45Q tax credit for carbon capture and sequestration to include utilization beyond enhanced oil recovery (EOR) and to boost the credit for saline storage. There is a bipartisan House companion bill led by Rep. Mike Conaway (R-TX). However, this companion bill does not include the non-EOR provision or the higher saline storage credit. Congress can act in 2017 to pass a 45Q tax proposal that includes the non-EOR and higher saline storage credit provisions in the Senate bill.

Barrasso-Schatz Air Capture Amendment to S. 2012 - The Energy Policy Modernization Act (EPMA)

During floor consideration of The Energy Policy and Modernization Act in January of 2016, the Senate accepted Amendment 3017 from Senators John Barrasso (R-WY) and Brian Schatz (D-HI) to expand the US Department of Energy (DOE) authority to award technology prizes to projects that separate carbon dioxide from dilute sources (e.g., direct air capture.)

[3] A consolidated list of shovel ready policies across all carbon removal strategies can be found in Appendix I.

Manchin Net-Negative CCS Amendment S. 2012 - The Energy Policy Modernization Act (EPMA)

In January 2016, Senator Joe Manchin (D-WV) offered Amendment 3270 to The Energy Policy and Modernization Act in order to modify provisions relating to the Coal Technology Program in the DOE's Office of Fossil Energy. This amendment formally names net-negative carbon dioxide emissions projects as a programmatic priority for DOE FE, and authorizes $22 million per year over five years to fund net-negative demonstration projects. The amendment also names other research objectives that directly support commercial-scale carbon removal, including the requirement to validate geologic assets for carbon storage and the opportunities for carbon utilization beyond sequestration.

H.R. 2883, The Master Limited Partnerships Parity Act

In the 114th and 113th Congresses, Senators Moran (R-KS) and Coons (D-DE) and Congressmen Ted Poe (R-TX) and Mike Thompson (D-CA) introduced legislation to expand the financing tool known as Master Limited Partnerships (MLP) beyond fossil energy and pipeline projects. MLPs are a business structure that is taxed as a limited partnership—reducing the tax burden for specific projects—but owned and traded like corporate stock on a market, allowing for greater liquidity. Under current law, CCS projects on fossil-fueled power plants cannot be structured as MLPs, but the MLP Parity Act (S. 1656 in the 114th Congress) would open these incentives to such projects. In addition, this bill can be strengthened by accommodating capture projects in which the carbon is utilized after capture.

S.843, Carbon Capture Improvement Act of 2017

Section 142 of the Tax Code has provided a tax-exempt bond market for select industries for over a century. Section 142 is designed to unlock private investment in projects that may not otherwise have access to traditional financing, but would have a public benefit, such as highway transfer facilities, sewage facilities, and green buildings (Internal Revenue Service, 2016). CCS and some other carbon removal projects would be an appropriate addition to the list of qualified projects for PAB-eligibility. Senators Portman (R-OH) and Bennett (D-CO) introduced legislation in 2015, the Carbon Capture Improvement Act, to allow private activity bonds for "traditional" CCS facilities and enhanced oil recovery. Such legislation can be expanded to accommodate capture projects where the carbon is otherwise utilized after capture.

OPPORTUNITY

Carbon Capture, Storage and Utilization (CCS) technologies provide an opportunity to "mine the sky" for CO_2 in the atmosphere, turning a waste product into a valuable resource. By capturing CO_2 directly from the air, CCS technology projects can provide an air-cleaning service while also supplying CO_2 as a resource for companies manufacturing products like building materials and consumer goods.

Many CCS approaches offer such carbon removal potential. They are distinguished from other more conventional CCS strategies by two criteria:

Capture of CO_2 from: sustainable bioenergy production or biomass utilization; or ambient air via direct air capture (DAC) technologies and clean energy.

Storage of CO_2 in: long-lived building materials or consumer goods like cements; or geologic destinations, such as depleted oil fields to support enhanced oil recovery, below-ground saline aquifers, or accelerated mineralization of the CO_2 in rock formations.

A note on the relationship between carbon-removal and low-carbon CCS[4]:

Carbon-removing CCS technologies can overlap considerably with traditional bioenergy and with CCS systems used with fossil energy and industrial production. Furthermore, CO2 captured from bioenergy or DAC sources can be used for short-lived utilization approaches (such as synthetic fuel or chemical production). It is important to include all of these related CCS and CO2 utilization solutions in discussions of carbon removal policy, as they can offer pathways to advance carbon removal CCS projects in the future, even if they do not result in immediate carbon removal.

[4]See Appendix IV for further explanation of atmospheric v. fossil CCS technologies

"The Federal Government is well positioned to lift barriers to large-scale commercialization of carbon removal."

There are a number of opportunities for carbon-removing CCS projects to gain market traction in the near term. There is already a significant demand for CO_2 use today, even without comprehensive carbon pricing. Markets already demand captured CO_2 for various applications, including the production of building materials, enhanced greenhouse agriculture, and chemical and fuel synthesis (Cuéllar-Franca, 2015).

In addition, proper geologic storage is safe, secure, and ready for scale. Decades of operational experience show that transport and storage of CO_2 underground can be accomplished safely and with low risk of reversibility. Moreover, many of the perceived risks surrounding transportation and security of CO_2 can be mitigated by greater emphasis on research and demonstration. Widely accepted regulations that protect public health and safety around carbon storage sites can also help reduce real and perceived risk (Holloway, 2005).

CLIMEWORKS

Climeworks direct air capture machine, or "mechanical tree", captures CO_2 from the air for uses including in greenhouses and storage underground.

BARRIERS AND POLICY OPTIONS

Uncertainties about future pathways for the commercialization of carbon removing CCS strategies

Despite a number of promising commercialization opportunities today, many barriers remain to large-scale commercialization of atmospheric CCS technologies. To address these uncertainties:

The Administration could establish an interagency working group to develop a carbon removal technology commercialization roadmap, building on the 2016 Secretary of Energy Advisory Board report on this topic to outline specific research programs at relevant agencies (Secretary of the Energy Advisory Board CO_2 Utilization Task Force, 2016). USGS and DOE can expand their mapping capabilities for geologic storage resources to identify optimal sites for carbon removing CCS projects.

