Environmental and Energy Study Institute

Fact Sheet

Biogas: Converting Waste to Energy

September 2017

The United States produces more than 70 million tons of organic waste each year. While source reduction and feeding the hungry are necessary priorities for reducing needless food waste, organic wastes are numerous and extend to non-edible sources, including livestock manure, agriculture wastes, waste water, and inedible food wastes.[1] When these wastes are improperly managed, they pose a significant risk to the environment and public health. Pathogens, chemicals, antibiotics, and nutrients present in wastes can contaminate surface and ground waters through runoff or by leaching into soils. Excess nutrients cause algal blooms, harm wildlife, and infect drinking water. Drinking water with high levels of nitrates is linked to hyperthyroidism and blue-baby syndrome.[2,3] Municipal water utilities treat drinking water to remove nitrates, but it is costly to do so.

Organic wastes also generate large amounts of methane as they decompose. Methane is a powerful greenhouse gas that traps heat in the atmosphere more efficiently than carbon dioxide. Given equal amounts of methane and carbon dioxide, methane will absorb 86 times more heat in 20 years than carbon dioxide.[4] To reduce greenhouse gas emissions and the risk of pollution to waterways, organic waste can be removed and used to produce biogas, a renewable source of energy. When displacing fossil fuels, biogas creates further emission reductions, sometimes resulting in carbon negative systems. Despite the numerous potential benefits of organic waste utilization, including environmental protection, investment and job creation, the United States currently only has 2,200 operating biogas systems, representing less than 20 percent of the total potential.[5]

Introduction

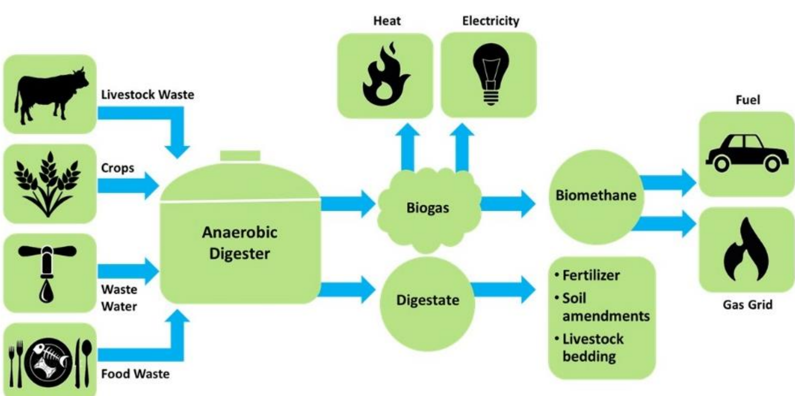

Figure 1: Anaerobic digestion process

What is biogas?

Biogas is produced after organic materials (plant and animal products) are broken down by bacteria in an oxygen-free environment, a process called anaerobic digestion. Biogas systems use anaerobic digestion to recycle these organic materials, turning them into biogas, which contains both energy (gas), and valuable soil products (liquids and solids).

Anaerobic digestion already occurs in nature, landfills, and some livestock manure management systems, but can be optimized, controlled, and contained using an anaerobic digester. Biogas contains roughly 50-70 percent methane, 30-40 percent carbon dioxide, and trace amounts of other gases.[6] The liquid and solid digested material, called digestate, is frequently used as a soil amendment.

Some organic wastes are more difficult to break down in a digester than others. Food waste, fats, oils, and greases are the easiest organic wastes to break down, while livestock waste tends to be the most difficult. Mixing multiple wastes in the same digester, referred to as co-digestion, can help increase biogas yields. Warmer digesters, typically kept between 30 to 38 degrees Celsius (86-100 Fahrenheit), can also help wastes break down more quickly.[7]

After biogas is captured, it can produce heat and electricity for use in engines, microturbines, and fuel cells. Biogas can also be upgraded into biomethane, also called renewable natural gas or RNG, and injected into natural gas pipelines or used as a vehicle fuel.

The United States currently has 2,200 operating biogas systems across all 50 states, and has the potential to add over 13,500 new systems.[8]

Figure 2: Operational biogas systems in the continental United States[7] (Courtesy: American Biogas Council)

The Benefits of Biogas

Stored biogas can provide a clean, renewable, and reliable source of baseload power in place of coal or natural gas. Baseload power is consistently produced to meet minimum power demands; renewable baseload power can complement more intermittent renewables. Similar to natural gas, biogas can also be used as a source of peak power that can be rapidly ramped up.[9] Using stored biogas limits the amount of methane released into the atmosphere and reduces dependence on fossil fuels. The reduction of methane emissions derived from tapping all the potential biogas in the United States would be equal to the annual emissions of 800,000 to 11 million passenger vehicles.[10] Based on a waste-to-wheels assessment, compressed natural gas derived from biogas reduces greenhouse gas emissions by up to 91 percent relative to petroleum gasoline.[11]

New York City spends roughly $400 million each year to transport 14 million tons of waste to incinerators and landfills. Diverting that waste to anaerobic digestion would turn a cost into an opportunity, generating revenue from energy production and co-products. Source: New York Times, June 2, 2017

In addition to climate benefits, anaerobic digestion can lower costs associated with waste remediation as well as benefit local economies. Building the 13,500 potential biogas systems in the United States could add over 335,000 temporary construction jobs and 23,000 permanent jobs.[12] Anaerobic digestion also reduces odors, pathogens, and the risk of water pollution from livestock waste. Digestate, the material remaining after the digestion process, can be used or sold as fertilizer, reducing the need for chemical fertilizers. Digestate also can provide additional revenue when sold as livestock bedding or soil amendments.

