U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Bioenergy: A Pathway to Decarbonization

To combat climate change, the United States is leading by example to build a 100% clean energy economy and reach net-zero emissions no later than 2050. The U.S. Department of Energy Bioenergy Technologies Office (BETO) works with its partners in government, academia, and industry to discover and deploy ways to remove carbon from the atmosphere and reduce greenhouse gas (GHG) emissions.

The Intergovernmental Panel on Climate Change has emphasized the urgent need for strong action to meet a 1.5-degrees Celsius reduction target for global warming.[1] One of the chief actions recommended to address the threats our world faces from climate change is mitigation of carbon-based GHG emissions.

Improved carbon conversion technologies, along with bio-based alternatives to fossil fuels and petrochemical-related products, are a cornerstone of BETO's efforts to help engineer carbon reduction and decarbonize the atmosphere.

Cleaner Fuel from Carbon Consuming Biomass

Biomass-based ethanol releases less carbon when burned than fossil fuels such as petroleum-based gasoline and diesel. In addition, the carbon dioxide (CO_2) emitted by burning ethanol is considered carbon neutral because the process of producing biomass material removes carbon from the atmosphere.[2]

Biomass—such as woody crops, energy crops, agricultural residues, and algae—used to produce biofuels, need CO_2 to grow, and thus, absorb it from the surrounding air during photosynthesis.

In 2020, BETO awarded roughly $14 million to seven projects dedicated to Algae Bioproducts and CO_2 Direct-Air-Capture (DAC) Efficiency.[3] DAC technologies absorb CO_2 from the atmosphere to grow high-quality algal biomass that can be converted to biofuels and products. The projects also focus on improving the quality and lowering the cost of algal biomass, making algae a more energy-intense national resource. Greater energy intensity means more biofuel from the same amount of algal biomass while reducing CO_2 in the air.

BETO and its partners are also exploring options to put CO_2 to productive use in ways that don't rely on photosynthesis.

Miscanthus, a perennial grass used as a biofuel and carbon capture system, is planted next to soybeans at the BioCentury Research Farm in Des Moines, Iowa.
Photo courtesy of Dennis Schroeder, National Renewable Energy Laboratory 47114.

Capturing Carbon and Putting It to Use

Manufacturing facilities can institute carbon capture measures that contain CO_2 emissions before it escapes into the atmosphere. CO_2 can be captured and sequestered deep beneath the ground or compressed and used for construction, but other options may offer carbon-neutral, or even carbon-negative solutions.[4]

When producing ethanol via fermentation, every molecule of fuel is accompanied by a molecule of CO_2, which amounts to approximately 45 tons of high-quality biogenic CO_2 every year.[5] Carbon dioxide captured during the manufacturing process can be fed to algae or other plants grown for future production, but it can also be put to use in other industries. For example, about 40% of the North American merchant market for CO_2 is provided by ethanol plants. This CO_2 can then be used for carbonating soda and beer.[6] Dry ice is also made from frozen CO_2 that comes from ethanol production.

Researchers are discovering new uses for captured greenhouse gases that can replace petrochemicals, a coproduct of drilling and refining oil, with a renewable and sustainable alternative.