Technology cost and performance

Technology costs remain high for first-generation carbon capture materials and systems. Costs are also high for advanced bioenergy and for many CO_2 utilization technologies compared to more mature energy and carbon management technologies. To help reduce costs and improve performance of carbon-removing CCS solutions, policymakers can:

DOE, USGS, and the National Science Foundation can increase investment in research for novel materials for DAC and bioenergy CO_2 capture, bioenergy supply chain logistics, geologic storage in saline aquifers and CO_2 mineralization, and cost-effective approaches for CO_2 utilization beyond EOR.

DOE can increase investment in demonstration projects at the $10M scale for emerging DAC technologies at the 1,000 tCO_2/yr level or greater with the goal of <$200/t CO_2 DAC by 2025. DOE can also leverage federal facilities such as the National Carbon Capture Center in Alabama to invest in full-scale pilots of innovative carbon capture technologies relevant to bioenergy and direct air of $50M-$200M.

"Further effort is required to improve carbon accounting and monitoring for all carbon removal solutions under the CCS technology umbrella."

Market and regulatory clarity

Uncertainties around tax and environmental regulations hinder the development of CCS projects. To clarify and strengthen markets and incentives for carbon removal CCS strategies, policymakers can:

Expand existing incentive programs that are applicable to CCS and bioenergy, and provide dedicated incentives for CO_2 capture from bioenergy and direct air sources via new legislative proposals.

Expand existing tax-advantaged financing mechanisms to be technology-agnostic and cover carbon-removing CCS options in addition to conventional projects.

Issue clear guidance on EPA Class VI regulations and expediently review permit applications, or promote state-level regulatory responsibility through grants of primacy.

Robust Lifecycle Carbon Assessment (LCA) frameworks for monitoring and verifying carbon sequestration

Further effort is required to improve carbon accounting and monitoring for all carbon removal solutions under the CCS technology umbrella. To remedy these gaps, DOE can increase funding to conduct LCA for the full range of carbon sequestration approaches gaining market traction today. EPA can also work with the Treasury Department to harmonize regulations pertaining to the reversibility of geologic CO_2 storage for tax accounting purposes.

Policy changes can encourage a shift from soil-depleting conventional agricultural practices towards perennial crops, no-till, cover cropping, and other strategies to restore agricultural soils, improve farm economics, and protect the environment.

AGRICULTURE SHOVEL READY POLICIES

H.R. 5316, the Healthy Soils and Rangeland Solutions Act

This bill, introduced in May 2016 by Rep. Jared Huffman (D-CA), would establish a grant program at the Department of Interior (DOI) for pilot projects to explore the restoration of degraded soils, the application of compost and biochar amendments, and grazing modifications on public lands. A pilot program as envisioned in H.R. 5316 would be a big step in understanding which management practices effectively promote biological carbon sequestration and would inform future management of public lands. Congress can reintroduce and pass this bill in the 115th Congress.

H.R. 3748, Water Efficiency via Carbon Harvesting and Restoration (WECHAR) Act of 2009

In 2009, House and Senate members introduced legislation called WECHAR to set up a joint DOI and USDA loan guarantee program to commercialize biochar production units. The bill specifically called for biochar projects that

produce net-negative carbon emissions. It would also support pilots of biochar production units in order to demonstrate commercial viability and evaluate the impacts of biochar across a variety of environmental conditions. Last, WECHAR authorized a grant program at USDA to research the attributes and environmental impacts of biochar. Congress can update and reintroduce this legislation in the 115th Congress.

Updating Cover Cropping Guidelines

The Federal Crop Insurance Corporation, managed by the USDA Risk Management Agency (RMA), insured 298 million acres in 2015, which covers 13% of total U.S. land. RMA prescribes actions that farmers receiving Federal Crop Insurance must take in order to control risks and qualify for the program, including guidelines for cover cropping. The RMA guidelines are unnecessarily complex and stringent, and a wide range of stakeholder groups led by the National Working Group on Cover Crops and Soil Health have petitioned RMA to relax them (National Working Group on Cover Crops and Soil Health. 2015). In the Crop Insurance title of the next Farm Bill, Congress can instruct RMA to simplify cover cropping guidelines to reduce bureaucratic burdens on farmers and expand cover cropping, which supports the long-term productivity and resiliency of the farm, while reducing soil erosion, increasing water retention, and increasing net soil organic carbon.

OPPORTUNITY

Carbon farming agricultural practices pull carbon dioxide from the atmosphere through photosynthesis and store carbon above ground (through crop residues, animal wastes, etc.) and below ground (soil biota, roots). Carbon farming practices have been demonstrated in a wide range of agricultural production systems, including:

Row crops

Breeding and deployment of more carbon-consumptive cultivars (e.g. extra-long roots), conservation tillage/no-till agriculture, cover cropping, and crop rotation.

Livestock

Ranchers that follow livestock grazing patterns or apply compost to maximize soil productivity and reduce perturbation, mimicking the ecology seen in natural rangelands.

Agroforestry

Incorporation of perennial crops like trees into other agricultural operations.

Biochar

Biochar as a soil amendment to enhance the productivity of agriculture and forestry practices and help retain water and nutrients in the soil under the right conditions (Toensmeier, 2016).

• • •

Agricultural soils have enormous and largely underutilized capacity to store carbon, and deliberate management activities can tap into this potential. One estimate from the United Nations "4/1000 Initiative," which seeks to boost overall global soil carbon content by 0.4 percent per year, suggested that increasing carbon levels in soils at that rate would halt the increase of CO_2 entering the atmosphere, even if fossil fuel emissions continued to rise. In addition, a survey of soil carbon content in California uncovered a wide range in how much carbon is being trapped from one acre to the next, highlighting the potential for major soil carbon increases with changes in management practices (Silver, 2010).

Many of the management practices that fall under the carbon farming umbrella have been demonstrated in commercial farm applications for decades or more. For instance, transitional organic crop production practices generate 18% lower GHG emissions than conventional production (Venkat, 2012). As a result, carbon farming practices can be implemented relatively swiftly with the right policy support.

"Agricultural soils have enormous and largely underutilized capacity to store carbon, and deliberate management activities can tap into this potential."