Biogas Feedstocks

Food Waste

Around 30 percent of the global food supply is lost or wasted each year.[13] In 2010 alone, the United States produced roughly 133 billion pounds (66.5 million tons) of food waste, primarily from the residential and commercial food sectors.[14] To address this waste, EPA's Food Recovery Hierarchy prioritizes source reduction first, then using extra food to address hunger; animal feed or energy production are a lower priority. Food should be sent to landfills as a last resort.[15] Unfortunately, food waste makes up 21 percent of U.S. landfills, with only 5 percent of food waste being recycled into soil improver or fertilizer.[16] Most of this waste is sent to landfills, where it produces methane as it breaks down. While landfills may capture the resultant biogas, landfilling organic wastes provides no opportunity to recycle the nutrients from the source organic material. In 2015, the EPA and USDA set goals to reduce the amount of food waste sent to landfills by 50 percent by 2030. But even if this goal is met, there will be excess food that will need to be recycled. The energy potential is significant. As just one example, with 100 tons of food waste per day, anaerobic digestion can generate enough energy to power 800 to 1,400 homes each year.[17] Fat, oil, and grease collected from the food service industry can also be added to an anaerobic digester to increase biogas production.

Landfill Gas

Landfills are the third largest source of human-related methane emissions in the United States.[18] Landfills contain the same anaerobic bacteria present in a digester that break down organic materials to produce biogas, in this case landfill gas (LFG). Instead of allowing LFG to escape into the atmosphere, it can be collected and used as energy. Currently, LFG projects throughout the United States generate about 17 billion kilowatt-hours of electricity and deliver 98 billion cubic feet of LFG to natural gas pipelines or directly to end-users each year.[19] For reference, the average U.S. home in 2015 used about 10,812 kilowatt-hours of electricity per year.[20]

Livestock Waste

A 1,000-pound dairy cow produces an average of 80 pounds of manure each day. This manure is often stored in holding tanks before being applied to fields. Not only does the manure produce methane as it decomposes, it may contribute to excess nutrients in waterways.[21] In 2015, livestock manure management contributed about 10 percent of all methane emissions in the United States, yet only 3 percent of livestock waste is recycled by anaerobic digesters.[22,23] When livestock manure is used to produce biogas, anaerobic digestion can reduce greenhouse gas emissions, reduce odors, and reduce up to 99 percent of manure pathogens.[24,25] The EPA estimates there is the potential for 8,241 livestock biogas systems, which could together generate over 13 million megawatt-hours of energy each year.[26]

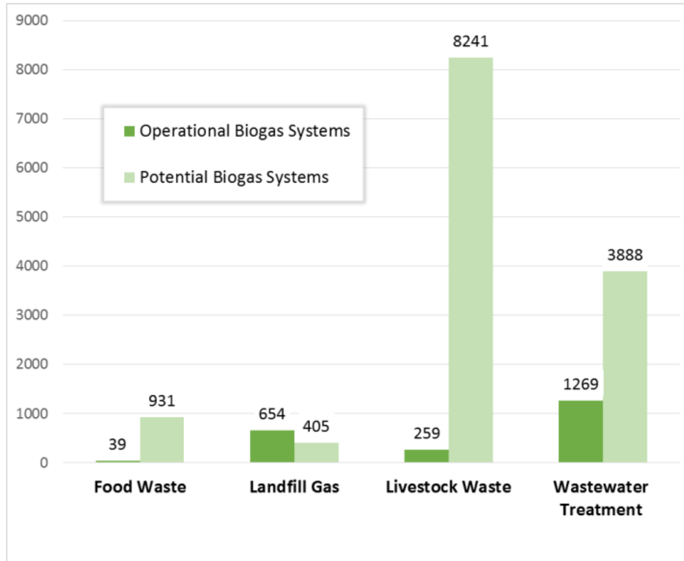

Figure 3: Current number of operational and potential biogas systems in the United States by feedstock. *EPA*

Wastewater Treatment

Many wastewater treatment plants (WWTP) already have on-site anaerobic digesters to treat sewage sludge, the solids separated during the treatment process. However, many WWTP do not have the equipment to use the biogas they produce, and flare it instead.[27] Of the 1,269 wastewater treatment plants using an anaerobic digester, only around 860 use their biogas.[28] If all the facilities that currently use anaerobic digestion—treating over 5 million gallons each day—were to install an energy recovery facility, the United States could reduce annual carbon dioxide emissions by 2.3 million metric tons—equal to the annual emissions from 430,000 passenger vehicles.[29]

