U.S. Department of Energy
Advanced Research Projects Agency – Energy (ARPA-E)

Request for Information (RFI) DE-FOA-0003421 on Engineering Solutions to Harvest Biomass Carbon for Durable Removal and Storage (Carbon Harvesting)

Introduction:

The purpose of this Request for Information (RFI) is to solicit input for a potential ARPA-E program focused on leveraging the zero-energy carbon dioxide capture process provided by photosynthesis to develop novel, transformational technologies that improve the energy efficiency of the carbon dioxide removal (CDR) sector.

CDR activity within the U.S. and global economies is necessary to reach the net zero targets established by public and private sector actors.[1] To meet the national net zero targets, the U.S. will need to remove approximately 500 million tons of carbon dioxide equivalents (CO_2-eq) per annum by 2050.[2,3] The energy required by CDR technologies today is substantial, in some cases exceeding 1,500 kilowatt hours (kWh) per ton. To achieve 500 million tons of CO_2-eq removal at an energy intensity of 1,500 kWh per ton would require approximately 750 terawatt hours (TWh), which is ≈20% of current U.S. power generation and 100% of current renewable power generation. Improving the efficiency of CDR will reduce the burden that it places on U.S. power generation and will allow renewable power generation to more efficiently decarbonize other sectors.

Atmospheric carbon removal via the harvesting, processing, and subsequent storage of biomass, which is the product of photosynthesis—a natural process that leads to direct capture of carbon dioxide from Earth's atmosphere— requires zero human-generated energy. These CDR technologies may also be used to decarbonize other energy technologies, reducing or even eliminating energy-related greenhouse gas (GHG) emissions.[4] Low-input CDR technologies could serve as a cost-efficient way to decarbonize energy systems where the cost of abatement remains significant, improving the resilience of that infrastructure to produce, deliver, and store energy in a net-zero future (See Figure 1).[5] This potential program and

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[1] U.S. Department of State and U.S. Executive Office of the President, "The Long-term strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050," (2021). https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

[2] Ton in this document refers to metric ton (1,000 kg).

[3] CO_2-eq is the amount of CO_2 emissions with the same global warming potential (GWP) over a certain timeframe as the gas(es) in question. This document refers to GWP-100 values (GWP of gases over 100 years). For example, CO_2 has a GWP-100 of 1, fossil CH_4 has a GWP-100 of 30 kg CO_2-eq/kg, etc.

[4] Emissions from U.S. aviation, for example, are 11 kg CO_2-eq per gallon of jet fuel consumed, according to the Greenhouse Gases, Regulated Emissions, and Energy Use In Transportation (GREET) model. Offsetting these emissions using today's CDR technologies, which sell for roughly $500 per ton-eq of CO_2, would cost the equivalent of $5.60 per gallon of jet fuel. Offsetting these emissions with more efficient carbon-harvesting technology at $100 per ton-eq would cost $1.12 per gallon.

[5] Goldman Sachs data suggests that, globally, 10 gigatons of current emissions would cost more than $200 per ton equivalent to abate (https://www.goldmansachs.com/pdfs/insights/pages/gs-research/carbonomics-gs-net-zero-models/report.pdf). The activities and energy infrastructure associated with such emissions might not be considered viable in a low-emissions future scenario.

resulting technologies would represent advances in fundamental and applied sciences and accelerate technological advancements in an area in which there exists substantial technical and financial uncertainty. This uncertainty reflects the fact that, to date, CDR technology has experienced only modest research, development, and optimization.