BARRIERS AND POLICY OPTIONS

Robust markets and fair regulations for carbon farmed products

To realize the promise of carbon farming, markets and regulations can do more to incentivize farmers to deploy carbon farming techniques at large scales. In many cases, farmers face regulatory barriers discouraging carbon farming strategies that would otherwise be profitable. To reduce these barriers, there are numerous opportunities for federal policy action, including:

Congress can reform existing USDA conservation programs, with the aim of incentivizing practices that sequester and store carbon. For example, the Conservation Measurement Tool used by the Conservation Stewardship Program to rank proposals and determine payment rates could be modified to accommodate carbon-sequestering practices more effectively. The Conservation Reserve Program could prioritize payments for lands that have the greatest carbon sequestration potential.

Cows can be part of the climate change solution. Policy can help ranchers monetize the benefits of carbon farming.

The Food and Drug Administration's Generally Recognized as Safe program can work expediently to approve the use of carbon-sequestering cultivars for use in food to boost consumer demand for carbon farming. Additionally, the Federal Trade Commission can partner with the USDA Agricultural Marketing Service to develop biochar standard or classification system that would improve consumer confidence in various biochar products on the market. Lastly, the USDA National Organic Program can assess how the Organic standard can be enhanced to encourage carbon farming practices.

Congress can modify the Federal Crop Insurance Program to encourage farmers to adopt the full range of carbon farming approaches.

Science and communication to improve understanding of soil carbon storage

Uncertainties around direct carbon benefits and other co-benefits of carbon farming, such as reduced reliance on fertilizers, are still too high to facilitate widespread investment in these practices based primarily on carbon storage value. The cost-effectiveness and efficacy of carbon farming depend on local climate and soil conditions, as well as transaction and administrative

costs, and the impact of these factors are not well understood in all places. Extension and education services have not kept pace with research, and carbon sequestration is not being considered as part of best practices. Policies that can address these barriers include:

USDA's Agriculture Research Service (ARS) and the National Institute of Food and Agriculture's Agriculture and Food Research Initiative (AFRI) can expand research and innovation activities related to carbon farming practices, including funding for new demonstration projects to evaluate and improve the carbon storage potential of new cultivars, soil management practices, grazing practices, and other innovative practices. ARS can also work with USDA Natural Resources Conservation Service (NRCS) to establish field sites, including on private lands, conducting longitudinal research on net GHG storage in soils.

USDA Conservation Innovation Grants can expand support projects aimed at demonstrating and improving the cost-effectiveness, integration, and efficacy of farming practices based on carbon storage value.

NRCS can accommodate carbon farming more robustly in its Best Management Practices recommendations, and expand engagement around the COMET platform.

USDA can lead a multi-pronged biochar field program with the goal of developing a strong biochar carbon quantification framework. Third-party assessments by groups like the National Academy of Sciences to understand biochar lifecycle emissions and all related co-benefits could also help synthesize existing scientific research and prioritize further support for biochar.

Easy to implement soil carbon monitoring strategies

Many farms cannot afford tools, strategies, and standards to monitor and verify how carbon cycles in and out of the land. Increased support for applied scientific research could help bring down costs of quantification of carbon and reduce uncertainties around soil carbon sequestration levels, bringing these techniques within reach for farmers. With greater monitoring and verification of soil carbon levels, farmers will have more opportunities to earn fair compensation for their carbon removal services. Agencies such as EPA's Office of Air and Radiation (OAR) and Office of Research and Development (ORD), as well as the USDA, are positioned well to collaborate on the development of more sophisticated, lower cost, and easily operable soil GHG monitoring technologies.

"Farmers will have more opportunities to earn fair compensation for their carbon removal services."

Policies and incentives that expand and protect healthy, sustained, and growing forests facilitate carbon sinks, a prosperous forest products industry, and numerous other ecosystem services across the United States.

FORESTS SHOVEL READY POLICIES

The Wildfire Budgeting, Response, and Forest Management Act of 2016

In the 114th Congress, Senator Lisa Murkowski (R-AK), Chairman of the Senate Energy and Natural Resources Committee, introduced legislation to end the U.S. Forest Service (USFS) practice of fire borrowing. This bipartisan bill was not completed by the end of the year. Congress can reintroduce this legislation and work to incorporate biomass production into the fuel reduction components of such a bill. For example, the Forest Service could be authorized to award biochar feedstock contracts up to 20 years, along with the timber and stewardship contracts already accommodated in the draft legislation, and give contract preference to entities that agree to convert the timber to biochar.

OPPORTUNITY

Forests use photosynthesis to capture and use CO_2 from the air, sequestering carbon in their biomass and soils. Forests cover about one-third of U.S. area, or about 765 million acres in the United States (Oswalt, 2017). Researchers estimate that existing U.S. forest stands sequester the equivalent of 1.2 billion tons of CO_2 per year or roughly 18% of national emissions (Oswalt, 2017; Lu, 2015).

Not only can preserving existing forests help draw carbon out of the atmosphere, but large deforested regions can also be restored and even expanded. This would boost the forest products industry, enhance natural landscapes, and offer greater ecosystem services to communities. In simulations produced by the National Academy of Science, afforestation and reforestation policies in the United States facilitated an increase in food production, ecosystem services, and carbon storage, while only marginally decreasing habitat for a quarter of modeled species (Lawler, 2014). According to a U.S. Department of Agriculture (USDA) report, approximately 200 million metric tons of carbon could be sequestered per year at a cost of $50 per ton CO_2, and this storage could increase up to 300 million tons per year at a price of $100 per ton CO_2 (Nielsen, 2014).

Forests remove CO_2 with technology tested for 3.4 billion years: Photosynthesis.

"Data from carbon stock monitoring on public lands is often hard to access and evaluate."

BARRIERS AND POLICY OPTIONS

Availability and quality of data on carbon stored in forests

While several agencies have contributed to developing a robust understanding of the carbon stocks in US forests, such as through the Forest Inventory and Analysis database, there is no comprehensive federal framework for evaluating the value of carbon stored through forest management activities. Furthermore, data from carbon stock monitoring on public lands is often hard to access and evaluate. These data gaps make it difficult to optimize forest management activities based on carbon sequestration potential, as well as to account for the contributions of forests in climate action plans. Policy options to address these barriers include:

The U.S. Geological Survey (USGS) can improve forest data quality by dedicating more resources in the LandCarbon program to studying the carbon cycle and ecological impacts of potential forest expansion and management approaches on both public and private lands (USGS, 2017).

