Biomass Can Fight Climate Change, but Only if You Do it Right

January 16, 2024 By **Audrey Denvir** and **Haley Leslie-Bole** Cover Image by: Fotokostic / Shutterstock

Explainer

Topic **U.S. Climate**

Biomass is fast becoming a topic of interest for governments looking for solutions to the climate crisis and cleaner energy sources. Of its multiple potential uses, carbon dioxide removal

(CDR) may be one of the best ways it can help achieve net-zero emissions goals. However, even with the best intentions, guidelines are needed to ensure a truly carbon-negative impact.

What Is Biomass and How Can it Curb Climate Change?

Biomass refers to any material that comes from living things, including wood and bark from trees, leaves or stems from plants, and even animal manure. When it comes to fighting climate change, carbon-rich biomass material can be used to remove carbon from the atmosphere, or it can be an alternative to fossil fuels for producing energy. In this context, biomass can be grown for the sole purpose of supplying material, or it can be collected as waste that results from other processes, such as agriculture and forestry.

Corn is a common crop used for biomass production. Agricultural waste, such as corn stover — the parts of the corn plant that are not harvested for food production — is one way to use the crop more sustainably. Photo by Matauw/Shutterstock.

However, unsustainable use of the finite biomass supply may hamper decarbonization efforts. If it is purposefully grown for fuel or as a carbon removal feedstock, biomass can be land-intensive and carry large carbon and environmental impacts. Purpose-grown biomass can displace food production, lower carbon sequestration potential and increase emissions from fertilizer, irrigation and harvest equipment used in the process.

In the U.S., for example, if decarbonization policies continue to incentivize purpose-grown biomass crops, particularly corn or soy crops or whole trees, there is a danger that these policies will move the U.S. further from its climate goals.

On the other hand, if sourced sustainably, biomass from wastes and residues from agriculture and forestry can support decarbonization.

To build a net-zero economy by 2050, biomass needs to come from only those sources that are truly carbon-negative. As many industries, including carbon removal, turn to biomass to help fight climate change, sustainable sourcing will be critical.

The Role of Biomass in Carbon Removal

The molecular structure of biomass contains a lot of carbon that originates from absorbed atmospheric carbon dioxide (CO2). This means that biomass has high carbon removal potential when it is used to make products, such as hydrogen or fuels, and is paired with a method for durable carbon sequestration.

Biomass carbon removal and storage (BiCRS) can provide decarbonization benefits both by producing products that replace fossil fuels and by producing carbon that can be stored. Whereas some plans for biomass energy prioritize energy generation, BiCRS prioritizes carbon removal and produces byproducts that can be used for energy.

According to Lawrence Livermore National Lab (LLNL), the amount of CO2 removal that can be achieved by 2050 in the U.S. using a sustainable biomass supply is estimated to be 884 million tons per year, equivalent to the amount of CO2 emitted by about 200 million cars each year.

Biomass carbon removal pathways

Biomass Source	Conversion Process	Product	Carbon Sinks
Agricultural wastes and residues	Gasification	Hydrogen	Carbon capture and storage
Forestry wastes and residues	Pyrolysis	Liquid fuels	Biochar
Perennial crops on marginal lands	Sawmill	Chemicals	Bio-oil
Municipal solid waste	Fermentation		Long-lived wood products
			Biomass burial

Source: Adapted from Lawrence Livermore National Lab, 2023

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Different chemical and physical processes break down biomass and turn it into energy, fuel or products while capturing the carbon that is contained in biomass. Some BiCRS pathways that are most promising for supporting economy-wide decarbonization are:

- **Gasification**, a process that produces synthesis gas, which can be used to produce liquid fuels, or hydrogen. Hydrogen can provide energy storage or be further reformed to create clean electrofuels or chemicals. Up to 100% of the carbon from these processes can be captured and sequestered underground.