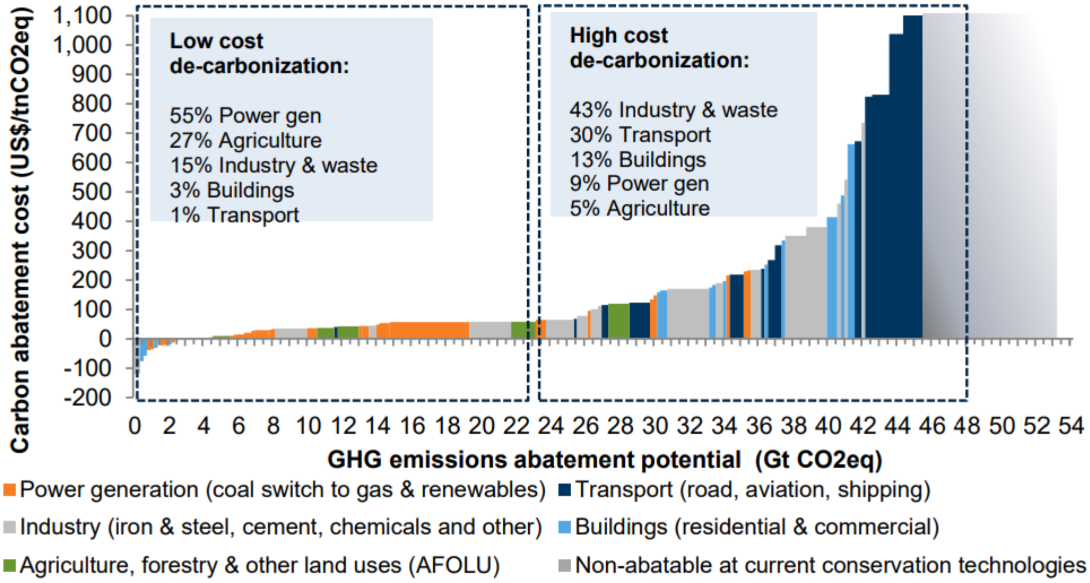

Figure 1. Global Marginal Abatement Curve.[6]

Specifically, this RFI focuses on:

1. Increasing the quantity and efficiency of carbon harvested from above-ground biomass per unit of land, energy, and other inputs, especially for low-productivity, low-input biomass west of the 100th Meridian (i.e., non-farmland areas);
2. Processing post-harvest biomass for maximized carbon storage durability and carbon efficiency;
3. Improving the management of nutrient cycles within this CDR approach; and
4. Understanding the potential economic and environmental underpinnings of sequestering purpose-grown biomass on rangelands.

As global carbon emissions continue to rise, increased urgency is required to develop and implement negative emissions technologies (NETs). Current projections require the removal of 20 gigatons (GT) CO_2-eq annually, at the global scale, by 2100, to keep global temperatures at or below 2°C above pre-industrial levels.[7] More specifically, difficult-to-decarbonize industries, such as aviation (approximately 0.3 GT CO_2-eq), need NETs to meet net-zero targets by 2050. Direct air capture and storage (DACS) is a NET approach that focuses on producing a pure stream of carbon dioxide, which is then stored

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[6] Goldman Sachs. “Carbonomics: Introducing the GS net zero carbon models and sector frameworks,” *Goldman Sachs Research* (2021). https://www.goldmansachs.com/pdfs/insights/pages/gs-research/carbonomics-gs-net-zero-models/report.pdf.

[7] de Coninck, H., Revi, A., Babiker, M., Bertoldi, P., Buckeridge, M., Cartwright, A., Dong, W., Ford, J., Fuss, S., Hourcade, J-C, Ley, D., Mechler, R., Newman, P., Revokatova, A., Schultz, S., Steg, L., and Sugiyama, T. “Strengthening and Implementing the Global Response,” *Global Warming of 1.5°C.* (2022): 313-444. Accessed June 2024. https://www.cambridge.org/core/books/global-warming-of-15c/D7455D42B4C820E706A03A169B1893FA

underground. The primary concern with DACS is cost (\$700 – \$3,000/ton CO_2-eq) and energy input (greater than 1,500 kWh of energy [kWh_e]/ton CO_2-eq).[8]