The Environmental Protection Agency (EPA), USGS and USFS can also collaborate on an effort to improve transparency and data availability on current forest carbon stocks and forecasting.

Economic incentives supporting forest carbon storage strategies

Few federal policy incentives exist for forest expansion and management for carbon sequestration as a dedicated outcome at this time, leading to markets that undervalue forest restoration and expansion. Policy options to create stronger markets for forest carbon sequestration include:

USDA can expand the Conservation Innovation Grant program to offer opportunities for innovative financing schemes that incentivize new forest management practices based on carbon sequestration value.

USFS can increase public-private partnerships and technical assistance for a wider use of harvested wood products from restored and expanded working forests.

In addition, USFS can incentivize the use of infested wood for biomass energy, with care to ensure the ecological integrity and recovery of the remaining forest. Lastly, USDA Agriculture Research Service (ARS) and the USFS can partner with USGS to investigate the potential for in situ biochar applications in forests, including its potential for wildfire risk reduction, soil health improvement, and enhancement of other ecosystem services.

Future regulatory or trading schemes for carbon can be designed to create incentives for private forest owners to increase standing carbon stocks.

America's forests, plants, soils, and wetlands store vast amounts of carbon.

Management plans and funding for forests on federal land

Current forest management plans do not explicitly seek to optimize carbon storage. In addition, the USFS budget for forest management and restoration is burdened by the practice of fire borrowing, where management funds are rerouted to emergency wildfire suppression. As a result, federal forest management activities do not enable as much carbon sequestration as optimal. Policy options to address these gaps include:

USFS can develop and implement forest management plans that include strategies for optimizing forest rotation ages, catalyzing the recovery of forests post-disturbance, and managing the transitions of forest species composition to prevent losses of carbon stocks and ensure high carbon sequestration capacity.

USDA and USFS can collaborate to research the ecological trade-offs of wide-scale forest expansion in previously unforested lands and incorporate best practices into public land management plans.

Congress can pass legislation to end fire borrowing, while making sure wildfire suppression is adequately funded through a dedicated resource stream, and that appropriations are increased for USFS reforestation and afforestation capacity and activities.

Congress can request a new study examining the costs and benefits of restoring degraded or impacted forests—including the ecological benefits for threatened and endangered species, water provision, reduced wildfire threat to nearby communities, and the value of carbon that will be sequestered in restored forests.

Peat wetlands, mangroves, and saline marshes in the United States have historically been neglected and degraded, but restoring and expanding wetlands can sequester significant amounts of carbon and provide other benefits to communities and nature.

OPPORTUNITY

Wetlands are ecosystems that are saturated with water for all or part of the year, a quality that allows them to have some of the highest carbon densities of all ecosystems. Globally, wetlands store an estimated 300 to 700 billion tons of carbon (Lenart, 2009).

In the United States, natural wetlands have been reduced by over 90% since the country's founding (Dahl, 1990). Constructing new wetlands can make an outsized contribution to carbon removal. Studies estimate that constructed wetlands can sequester 2.7-24 tons of CO_2 per hectare per year (de Klein, 2014).

Wetlands also offer a range of high-value economic, environmental, and social benefits. Both natural and constructed wetlands offer unparalleled ecosystem services, such as biodiversity support, water quality improvement, flood abatement, and recreation (Zedler, 2005).

"Both natural and constructed wetlands offer unparalleled ecosystem services."

BARRIERS AND POLICY OPTIONS

Aligning economic incentives with wetland preservation and expansion. Wetlands are often displaced by more financially lucrative or productive land uses and conversion opportunities, like urban development. A number of incentives for wetland preservation and expansion exist today, but can be strengthened to better counteract such competition, including:

The Fish & Wildlife Service (FWS)'s National Coastal Wetlands program and the North American Wetlands Conservation Grants (NAWCA) can be expanded and modified to prioritize carbon storage. In the past two decades, NAWCA programs have funded nearly 3,000 projects over 33 million acres of wetlands, with about a third of funds coming from the federal government. FWS can incorporate carbon sequestration as a criterion in grants for these projects, and expand grantmaking to reflect the value this program brings in carbon storage services.

The USDA Wetlands Reserve Program provides financial incentives to private landowners and farmers to conserve and restore wetlands. This program could also be expanded and refined to prioritize carbon storage as a key restoration metric.

Section 404 of the Clean Water Act and the mitigation banks it supports at EPA's Office of Wetlands, Oceans and Watersheds could be enhanced to prioritize carbon sequestration. This section of the Clean Water Act provides for the protection of wetlands. It requires developers to preserve wetlands and to build compensatory mitigation projects where the destruction of wetlands is unavoidable.

Globally, wetlands store an estimated 300 to 700 billion tons of carbon.

"Studies estimate that constructed wetlands can sequester 2.7-24 tons of CO_2 per hectare per year."

Improving understanding of greenhouse gas fluxes and high value restoration opportunities

Additional science can improve our ability to quantify the value of carbon sequestered in wetland restoration and to learn more about the fluxes of various greenhouse gases (GHGs) in restored wetlands. Investments in technologies and methods for monitoring and measuring the flows of GHGs in natural and constructed wetlands could drive down costs and increase both usability and accuracy of measurement tools, and enable greater payments to wetland managers for carbon sequestration services. Additional research to map out the highest potential restoration opportunities in the United States would help prioritize and accelerate the implementation of projects. There is a general consensus that enhancing the carbon values of wetlands will also achieve desirable outcomes for general conservation and wildlife habitat, but the ecological relationship between carbon sequestration and these co-benefits has not been well quantified and communicated with local policymakers and land-use planners. Policy strategies to address these barriers include the following:

The EPA can update the National Wetlands Condition Assessment to evaluate carbon storage capacity of wetland in addition to the data on vegetation, soil, hydrology, water chemistry, algae, and buffer characteristics that are currently tracked.

Relevant agencies, including the USGS, FWS, USFS, the National Oceanic and Atmospheric Administration, and others can collaborate on a joint effort to improve modeling and measurement of the carbon stocks and fluxes from existing wetlands.

The EPA Office of Air and Radiation (OAR) and the Office of Research and Development (ORD) can collaborate to develop and deploy more sophisticated, easily operable, and lower-cost carbon monitoring technologies to allow for more cost-effective assessments of the efficacy and permanence of carbon sequestration in wetlands. Examples of emerging technologies that can support such monitoring include unmanned aerial vehicles and remotely operated/autonomous vehicles.

