



Energy Analysis

Biogas Potential in the United States

Biogas is the gaseous product of anaerobic digestion, a biological process in which microorganisms break down biodegradable material in the absence of oxygen. Biogas is comprised primarily of methane (50%–70%) and carbon dioxide (30%–50%), with trace amounts of other particulates and contaminants. It can be produced from various waste sources, including landfill material; animal manure; wastewater; and industrial, institutional, and commercial organic waste. Biogas can also be produced from other lignocellulosic biomass (e.g., crop and forest residues, dedicated energy crops) through dry fermentation, co-digestion, or thermochemical conversions (e.g., gasification).

Biogas can be combusted to provide heat, electricity, or both. In addition, it can be upgraded to pure methane—also called biomethane or renewable natural gas—by removing water, carbon dioxide, hydrogen sulfide, and other trace elements. This upgraded biogas is comparable to conventional natural gas, and thus can be injected into the pipeline grid or used as a transportation fuel in a compressed or liquefied form. Renewable natural gas is considered a “drop-in” fuel for the natural gas vehicles currently on the road and can qualify as an advanced biofuel under RFS2. It can also be a source for renewable hydrogen, which can be used in stationary fuel cells and fuel cell electric vehicles.

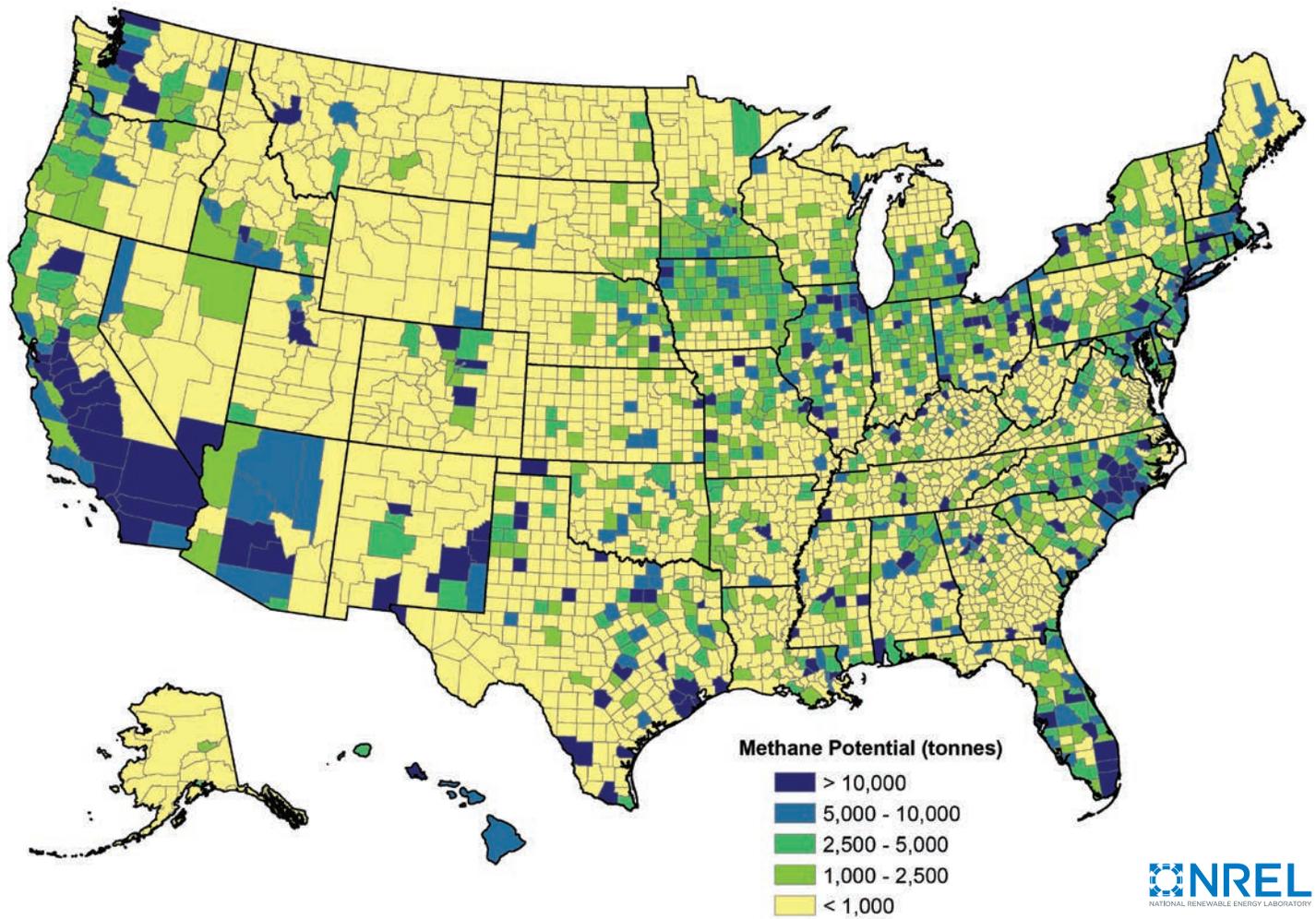
The methane content of biogas is the usable portion of the gas and determines its calorific value. The methane potential from landfill material, animal manure, wastewater, and industrial, institutional, and commercial organic waste in the United States is estimated at about 7.9 million tonnes per year, which is equal to about 420