In contrast, land-based CDR methods are cheaper (less than \$250/ton CO_2-eq) and use far less energy (less than 250 kWh_e/ton CO_2-eq).[9] Currently, the industry harvests waste biomass such as forest residue, corn stover, rice husks, etc., which is limited.[10] The biomass is dried and processed, most commonly by pyrolyzing biomass into biochar before depositing it onto agricultural fields for storage.[11] Another common technique is to dry, grind, and/or compress biomass into dense bricks before it is stored into secure landfills.[9] Current processes do not return nutrients back to the environment during processing, risking consistent biomass growth year after year. Further, these processes are energy intensive and costly, making them unlikely to meet the U.S. Department of Energy (DOE) Carbon Negative Shot of \$100/ton CO_2-eq.[12] ARPA-E is thus interested in supporting the research and development of new energy-efficient biomass processing technologies, as well as sustainable biomass harvesting systems, to increase the energy efficiency of the CDR sector. In essence, carbon harvesting is a three-step process:

1. Cultivate and harvest biomass.
2. Process the biomass to prevent degradation and return nutrients back to the soil.
3. Durably store the processed biomass and minimize degradation to carbon dioxide and/or methane.

Step 1 requires development of sustainable, biodiverse crop systems on lands not currently used for food production. The chief challenge facing biomass-generated NETs (i.e., Biomass Carbon Removal and Storage [BiCRS][13]), including carbon harvesting, is the need to annually generate large amounts of sustainable biomass. ARPA-E recognizes the potential for harvesting biomass on low-yield (i.e., marginal) acreage where food and/or biofuels production is not economically viable. ARPA-E seeks further information on technological approaches to add biomass to (or amend) previously converted and existing grassland prairies and rangelands, as well as to marginal and abandoned land within row cropping systems, with marginality defined economically or by underlying environmental conditions. Genetic and agronomic technologies that increase carbon yield per input will be critical to delivery of adequate biomass supply.

Regarding Step 2, there are various methods to prepare biomass carbon for sequestration, but all share the goal of minimizing energy consumption required, to ensure the biomass no longer decays and releases carbon dioxide or methane. New processes may include ones that simultaneously generate

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[8] Baylin-Stern, A., and Berghout, N. "Is carbon capture too expensive?" Last modified February 17, 2021, https://www.iea.org/commentaries/is-carbon-capture-too-expensive.

[9] Yablonovitch, E. and Deckman, H.W., "Scalable, economical, and stable sequestration of agricultural fixed carbon," *Proceedings of the National Academy of Science* 120, no. 16 (2023). Accessed June 2024. https://www.pnas.org/doi/epdf/10.1073/pnas.2217695120.

[10] U.S. Department of Energy. 2024. 2023 Billion-Ton Report: An Assessment of U.S. Renewable Carbon Resources. M. H. Langholtz (Lead). Oak Ridge, TN: Oak Ridge National Laboratory. ORNL/SPR-2024/3103. doi: 10.23720/BT2023/2316165.

[11] Soeherman, J.K., Jones, A.J., and Dauenhauer, P.J. "Overcoming the Entropy Penalty of Direct Air Capture for Efficient Gigatonne Removal of Carbon Dioxide,"*ACS Engeering*, 3 (2023). Accessed August 2024.

[12] U.S. Department of Energy. "Energy Earthshots Initiative," (2023). Accessed August 2024. https://www.energy.gov/energy-earthshots-initiative.

[13] Sandalow, D., Aines, R., Friedmann, J., McCormick, C., and Sanchez, D., "Biomass Carbon Removal and Storage (BiRCS) Roadmap," Accessed June, 2024. https://www.osti.gov/servlets/purl/1763937.

carbon bricks and return needed nutrients back to the soil. One suite of options includes thermochemical conversion technologies to convert the biomass into biochar (solid), bio-oil (liquid), and/or gas. Another option for processing biomass is to dry and salt it such that bacteria or fungi cannot decompose it. Other options include biochemical processing that make cellulose and hemicellulose recalcitrant, or even immune, to typical enzymatic-driven decomposition by microbes. A key challenge facing all biomass-dependent systems is the expense associated with transporting biomass. As such, mobilization and miniaturization of processing technologies may be a critical quality for eventual rollout, as high capital expenses are difficult to sustain in low-productivity biomass catchments. It may be important to leverage current technologies to minimize capital and maximize stranded assets. Finally, it may be possible to co-optimize engineered properties of the feedstock (e.g., ratio between lignin and celluloses, plant architecture, leaf density) with the conversion and stabilization process.