MOVING FORWARD

Carbon removal strategies can create the industries and jobs of the future while also helping to reduce climate risks. Whether this promise becomes reality, however, depends on the extent to which leaders step forth today to create the policies that support research, innovation, and deployment of promising carbon removal strategies.

The policy levers presented in this report offer a menu of actionable steps that policymakers—regardless of ideology and partisan affiliation—can take to advance carbon removal strategies. This menu of options offers opportunities for leaders to take action across a wide range of government offices, showing that carbon removal is no niche idea.

Now is the time for leaders to seize these and other promising carbon removal ideas and translate them into effective policy. Emerging leaders must now make carbon removal strategies a priority, and tailor policies to meet the needs of their constituents – ensuring a prosperous, bright, and clean future for generations to come.

APPENDICES

APPENDIX I: SHOVEL READY POLICIES FOR CONGRESS

In 2017, Congress can reintroduce and pass legislation from past Congresses relevant to carbon removal solutions, including the following measures.

S.3179 - Carbon Capture Utilization and Storage Act. Amending Section 45(Q) of the Tax Code to expand and enhance credits for CO_2 utilization and storage. In July 2016, Senators Heidi Heitkamp (D-ND) and Sheldon Whitehouse (D-RI) introduced legislation to extend and expand the 45Q tax credit for carbon capture and sequestration to include non-EOR utilization and to boost the credit for saline storage. There is a bipartisan House companion bill led by Rep. Mike Conaway (R-TX). However, this companion bill does not include the non-EOR provision or the higher saline storage credit. Congress can act in 2017 to pass a 45Q tax proposal that includes the non-EOR and higher saline storage credit provisions in the Senate bill.

Barrasso-Schatz Air Capture Amendment to S. 2012 - The Energy Policy Modernization Act (EPMA). During floor consideration of The Energy Policy and Modernization Act in January of 2016, the Senate accepted Amendment 3017 from Senators John Barrasso (R-WY) and Brian Schatz (D-HI) to expand DOE's authority to award technology prizes to projects that separate carbon dioxide from dilute sources (e.g., direct air capture.)

Manchin Net-Negative CCS Amendment to S. 2012 - The Energy Policy Modernization Act (EPMA). In January 2016, Senator Joe Manchin (D-WV) offered Amendment 3270 The Energy Policy and Modernization Act in order to modify provisions relating to the Coal Technology Program in the DOE's Office of Fossil Energy. This amendment formally names net-negative carbon dioxide emissions projects as a programmatic priority for DOE FE, and authorizes $22 million per year over five years to fund net-negative demonstration projects. The amendment also names other research objectives that directly support commercial-scale carbon removal, including the requirement to validate geologic assets for carbon storage and the opportunities for carbon utilization beyond sequestration.

H.R. 2883, The Master Limited Partnerships Parity Act. In the 114th and 113th Congresses, Senators Moran (R-KS) and Coons (D-DE) and Congressmen Ted Poe (R-TX) and Mike Thompson (D-CA) introduced legislation to expand the financing tool known as MLPs beyond fossil energy and pipeline projects. MLPs are a business structure that is taxed as a limited partnership - reducing the tax burden for specific projects- but is owned and traded like corporate stock on a market, allowing for greater liquidity. Under current law, CCS projects on fossil-fueled power plants cannot be structured as MLPs, but the MLP Parity Act (S. 1656 in the 114th Congress) would open these incentives to such project. In addition, this bill can be strengthened by accommodating capture projects with where the carbon is utilized after capture.

APPENDICES

S.843, Carbon Capture Improvement Act of 2017. Section 142 of the Tax Code has provided a tax-exempt bond market for select industries for over a century. Section 142 is designed to unlock private investment in projects that may not otherwise have access to traditional financing, but would have a public benefit, such as highway transfer facilities, sewage facilities, and green buildings (Internal Revenue Service, 2016). CCS and some other carbon removal projects would be an appropriate addition to the list of qualified projects for PAB-eligibility. Senators Portman (R-OH) and Bennett (D-CO) introduced legislation in 2015, the Carbon Capture Improvement Act, to allow private activity bonds for "traditional" CCS facilities and enhanced oil recovery. Such legislation can be expanded to accommodate capture projects where the carbon is otherwise utilized after capture.

H.R. 5316, the Healthy Soils and Rangeland Solutions Act. This bill, introduced in May 2016 by Rep. Jared Huffman (D-CA), would establish a grant program at the Department of Interior for pilot projects to explore the restoration of degraded soils, the application of compost and biochar amendments, and grazing modifications on public lands. A pilot program as envisioned in H.R. 5316 would be a big step in understanding what management practices result in effective biological carbon sequestration and would inform future management of public lands. Congress can reintroduce and pass this bill in the 115th Congress.