- **Pyrolysis**, a high-heat process that creates charcoal-like biochar and bio-oil. Biochar can be used as a soil additive that sequesters carbon, and bio-oil can be injected underground or mixed with products like asphalt to provide carbon removal, or it can be further refined to make hydrogen or other valuable fuels.
- **Products and burial,** a pathway that relies on the natural ability of forest residue and wood to decay slowly. Forestry residues that are too small to be used for timber can be used to create other building materials like particle board that store carbon. Biomass can also be permanently buried in special underground containers when the transportation of waste biomass is difficult. Biomass burial may be a cost-effective BiCRS pathway in some areas, such as in forests with high fire risk and large quantities of flammable biomass.
- **Fermentation,** a process of turning biomass into alcohol and capturing the carbon that is produced. Today, most biomass fermentation uses corn to make ethanol, but the production of biofuels using biomass wastes and residues is a more sustainable option.

While there is potential for BiCRS to play a significant role in U.S. carbon removal, some BiCRS pathways like biomass burial and underground injection of bio-oil are in development or only exist at a pilot scale. Other BiCRS approaches like biomass gasification for carbon removal and hydrogen production will require costly new facilities to create a steady demand for biomass for these uses.

Despite the nascence of these approaches, companies are attracting millions of dollars of federal and private investment, signaling the likely expansion of the industry. BiCRS accounts for 90% of carbon removal that has been delivered through the voluntary carbon offset market to date. As the industry grows, it is critical that it be held to high biomass sourcing standards. Otherwise, there is a danger that BiCRS will grow to rely on feedstocks that displace other critical land uses and fail to provide carbon removal.

How to Sustainably Source Biomass in the US

The use of biomass is often assumed to have net-zero carbon emissions since plants sequester carbon as they grow. However, such assumptions overlook sacrificed land carbon sequestration, the time it takes for plants and trees to regenerate, and the emissions associated with growing crops and refining biomass to create products. To be truly carbon-negative and sustainable, biomass carbon removal should abide by the following principles of sourcing. (These principles are tailored to the U.S., but other countries or regions can and should develop their own.)

1) Prioritize wastes, residues and by-products.

The sources of biomass most likely to be carbon negative are wastes, residues and by-products from unused plant or animal materials that result from normal farm, forestry or municipal operations. Agricultural waste can include corn stover — the parts of the corn plant that are not harvested for food production — rice hulls and nut shells. Forestry wastes include wood and paper mill residues, such as sawdust and black liquor — the substance that remains after the pulping of wood to make paper — and woody waste from forestry operations or dead wood from natural disasters. Finally, municipal waste comes from urban and residential areas and includes things like food waste from homes and restaurants.