Step 3 requires storing the processed biomass. Some approaches store biomass underground by pumping bio-oil into abandoned oil wells or by wrapping biomass in a durable material to protect against moisture, bacteria, and/or fungi. Above-ground storage is also possible and includes depositing biochar in soil.[14] Stored product phase, form factor, and density should be carefully matched with storage site, to durably store as much material as possible. Regardless of how it is achieved, storage must be durable and verifiable to satisfy voluntary carbon credit purchasers.

Like other land-intensive technology pathways, carbon harvesting may confront land use conflicts as it scales. Land use changes can be a source of GHG emissions and reduce ecosystem services. This RFI seeks information on appropriate technology gaps that would enable identification of appropriate land for carbon-harvesting activities. This RFI also seeks information on technology gaps that prevent the identification and cultivation of biomass as part of a cover-cropping system on present cropland. Finally, this RFI seeks information on metrics that would provide evidence that carbon-harvesting activities are causing minimal harm, or conversely, benefiting the ecosystems in which they occur.

Potential Research Area #1: Feedstocks for Energy-Efficient CDR

This RFI seeks information on technologies that would enable sustainable biomass feedstock production with high energy efficiency and low production costs. Historic research and practice have shaped many species to maximize production potential for traditional uses of food, fuel and fiber. As a consequence, there has been limited research to optimize plants for above-ground carbon drawdown.[15] There also has been limited identification of the optimal acreage and growing zones for specific carbon-harvesting feedstocks, which could include a much broader set of plant species than those which have been optimized for today's agricultural needs. Except in the case of rangelands, biomass production systems have generally failed to incorporate multiple, native species, despite the recognition that the inclusion of such species would generate a variety of ecosystem services, including pollination, drought tolerance,

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[14] Schmidt, H.P., Anca-Couce, A., Hagemann, N., Werner, C., Gerten, D., Lucht, W., and Kammann, C. "Pyrogenic carbon capture and storage," *GCB-Bioenergy.* 11, No. 4 (2019): 573-591. Accessed June, 2024. https://onlinelibrary.wiley.com/doi/epdf/10.1111/gcbb.12553.

[15] Tao, Y., Chiu, L., Hoyle, J.W., Dewhirst, R.A., Richey, C., Rasmussen, K., Du, J., Mellor, P., Kuiper, J., Tucker, D., Crites, A., Orr, G.A., Heckert, M.J., Godinez-Vidal, D., Orozco-Cardenas, M.L., and Hall, M.E. "Enhanced Photosynthetic Efficiency for Increased Carbon Assimilation and Woody Biomass Production in Engineered Hybrid Poplar," *Forests*, 14 No. 4, 827 (2023): 827. Accessed June, 2024. https://www.mdpi.com/1999-4907/14/4/827.

improved soil health, and pest control. ARPA-E seeks information on potential technologies to increase the drawdown of atmospheric carbon dioxide, via photosynthesis, into harvestable plant biomass, with special interest in production systems that locate biomass production in low-energy input production and harvesting systems, and within the context of sustainable, multispecies consortia.

Potential Research Area #2: Low-Energy Biomass Processing and Storage

Traditional biomass decays through natural processes, releasing carbon dioxide or methane. To effectively remove carbon from the atmosphere, this natural degradation must be stopped or slowed to a scale of hundreds of years. There are several techniques to sterilize biomass including thermochemical conversion (e.g., pyrolysis and torrefaction), drying, and/or induced toxicity.

Many of today's biomass-processing technologies are based on thermochemical biofuels production technologies such as gasification and pyrolysis. These technologies are extremely energy intensive. Carbon harvesting's objective is to produce a stable, carbon-rich material for storage at reduced cost and with substantially greater energy efficiency. This objective both enables and requires entirely new thinking and engineering. If this objective is achieved, the energy efficiency of the CDR sector will dramatically improve. Technologies that simultaneously harvest and pre-process, or process, biomass for storage are of particular interest.