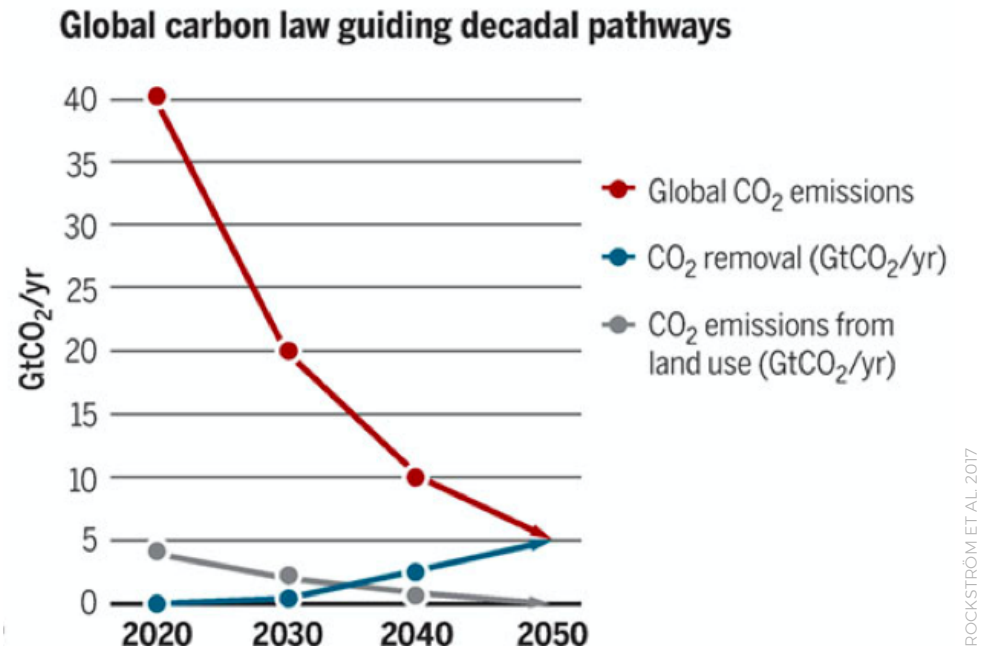
H.R.3748, Water Efficiency via Carbon Harvesting and Restoration (WECHAR) Act of 2009. In 2009, House and Senate members introduced legislation called WECHAR to set up a joint DOI-USDA loan guarantee program to commercialize biochar production units. The bill specifically called for biochar projects that produce net-negative carbon emissions. It would also support pilots of biochar production units in order to demonstrate commercial viability and evaluate the impacts of biochar across a variety of environmental conditions. Last, WECHAR authorized a grant program at USDA to research the attributes and environmental impacts of biochar. Congress can update and reintroduce this legislation in the 115th Congress.

Updating Cover Cropping Guidelines. The Federal Crop Insurance Corporation, managed by the USDA Risk Management Agency (RMA), insured 298 million acres in 2015 - 13% of total US land. RMA prescribes actions that farmers receiving Federal Crop Insurance must take in order to control risks and qualify for the program, including guidelines for cover cropping. The RMA guidelines are unnecessarily complex and stringent, and a wide range of stakeholder groups led by the National Working Group on Cover Crops and Soil Health have petitioned RMA to relax them (National Working Group on Cover Crops and Soil Health. 2015). In the Crop Insurance title of the next Farm Bill, Congress can instruct RMA to simplify cover cropping guidelines to reduce bureaucratic burdens on farmers and expand cover cropping, which supports the long-term productivity and resiliency of the farm, while reducing soil erosion, increasing water retention and increasing net soil organic carbon.

The Wildfire Budgeting, Response, and Forest Management Act of 2016. In the 114th Congress, Senator Lisa Murkowski (R-AK), Chairman of the Senate Energy and Natural Resources Committee, introduced legislation to end the U.S. Forest Service (USFS) practice of fire borrowing. This bipartisan bill was not completed by the end of the year. Congress can reintroduce this legislation and work to incorporate biomass production into the fuel reduction components of such a bill. For example, the Forest Service could be authorized to award biochar feedstock contracts up to 20 years, along with the timber and stewardship contracts already accommodated in the draft legislation, and give contract preference to entities that agree to convert the timber to biochar.

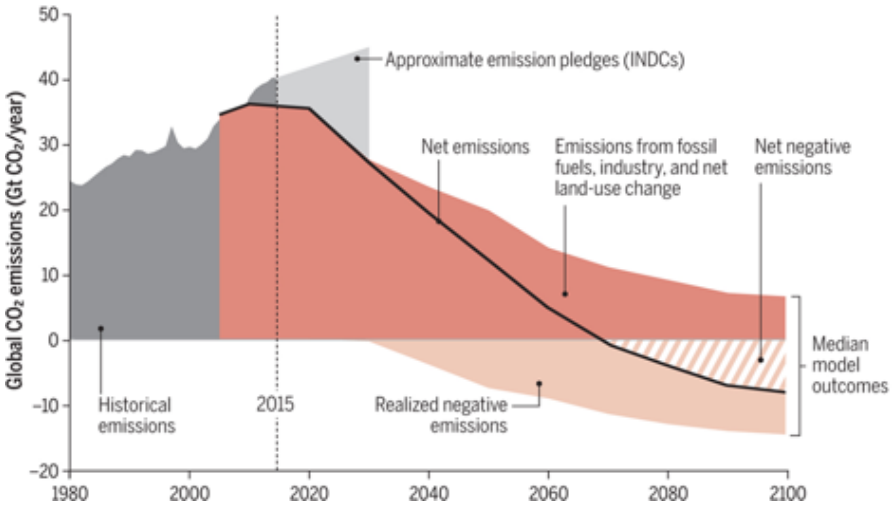
APPENDIX II: CLIMATE MATH

Carbon removal of billions of metric tons per year is needed by midcentury to meet the goals of Paris Agreement, even if global emissions halve every decade in parallel (Rockström, 2017).



Even with steep emissions reductions, large-scale carbon removal is needed by midcentury to meet the Paris Agreement commitments.

In addition, large-scale deployments of carbon removal solutions would be highly valuable—and perhaps essential—as early as 2030 in limiting global warming to 2°C above pre-industrial averages (Van Vuuren et al. 2011).



ANDERSON & PETERS, 2016

Integrated assessment models show that it is economically optimal to begin deploying carbon removal at large scale by 2030.