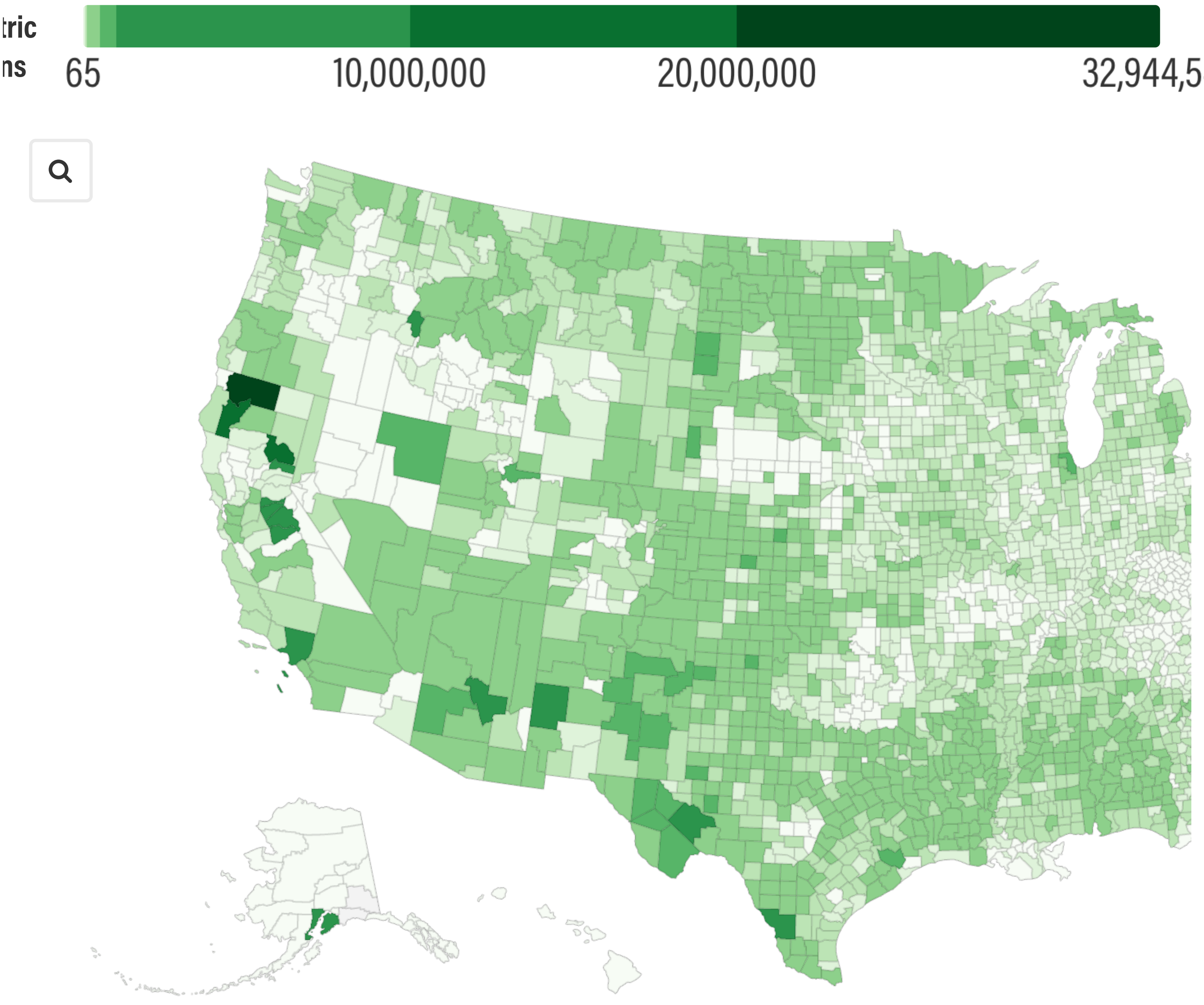
Food waste is one way to sustainably source materials for biomass. Photo by joerngebhardt68/Shutterstock.

Many wastes and residues are currently burned or left to decompose, which releases carbon into the atmosphere. Using wastes for BiCRS can avoid these emissions and replace more carbon-intensive energy sources, like fossil fuels. However, when wastes are removed from fields or forests, good management is essential for maintaining soil health and ecological functioning. Certain sustainable agricultural practices entail retaining residues, as the decomposition of dead material is an important ecological process. More research is needed to determine the appropriate amount of agricultural and forestry wastes that should be left on farms and forest floors to maintain soil health.

The recent analysis by LLNL projects a potential future supply of almost 500 million dry tons per year of biomass wastes and residues that could be used for CDR by 2050. This study includes agriculture, forestry and municipal waste, including wood from fire treatments in western U.S. forests.

US Sustainable Biomass Supply in 2050

Total Sustainable Biomass Supply | Forestry Waste | Municipal Waste | Agricultural Residues and Perennial Crops



Source: Lawrence Livermore National Lab, 2023

2) Forestry wastes, residues and by-products should come from ecologically managed forests.

When done responsibly, BiCRS may provide a win-win opportunity by using material from forestry practices that would otherwise decay or burn. However, there is a danger that growing a market for forestry wastes could incentivize over-harvesting of forests and plantations. This is particularly relevant for western U.S. forests, where excess woody biomass must be removed to prevent the risk of severe wildfires that could permanently damage a forest's ability to sequester carbon. LLNL estimates that close to 108 million tons of biomass could be produced per year from wildfire mitigation treatments by 2050. Strong forestry governance and rigorous ecological management standards are needed; otherwise, a strong woody biomass market runs the risk of causing profit-driven suppliers to over-exploit forests.