The process to convert CO_2 to a productive feedstock is traditionally very

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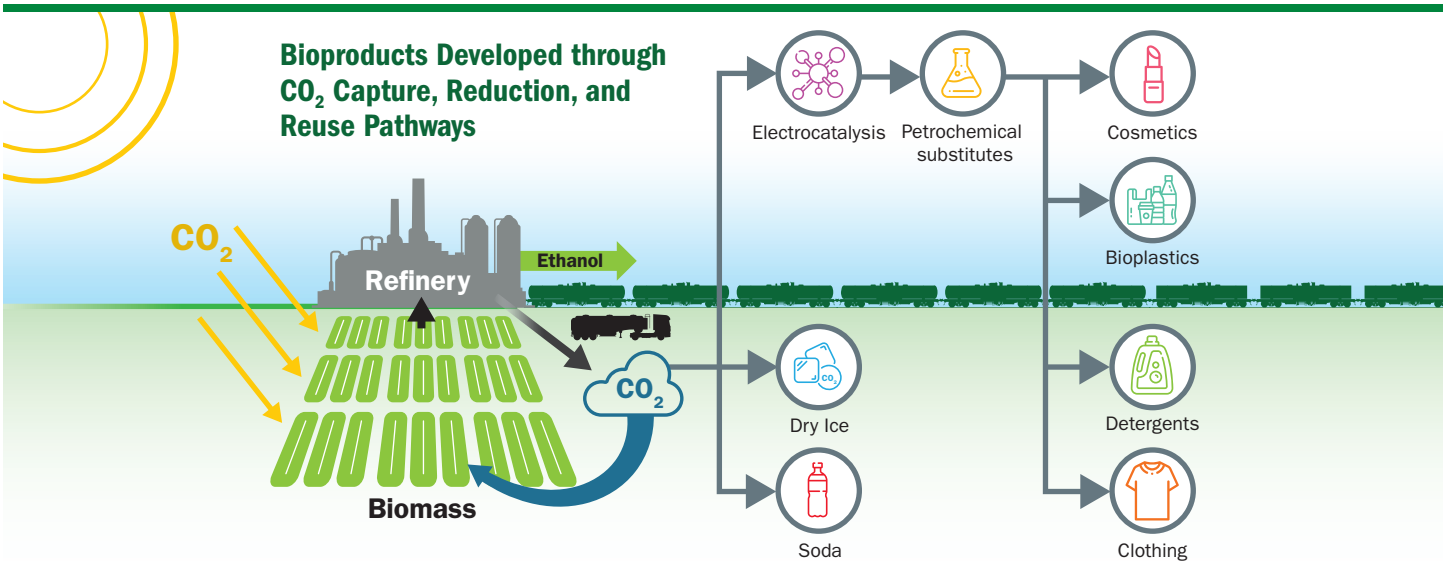

An example of how an existing biorefinery could capture and reuse carbon from its operations to feed the growth of on-site biomass to manufacture common products. *Illustration courtesy of BETO.*

difficult, but BETO is funding alternative solutions, such as electrocatalysis, that could make it more commercially feasible.[7] Electrocatalysis can use renewable electricity to convert CO_2 without the high temperature, high pressure environments needed for other catalytic conversion methods. Scientists have been successful with electrocatalysis in lab settings, and BETO funding is supporting three separate projects aiming to scale this closer to an industrial level.[8] The process can turn CO_2 into other chemicals, like carbon monoxide, formic acid, and methanol. These chemicals can then be used to create biofuels, cleaning products, cosmetics, or many of the items companies traditionally produce from fossil fuel-based chemicals.

Plastic bottles, grocery bags, car interiors, and countless items we encounter every day are constructed from plastic petrochemicals derived from petroleum or natural gas. Instead, the same items can be constructed from renewable, organic materials produced or grown in a sustainable manner.[9]

Smaller Carbon Footprints, Brighter Future

Bio-based fuels and products have smaller carbon footprints than their fossil-based counterparts because they absorb CO_2 from the atmosphere or utilize CO_2 captured emissions from industrial sources. As agricultural practices become more sustainable and lead to higher yields of more energy intense crops, the net benefits of biofuels are becoming even more pronounced.

BETO is researching ways to reduce the carbon output of fuels and replace carbon-emitting products we use every day. Progress in these areas will contribute to the U.S. commitment to reduce GHG emissions and improve sustainability in the decades to come. ■

About the Bioenergy Technologies Office

BETO supports research, development, and demonstration to enable the sustainable use of domestic biomass and waste resources for the production of biofuels and bioproducts. BETO's overall goals are designed to:

- Lower costs and reduce technology risks for production of biofuels and bioproducts
- Improve environmental benefits of bioenergy production
- Reduce greenhouse gas emissions from the transportation, industrial, and agricultural sectors to address the climate crisis
- Support the scale-up of sustainable, low-carbon biofuel production technologies
- Create economic opportunities and good-paying jobs in agriculture and manufacturing sectors.

Meeting these goals requires significant and rapid advances in technology development and innovation across the entire biomass-to-bioenergy supply chain.

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BIOENERGY TECHNOLOGIES OFFICE

For more information, visit:
energy.gov/eere/bioenergy

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