APPENDIX III: CARBON REMOVAL APPROACHES IN CONTEXT

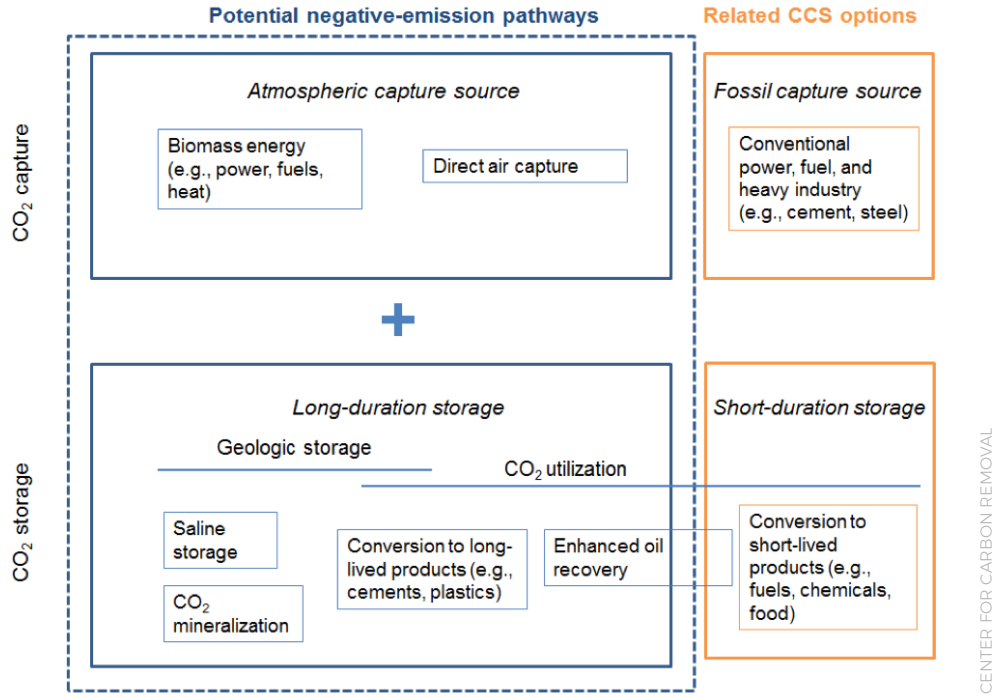
Carbon removal approaches offer opportunities to advance the existing conversation on mitigating climate risks and to include new voices in the climate solution conversation.

Climate Change Mitigation Approach	Ecosystems (Forests and wetlands)	Agriculture	CCS technology
Traditional mitigation	Conservation / avoided deforestation Avoided destruction of wetlands	On-farm GHG emissions reductions Capture and re-use of on-farm methane emissions	*Capture:* on fossil fueled power plants and/or other heavy industry *Storage:* enhanced oil recovery
Carbon removal	Forest expansion and management for carbon storage. Expansion and construction of wetlands	Soil carbon sequestration Increased above and below ground biomass stocks	*Capture:* bioenergy, direct air capture *Storage:* Geologic carbon storage (including CO_2 mineralization), utilization in long-lived building materials and consumer goods.

CENTER FOR CARBON REMOVAL

Carbon removal solutions offer an extension of conventional climate mitigation approaches.

APPENDIX IV: CCS APPROACH SCHEMATIC



For a CCS approach to be carbon removing, it must both capture CO_2 from an atmospheric source and sequester carbon for long durations. Because of the overlapping nature of carbon removing and low-carbon CCS approaches, it is valuable to develop a full complement of CCS strategies, as all pieces of the CCS chain drive benefits across technology verticals.

REFERENCES

REFERENCES

Anderson, K., & Peters, G. (2016). The trouble with negative emissions. *Science, 354*(6309), 182-183.

Carbon Capture Improvement Act of 2017, S.843. 115th Congress. (2017). Retrieved from https://www.congress.gov/bill/115th-congress/senate-bill/843

Carbon Capture Utilization and Storage Act, S.3179. 114th Congress (2016). Retrieved from https://www.congress.gov/bill/114th-congress/senate-bill/3179

Cuéllar-Franca, R. M., & Azapagic, A. (2015). Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts. *Journal of CO_2 Utilization, 9*, 82-102.

Dahl, T.E. (1990). Wetlands losses in the United States, 1780's to 1980's. *Report to the Congress*. No. PB-91-169284/XAB. St. Petersburg, FL: National Wetlands Inventory.

de Klein, J. J., & van der Werf, A. K. (2014). Balancing carbon sequestration and GHG emissions in a constructed wetland. *Ecological Engineering*, 66, 36-42.

Elzen, Den M., Hare, W., Höhne, N., Levin, K., Lowe, J., Riahi, K., ... & Ward, M. (2010). *The Emissions Gap Report: Are the Copenhagen Accord pledges sufficient to limit global warming to 2 deg. C or 1.5 deg. C? A preliminary assessment.* United Nations Environment Programme

Holloway, S. (2005). Underground sequestration of carbon dioxide—a viable greenhouse gas mitigation option. *Energy, 30*(11), 2318-2333.

Internal Revenue Service (2016). *Publication 4078 Tax-Exempt Private Activity Bonds*. Publication 4078 (Rev. 1-2016) Catalog Number 34662G. Retrieved from https://www.irs.gov/pub/irs-pdf/p4078.pdf

Lawler, J. J., Lewis, D. J., Nelson, E., Plantinga, A. J., Polasky, S., Withey, J. C., ... & Radeloff, V. C. (2014). Projected land-use change impacts on ecosystem services in the United States. *Proceedings of the National Academy of Sciences, 111*(20), 7492-7497.

Lenart, M. (2009). An unseen carbon sink. *Nature Reports Climate Change*, 137-138.

Lu, X., Kicklighter, D. W., Melillo, J. M., Reilly, J. M., & Xu, L. (2015). Land carbon sequestration within the conterminous United States: Regional and state level analyses. *Journal of Geophysical Research: Biogeosciences, 120*(2), 379-398.

Master Limited Partnerships Parity Act, H.R. 2883. 114th Congress. (2015). Retrieved from https://www.congress.gov/bill/114th-congress/house-bill/2883

McSweeny, R., & Pearce, R. (2016). Only Five Years Left Before 1.5C carbon budget is blown. *Carbon Brief*. Retrieved from https://www.carbonbrief.org/analysis-only-five-years-left-before-one-point-five-c-budget-is-blown

Nielsen, A. S. E., Plantinga, A. J.; Alig, R. J. (2014). New cost estimates for carbon sequestration through afforestation in the United States. Gen. Tech. Rep. PNW-GTR-888. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Oswalt, S. N., Miles, P. D., Pugh, S. A., & Smith, W. B. (2018). Forest resources of the United States, 2017: A technical document supporting the Forest Service 2020 RPA Assessment. Gen. Tech. Rep. WO. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office.

Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. *Science, 355*(6331), 1269-1271.

Secretary of the Energy Advisory Board CO_2 Utilization Task Force. (December 12, 2016). *Letter for the Secretary Of Energy Advisory Board*. Retrieved from https://www.energy.gov/sites/prod/files/2016/12/f34/SEAB-CO2-TaskForce-FINAL-with%20transmittal%20ltr.pdf

Silver, W. L., Ryals, R., & Eviner, V. (2010). Soil carbon pools in California's annual grassland ecosystems. *Rangeland Ecology & Management, 63*(1), 128-136.