Some organizations and companies are working to create sustainability standards to ensure effective, measurable and verifiable sustainability practices. The Forest Stewardship

Council provides certification for forestry operations but does not address biomass sourcing specifically. Other companies and organizations, like Carbon Direct and the Roundtable on Sustainable Biomaterials, are working on certification criteria specifically for sustainably sourcing woody biomass from forests. Importantly, even where certification standards exist, enforcement is often a challenge that needs to be addressed.

3) Biomass crops should be limited to native perennial species on marginal lands.

While the use of wastes and residues should be prioritized, there may be opportunities for certain crops to be grown for the purpose of carbon removal. This should only be done sparingly, ideally after waste sources are depleted. These crops should be limited to perennial species that are native to a given region to help reduce negative impacts to biodiversity, habitats, or water and nutrient cycling. For example, native perennial grasses on restored prairie lands can support biodiversity and can be harvested for CDR. Similarly, native trees grown on unused agricultural land for biomass can provide some of the ecosystem services of tree cover, including enhanced air quality and reduced soil erosion. Importantly, management of these crop systems should limit inputs of fertilizer, irrigation and tillage — all of which have associated greenhouse gas emissions and negative ecosystem impacts.

Purpose-grown biomass crops should also be limited to marginal lands, or lands that are technically designated for agriculture or other human use but are relatively unproductive. Marginal lands may include brownfield sites — areas which have contaminants or hazardous substances — abandoned mines, or former and unproductive agricultural lands, as long as they are not currently being cultivated for other purposes.

Biomass should not be grown on natural or protected lands. If natural lands are converted to biomass production systems, they will likely undergo a drastic decrease in carbon storage from either their vegetation, soil or both. As such, lands with large natural carbon stores in soil or aboveground vegetation should never be compromised for the sake of sourcing biomass. To protect other ecosystem services, companies sourcing biomass for CDR should ensure biomass is not grown in areas of high-conservation value.

Timber from the Chatahoochee National Forest in Georgia. Forestry wastes that can be used for biomass include wood and paper mill residues, such as sawdust and black liquor — the substance that remains after the pulping of wood to make paper — and woody waste from forestry operations. Photo by Cecilio Ricardo / USDA Forest Service.

Biomass should also not be grown on prime farmland, which could displace food production or cause expansion of crop production to other, less productive lands. This indirect land use change could have high carbon costs. Because of this, dedicated corn or soy crops for biofuel production are not appropriate sources of carbon dioxide removal. Even if the biofuel production includes carbon capture and sequestration, emissions related to growing these crops and displaced food production prevent these biofuel systems from being carbon negative.

The LLNL study, which applied sustainability criteria to their projections, shows the potential to annually harvest up to 129.4 million dry tons of native switchgrass on marginal lands and 17.8 million dry tons per year from mowing restored prairie on Conservation Reserve Program (CRP) lands by 2050. If future policies incentivize harvest from CRP land, policy guardrails must protect wildlife habitat and other ecosystem benefits.

Using Biomass Responsibly

Biomass is a limited resource with many possible uses, from plastics and animal feed to energy generation and carbon removal. While BiCRS *might* be the most efficient use of biomass for supporting an economy-wide decarbonization, decision-makers should also consider alternative uses, particularly those that involve long-term carbon storage, like durable and recyclable products. In some cases, the optimal climate benefit of biomass may be from leaving it in place on natural landscapes to preserve the ecosystem services it provides.

In all cases of biomass use, input from local and Indigenous communities must be carefully considered to ensure no harm is being done. Biomass processing facilities must take steps to minimize negative air and water quality impacts. And moreover, policymakers at all levels should enact policies or regulations to prevent any undue environmental burden of biomass harvesting, processing or usage on historically disadvantaged communities.

With the growing demand for biomass, policymakers will also have to create guidelines and policies that can be tailored to the complex realities of different biomass types and BiCRS methods. Guardrails must prevent the use of biomass feedstocks that contribute to land use change, cause environmental degradation, or do not truly remove carbon.

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