billion cubic feet or 431 trillion British thermal units. This amount could displace about 5% of current natural gas consumption in the electric power sector and 56% of natural gas consumption in the transportation sector (EIA 2013). While this resource potential appears small and easy to overlook given the abundance of relatively inexpensive natural gas, it presents an opportunity for greenhouse gas mitigation (methane is 21 times more potent than carbon dioxide) and production of renewable energy fuel. These waste resources are underutilized and considered “low-hanging fruit” in biogas generation thus their use could stimulate further development of the industry in the United States.

Estimated Methane Generation Potential for Select Biogas Sources in the United States

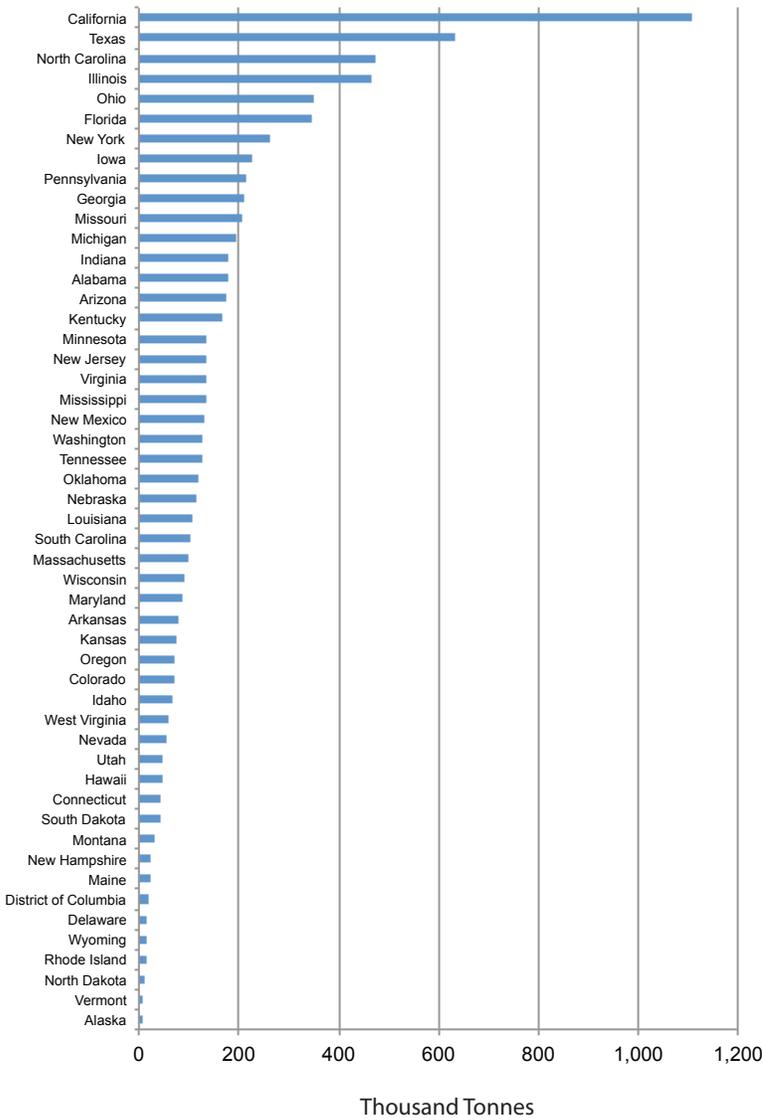
Source	Methane Potential (tonnes/yr)
Wastewater	2,339,339
Landfills*	2,454,974
Animal manure	1,905,253
IIC organic waste	1,157,883
Total	7,857,449

* Includes candidate landfills only as defined by the EPA's Landfill Methane Outreach Program