The Energy Policy Modernization Act (EPMA), S. 2012. 114th Congress. (2015). Retrieved from https://www.energy.senate.gov/public/index.cfm/2015/7/the-energy-policy-modernization-act-of-2015

The Healthy Soils and Rangeland Solutions Act, H.R. 5316. 114th Congress. (2016). Retrieved from https://www.congress.gov/bill/114th-congress/house-bill/5316

The National Working Group on Cover Crops and Soil Health. (2015) *Recommendations from the National Working Group on Cover Crops and Soil Health*. Retrieved from http://www.nacdnet.org/wp-content/uploads/2016/06/Working_Group_Report_and_Recommendations.pdf

The Wildfire Budgeting, Response, and Forest Management Act of 2016. 114th Congress, 2nd Session. (2016). Retrieved from http://www.energy.senate.gov/public/index.cfm/files/serve?File_id=1C7CC535-A986-4B28-A56C-9F6B58BEBECB

Toensmeier, E. (2016). *The carbon farming solution: A global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security*. White River Junction, VT: Chelsea Green Publishing.

United States Fish and Wildlife Service (2017). *North American Wetlands Conservation Act: Protecting, Restoring and Enhancing Wetland Habitats For Birds*. Retrieved from https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php

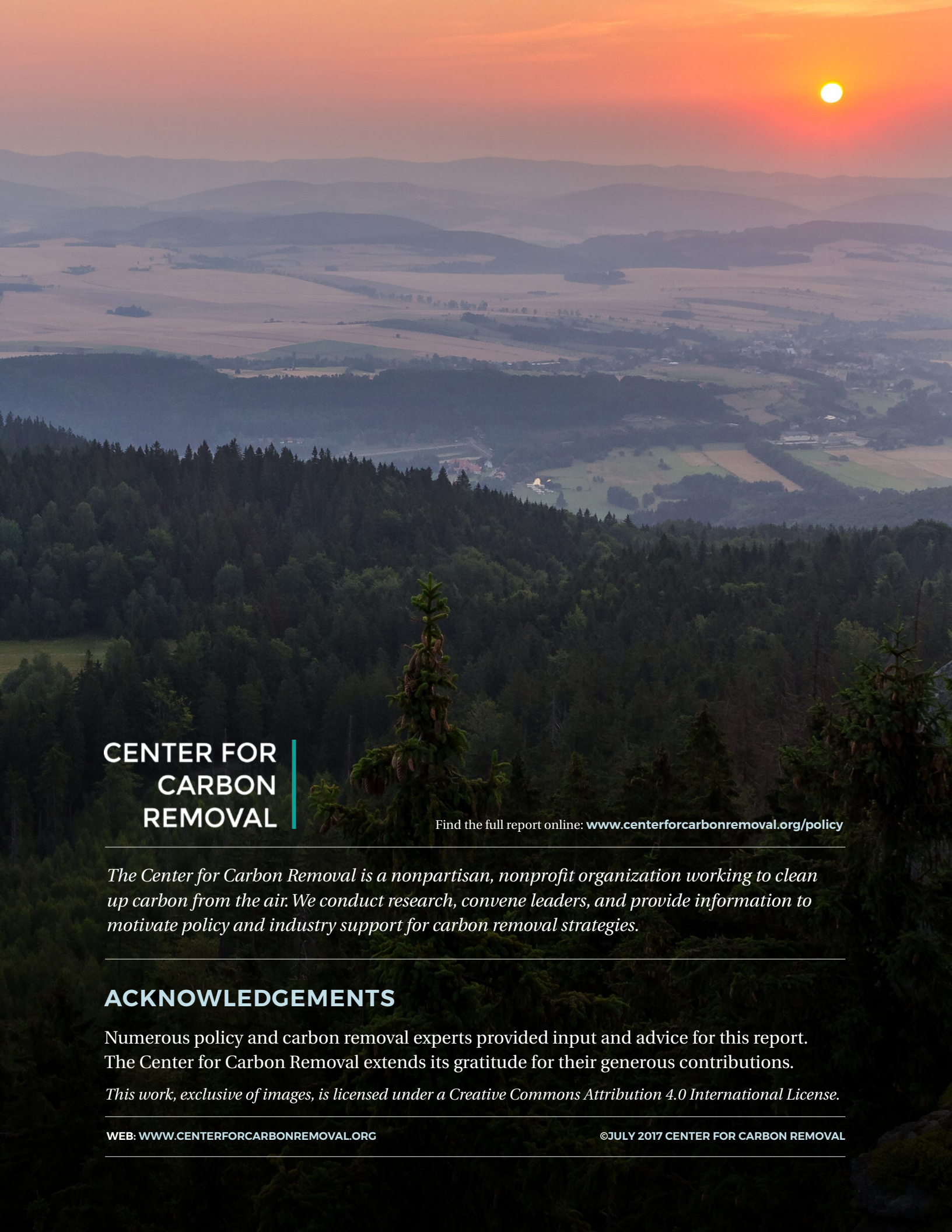
United States Geological Survey (2017). *Land Carbon*. Retrieved from https://www2.usgs.gov/climate_landuse/land_carbon/default.asp

Venkat, K. (2012). Comparison of twelve organic and conventional farming systems: a life cycle greenhouse gas emissions perspective. *Journal of Sustainable Agriculture, 36*(6), 620-649.

Vuuren, Van D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., ... & Masui, T. (2011). The representative concentration pathways: an overview. *Climatic Change, 109*(1-2). 5–31.

Water Efficiency via Carbon Harvesting and Restoration (WECHAR) Act of 2009, H.R.3748. 111th Congress. (2009). Retrieved from https://www.congress.gov/bill/111th-congress/house-bill/3748

Zedler, J. B., & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources, 30*, 39-74.



CENTER FOR CARBON REMOVAL

Find the full report online: **www.centerforcarbonremoval.org/policy**

The Center for Carbon Removal is a nonpartisan, nonprofit organization working to clean up carbon from the air. We conduct research, convene leaders, and provide information to motivate policy and industry support for carbon removal strategies.

ACKNOWLEDGEMENTS

Numerous policy and carbon removal experts provided input and advice for this report. The Center for Carbon Removal extends its gratitude for their generous contributions.

WEB: WWW.CENTERFORCARBONREMOVAL.ORG