BRIEF # 10

PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

The Bioenergy Opportunity

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses key findings from the following report: Anela Arifi and Christopher B. Field, "Pathways to Carbon Neutrality in California: The Bioenergy Opportunity", Stanford Center for Carbon Storage and Stanford Carbon Removal Initiative, April 2022.

California has an abundance of biomass-based resources derived from the state's diverse agricultural, urban waste and forest streams. These biomass resource types can be converted to bioenergy products that have many potential applications across California's energy system, including renewable electricity generation, pipeline biomethane production (also known as renewable natural gas) and low carbon transportation fuel production. However, today, most of the carbon from this biomass returns to the atmosphere as carbon dioxide (CO_2) or methane (CH_4) as the biomass naturally decays or gets burned, representing an opportunity lost for bioenergy production.

KEY FINDINGS

1. Utilizing waste resources to produce useful bioenergy products in California avoids methane (CH_4) and/or carbon dioxide (CO_2) emissions that would have been released through waste decomposition or combustion and displaces fossil fuel use.

2. The total biogas potential from dairy manure, landfill gas, wastewater sludge, food waste, and green waste in California is about 192 billion cubic feet (BCF) today, 214 BCF in 2025, and 190 BCF in 2045. While dairy manure biogas and wastewater biogas potential increases over time due to higher rates of anaerobic digester installment and/or population growth, landfill gas decreases due to stringent waste diversion policies in the state.

3. The total current biogas potential represents about 9% of the total natural gas consumption in California. The biogas potential is also larger than the 25 BCF of natural gas consumed as transportation fuel in the state.

4. If the total gross biogas potential were utilized for energy production, California's total emissions could be reduced by about 8%.

5. The total gross solid waste potential from MSW and agricultural residues is about 23 million bone dry tons (BDT) today, 23.6 million BDT in 2025 and 26.9 million BDT in 2045.

6. There are currently only a few projects in California that either combust, gasify, or pyrolyze solid waste to produce electricity or liquid fuel because of strict environmental laws or because of slow technology adoption.

7. If the total gross solid waste potential were utilized for energy production, California's total emissions could be reduced by 1-5% depending on the conversion process and the end-product.

8. California's current biodiesel and ethanol production is supplied largely by imports. Biodiesel imports are mostly international while ethanol imports are mostly Midwestern.

9. On a petajoule basis for comparison of biomass and bioenergy resources, landfill gas holds the greatest energy potential in the waste category currently. In 2045, however, MSW and agricultural residues such as lumber, orchard residue and almond hulls represent the most significant energy potential.

10. The production of vehicle fuel from biogas becomes economically feasible only when the Low-Carbon Fuel Standard (LCFS) and the Renewable Fuel Standard credits are harvested. The LCFS is also a strong driver for imports of ethanol and biodiesel into California.

11. All biomass resources assessed release CO_2 at the time of conversion. That CO_2 can be captured and stored permanently making the production of bioenergy one of the most critical carbon-negative options necessary for achieving net-zero global emissions. While an assessment of bioenergy with capture and storage technology is out of the scope of this study, biomass and bioenergy potential presented can serve as a basis for quantifying negative emissions potential in decarbonization scenarios.

12. Gasifying biomass to hydrogen could lead to largest emission reduction benefits if coupled with CCS given high process emissions that are capturable.

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