Previously explored techniques for storing biomass include drying and wrapping in a water-impervious container, pumping biogenic slurries into abandoned oil wells, and engineering plants with modified compositions that resist decay. ARPA-E seeks additional information on the cost, sustainability, durability, and innovation potential for each of these techniques.

Potential Research Area #3: Nutrient Retention in the Biosphere

To set the scale of the nutrient challenge associated with carbon harvesting, consider that sequestration of 300 megatons (Mt) CO_2-eq via carbon harvesting (the approximate annual GHG emissions associated with U.S. aviation) necessitates sequestration of roughly 181-218 Mt of biomass.[16] Nitrogen and phosphorous are likely to represent approximately 2.5% and 0.25% of plant biomass, respectively,[17] meaning 5.5 Mt of nitrogen and 0.55 Mt of phosphorus would be removed yearly. By comparison, in 2021, nitrogen and phosphorus fertilizers applied to corn in the U.S. totaled 12 Mt and 1.85 Mt, respectively.[18] As such, nutrient efficiency could be a key consideration in the sustainability of large-scale carbon-harvesting activities.

Nutrient efficiency could be a cross-cutting technology theme within carbon-harvesting development, as efficiencies could be gained in biomass sourcing and/or processing. Some perennial crops remobilize more than 40% of above-ground nitrogen back to roots/soil, which potentially might be enhanced

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[16] 300 Mt of CO_2-eq is present in approximately 181 Mt of biomass, based on 0.45% carbon ratio in biomass and 44:12 translation of plant carbon into carbon dioxide (i.e., 300 x 45% x 44/12 = 181). Scaling up to 218 Mt biomass would allow up to 20% carbon loss, achieved from processes required within the sequestration of that biomass.

[17] Gusewell, S., "N:P ratios in terrestrial plants," *New Phytologist,* 164 (2004): 243-266. Accessed June, 2024. https://nph.onlinelibrary.wiley.com/doi/full/10.1111/j.1469-8137.2004.01192.x.

[18] U.S. Department of Agriculture National Agriculture Statistics Service, "2021 Agricultural Chemical Use Survey 2021," *NASS Highlights,* 2022-1 (2022). Accessed June, 2024. https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/2021_Field_Crops/chemhighlights-corn.pdf. (P calculated as 0.43 of P205 amount).

further. For processing, ARPA-E is interested in techniques that could efficiently separate carbon from key nutrients so that nutrients can be retained within the biosphere. This RFI identifies innovations in pyrolysis, electrolysis, biochemistry, and materials separations as key areas of interest.

Potential Research Area #4: Relative Environmental and Economic Costs
Scaling carbon harvesting to a roughly 200 Mt-scale requires sound environmental and economic models. In a worst-case scenario, carbon harvesting could reduce biodiversity, decrease soil health, rely on high inputs of synthetic fertilizers, and deplete groundwater for irrigation. Economic viability from seed to storage is equally important. ARPA-E is thus interested in economically viable carbon-harvesting systems that maximize both above-ground biomass and biodiversity, return nutrients back to the soil, and minimize reliance on irrigation and synthetic fertilizers.

The U.S. DOE Carbon Negative Shot sets a carbon dioxide removal price of $100 per ton of carbon dioxide (tCO_2).[19] For carbon harvesting to meet this goal, ARPA-E suggests cost targets of $50/$tCO_2$ for both purpose-grown biomass and its processing and storage. For biomass production, this equates to roughly $82 per dry ton of sustainable biomass (assuming 45% carbon by weight), which is in line with current DOE Bioenergy Technologies Office initiatives.[20]

RFI Guidelines:

CAREFULLY REVIEW ALL RFI GUIDELINES BELOW.

Note that the information you provide will be used by ARPA-E solely for program planning, without attribution. **THIS IS A REQUEST FOR INFORMATION ONLY. THIS NOTICE DOES NOT CONSTITUTE A FUNDING OPPORTUNITY ANNOUNCEMENT (FOA). NO FOA EXISTS AT THIS TIME.**

The purpose of this RFI is solely to solicit input for ARPA-E's consideration to inform the possible formulation of future research programs. ARPA-E will not provide funding or compensation for any information submitted in response to this RFI, and ARPA-E may use information submitted to this RFI without any attribution to the source. This RFI provides the broad research community with an opportunity to contribute views and opinions.