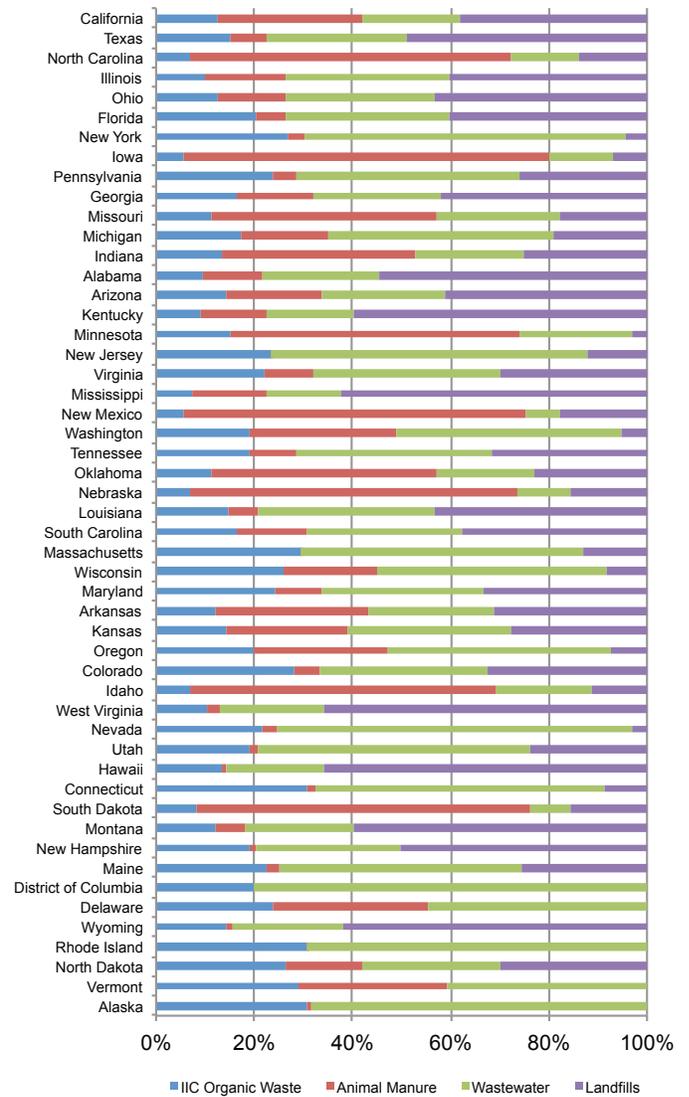
Estimated methane generation potential for select biogas sources by county

This analysis estimates the methane potential from wastewater; animal manure; landfills (candidate landfills only as defined by the EPA's Landfill Methane Outreach Program); and industrial, institutional, and commercial organic waste. It does not consider other lignocellulosic material or lipids.



Estimated methane generation potential for select biogas sources by state

The methane generation potential is expected to be much higher if lignocellulosic biomass resources are used. Future estimates reach 4.2 trillion cubic feet per year, or about 4,318 trillion British thermal units (NPC 2013), which could displace about 46% of current natural gas consumption in the electric power sector and the entire natural gas consumption in the transportation sector (EIA 2013a). This potential corresponds to about 35 billion gasoline gallon equivalents, which is three times more than current gasoline consumption (EIA 2013b). However, this estimate assumes that all biomass resources are used for biogas production and it does not account for competing uses, such as the production of other fuels or power generation in dedicated



Estimated contribution of select biogas sources to states' total methane generation potential

or co-fired power plants. This estimate also considers only thermal gasification, which is a well-understood technology used in coal conversions but not yet proven at large scale for biomass resources.

Lignocellulosic biomass is a promising candidate for anaerobic digestion, a conversion pathway explored extensively in Europe but not in the United States. Future work will examine the biogas generation potential from solid biomass resources via anaerobic digestion in the United States and compare the output and efficiency to the biogas potential from solid biomass via thermochemical conversion pathways (also called syngas).

References

"Monthly Energy Review: Energy Consumption by Sector." (2013a). U.S. Energy Information Administration (EIA). Accessed 2013: www.eia.gov/totalenergy/data/monthly/.

"Refiner Motor Gasoline Sales Volumes." (2013b). EIA. Accessed 2013: www.eia.gov/dnav/pet/pet_cons_refmg_d_nus_VTR_mgalpd_a.htm.

The National Petroleum Council (NPC). (1 August 2013). "Renewable Natural Gas for Transportation: An Overview of the Feedstock Capacity, Economics, and GHG Emission Reduction Benefits of RNG as a Low-Carbon Fuel." 41 pp. Accessed 2013: www.npc.org/FTF_Topic_papers/22-RNG.pdf. (working document).

Saur, G.; Milbrandt, A. (forthcoming). "Renewable Hydrogen Potential from Biogas in the United States." NREL/TP-5400-60283. Golden, CO: National Renewable Energy Laboratory.

Additional Information

- U.S. Environmental Protection Agency's Landfill Methane Outreach Program (LMOP): www.epa.gov/lmop/
- AgSTAR Program, a collaborative effort of the U.S. Environmental Protection Agency, U.S. Department of Agriculture, and U.S. Department of Energy: www.epa.gov/agstar/
- Opportunities for Combined Heat and Power at Wastewater Treatment Facilities: Market Analysis and Lessons from the Field: www.epa.gov/chp/documents/wwtf_opportunities.pdf
- National Renewable Energy Laboratory, Biomass Maps: www.nrel.gov/gis/biomass.html
- U.S. Department of Agriculture (USDA), Rural Development: www.rurdev.usda.gov/LP_BusinessPrograms.html
- American Biogas Council: www.americanbiogascouncil.org/
- Database of State Incentives for Renewable Energy (DSIRE): www.dsireusa.org/index.cfm?EE=0&RE=1



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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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