No material submitted for review will be returned and there will be no formal or informal debriefing concerning the review of any submitted material. ARPA-E may contact respondents to request clarification or seek additional information relevant to this RFI. All responses provided will be considered, but ARPA-E will not respond to individual submissions or publish publicly a compendium of responses. **Respondents shall not include any information in the response to this RFI that could be considered proprietary or confidential**.

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[19] U.S. Department of Energy Office of Fossil Energy and Carbon Management, "Carbon Negative Shot," Last updated January 4, 2024. Accessed June, 2024. https://www.energy.gov/fecm/carbon-negative-shot.
[20] Elless, M., "Overview of Feedstock Technologies Program," (2021). Last updated March 9, 2021. Accessed June, 2024. https://www.energy.gov/sites/default/files/2021-04/beto-00-peer-review-2021-feedstk-elless.pdf.

Responses to this RFI should be submitted in PDF format to the email address **ARPA-E-RFI@hq.doe.gov** by **5:00 PM Eastern Time on September 27, 2024.** Clearly state which specific question each response answers by noting the research area and question number. Emails should conform to the following guidelines:

- Insert "<your organization name> – Response to Carbon Harvesting RFI" in the email subject line.
- In the body of your email, include your name, title, organization, type of organization (e.g., university, non-governmental organization, small business, large business, federally funded research and development center [FFRDC], government-owned/government-operated [GOGO]), email address, telephone number, and area of expertise.
- Responses to this RFI are limited to no more than 10 pages in length (12-point font size).
- Responders are strongly encouraged to include preliminary results, data, and figures that describe their potential materials, designs, or processes.

RFI Questions:

The questions posed in this section are organized into several different groups. Respondents may provide responses and information about any of the following questions. **ARPA-E does not expect any one respondent to answer all, or even many, of the questions in this RFI.** In your response, indicate the question number (e.g., Response to Research Area 1 Question #2). Appropriate citations are highly encouraged. Respondents are also welcome to address other relevant scalability and related environmental and economic impacts that are not outlined below.

ARPA-E is specifically interested in improving the ecological sustainability, carbon yield, carbon efficiency, energy-intensity, cost, monitoring reliability, and carbon storage lifetime. Answers to the RFI questions will need to address at least one of the following metrics:

- Carbon yield (tons C/ha): The amount of carbon contained in the harvestable biomass per hectare (ha) of land per year.
- Carbon efficiency (%): After a full life-cycle analysis (LCA), the net amount of CO_2-eq removed from the atmosphere divided by the amount of carbon dioxide consumed by the biomass. This metric accounts for all sources of carbon emissions, such as farming equipment, changing soil carbon levels, energy inputs, etc.
- Energy intensity of sequestration (kWh/tCO_2-eq): The amount and type of externally supplied energy required to sequester one ton of CO_2-eq.
- Nutrient loss rate (%): Fraction of nitrogen, phosphorus, and trace minerals that is permanently sequestered as a fraction of the nutrients in the biomass before senescence. The metric is expected to be different for different nutrients.
- Cost ($/ton): The price to capture, process, and store one ton of CO_2-eq from the atmosphere.
- Monitoring reliability (%): Error in measurement and tracking of leaking CO_2-eq from stored biomass.
- Carbon storage lifetime (years): Half-life of carbon sequestration technique.

Provide evidence-based answers and/or commentary in response to the following:

Potential Research Area #1: Feedstocks for Carbon Uptake

1. What factors limit carbon drawdown by a plant or plant consortia? To what extent is photosynthetic capacity a limiting factor in plant carbon sequestration—particularly in areas with limited water and/or nutrients?
2. How could plants be engineered to increase their yields in water-limited regions?
3. What qualities in a crop or crop consortia optimized for carbon harvesting would maximize grower acceptance and interest?
4. What technologies or research would be necessary to increase the harvestable, photosynthetically-generated biomass productivity of regionally-appropriate plant consortia?
5. What research would inform optimization of a plant species mix for both harvestable above-ground biomass and biodiversity?
6. How might crop consortia affect the harvesting schedule, compared to monocrops? And how might it affect nutrient recycling?
7. What are the ideal properties of additional crops that increase the harvestable above-ground biomass without displacement of that setting's primary crop (e.g., switchgrass, big bluestem)?
8. What qualities of photosynthetically-generated biomass enable the most economical harvest and, if necessary, preprocessing (e.g., drying, chopping, shredding)?
9. What automated, robotic harvesting technologies could harvest senesced biomass on rangelands? What advances in automation and robotics are needed to achieve this?

Potential Research Area #2: Optimizing Biomass Processing and Storage

<u>Processing</u>

1. What research and technology development could be applied to treat biomass for maximum durable storage (e.g., biochemical treatments, chemical reaction engineering, photochemistry, gas-liquid-solid chemistries, electrolysis)?
2. How can cellulose, hemicellulose, and lignin be modified such that relevant enzymes (i.e., cellulases, peroxidases) are no longer able to initiate their decomposition?
3. What is the state of the art in biomass drying, and what are emerging alternatives?
4. What is an ideal scale for a carbon-harvesting conversion or processing technology, and why?
5. What research or technologies could enable on site carbon-harvesting conversion and storage?
6. What processes can separate nutrients and carbon, enabling the return of nutrients to soil and long-term carbon storage?

<u>Storage</u>

7. How can the stability of stored organic material be verified within 1-3 years?
8. What are the ideal options and locations for long-term (greater than 100 years) storage of organic material?
9. What bio/geo/chemical reactions may occur with bio-oil, torrefied, and untreated biomass with and without water present in below ground reservoirs?

Potential Research Area #3: Nutrient Loss Minimization

1. How could the nutrient-loss rate be limited to less than 10%?
2. What plant traits or agronomic practices could reduce the nutrient loss rate by increasing the return of plant nutrients to the soil before biomass harvest?
3. What research or technologies could enable the engineering of soil biota to increase nutrient-cycling efficiency?
4. What biomass pre-processing or processing technologies could be employed, in isolation or in conjunction with plant traits, to reduce the nutrient-loss rate to less than 10%?
5. What research would be necessary to harvest above-ground biomass in a way that mimics natural nutrient cycling systems and events (i.e., fire, grazing)?

Potential Research Area #4: Relative Environmental and Economic Costs

Economic sustainability

1. Which research projects or agronomic technologies are necessary to enable biomass production—especially of native plants (genetically modified or otherwise)—at a cost less than $82/ton?
2. What research would be necessary to identify factors, other than crop profitability, that might reduce acceptance of carbon-harvesting practices?
3. What research is necessary to implement conversion and processing technologies that prepare biomass for durable storage at a cost less than $50/ton CO_2-eq removed?
4. What aspects of a carbon-harvesting system would enable that system to qualify for 45Q or other federal or state-level carbon sequestration tax credits?[21]
5. What is the energy efficiency (kWh/ton CO_2-eq removed) of today's DAC technologies? What technology innovations are needed to reduce the energy consumption to <150 kWh/ton CO_2-eq removed?

Environmental sustainability

6. Assuming appropriate sustainability practices, where and/or what types of land are appropriate for carbon harvesting? Which species would you consider in those areas?
7. What are the best and most economically efficient ways to measure and gauge soil health, biodiversity, and/or ecosystem services provisioning?
8. What research would enable remote sensing data to measure the impact of carbon-harvesting practices on soil and ecosystem quality?
9. What research is necessary to assess the sustainability of matrix or other mixed planting techniques that increase biomass in a plant consortium?
10. What are other potential environmental risks of large-scale deployment of carbon harvesting?

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[21] U.S. Code, 26 USC 45Q "Credit for carbon oxide sequestration", in effect on July 9, 2024. Accessed via U.S. House of Representatives, https://uscode.house.gov/view.xhtml?req=(title:26+section:45Q+edition:prelim.