Crop Residues

Crop residues can include stalks, straw, and plant trimmings. Some residues are left on the field to retain soil organic content and moisture as well as prevent erosion. However, higher crop yields have increased amounts of residues and removing a portion of these can be sustainable. Sustainable harvest rates vary depending on the crop grown, soil type, and climate factors. Taking into account sustainable harvest rates, the U.S. Department of Energy estimates there are currently around 104 million tons of crop residues available at a price of $60 per dry ton.[30] Crop residues are usually co-digested with other organic waste because their high lignin content makes them difficult to break down.

Biogas End Uses

Raw Biogas and Digestate

With little to no processing, biogas can be burned on-site to heat buildings and power boilers or even the digester itself. Biogas can be used for combined heat and power (CHP) operations, or biogas can simply be turned into electricity using a combustion engine, fuel cell, or gas turbine, with the resulting electricity being used on-site or sold onto the electric grid.[31]

Digestate is the nutrient-rich solid or liquid material remaining after the digestion process; it contains all the recycled nutrients that were present in the original organic material but in a form more readily available for plants and soil building. The composition and nutrient content of the digestate will depend on the feedstock added to the digester. Liquid digestate can be easily spray-applied to farms as fertilizer, reducing the need to purchase synthetic fertilizers. Solid digestate can be used as livestock bedding or composted with minimal processing.[32] Recently, the biogas industry has taken steps to create a digestate certification program, to assure safety and quality control of digestate.[33]

Renewable Natural Gas

Renewable natural gas (RNG), or biomethane, is biogas that has been refined to remove carbon dioxide, water vapor, and other trace gases so that it meets natural gas industry standards. RNG can be injected into the existing natural gas grid (including pipelines) and used interchangeably with conventional natural gas. Natural gas (conventional and renewable) provides 26 percent of U.S. electricity, and 40 percent of natural gas is used to produce electricity.[34,35] The remainder of natural gas is used for commercial purposes (heating and cooking) and for industrial ones. RNG has the potential to replace up to 10 percent of the natural gas used in the United States.[36]

With biogas systems, dairies, farms, and industry can reduce operational costs using their own organic wastes to power their equipment and buildings. Fair Oaks Dairy in Indiana produces 1.2 million cubic feet of biogas each day with manure from 9,000 dairy cows. Some of the biogas is upgraded to CNG and used to power trailers delivering milk to Fair Oaks processing plants, reducing their use of diesel fuel by 1.5 million gallons per year.
Source: EPA

Compressed Natural Gas and Liquefied Natural Gas

Like conventional natural gas, RNG can be used as a vehicle fuel after it is converted to compressed natural gas (CNG) or liquefied natural gas (LNG). The fuel economy of CNG-powered vehicles is comparable to that of conventional gasoline vehicles and can be used in light- to heavy-duty vehicles.[37] LNG is not as widely used as CNG because it is expensive to both produce and store, though its higher density makes LNG a better fuel for heavy-duty vehicles that travel long distances.[38] To make the most of investments in fueling infrastructure, CNG and LNG are best suited for fleet vehicles that return to a base for refueling. The National Renewable Energy Laboratory estimates RNG could replace five percent of the natural gas used to produce electricity and 56 percent of the natural gas used to produce vehicle fuel.[39]

Federal Policies Supporting the Biogas Industry

The Renewable Fuel Standard

The Renewable Fuel Standard (RFS) was created by Congress as part of the 2005 Energy Policy Act. The RFS requires the blending of renewable fuels into the U.S. transportation fuel supply. Currently about 10 percent of the gasoline supply is provided by renewable fuel, primarily ethanol. The RFS sets fuel volumes for a variety of fuel categories: biomass-based diesel, advanced biofuel, cellulosic biofuel, and renewable fuel as a whole. Each category has a required minimum reduction in greenhouse gases.

Production of cellulosic biofuel (in gallons) by fuel type [40]

	Ethanol	Renewable CNG	Renewable LNG
2015	2,181,096	81,490,266	58,368,879
2016	3,805,246	116,582,508	71,974,041
2017*	3,536,721	56,916,606	34,224,820

*As of July 2017

EPA approved biogas as a qualifying cellulosic feedstock under the RFS in 2014. Cellulosic biofuels must be 60 percent less greenhouse gas-intensive than gasoline.[41] Currently, most of the cellulosic fuel volumes are being met through the use of RNG as a vehicle fuel. Compliance with the RFS is tracked through renewable identification numbers (RINs) that can be traded, and RINs for cellulosic biofuels can earn RNG producers $40/MMBtu (as of September 2017).[42] According to biogas producers, the RFS has become an important driver of investment in the industry.

As part of the approval of biogas, the EPA updated the RFS to allow biogas-derived electricity used as vehicle fuel to qualify for RINs, or "e-RINs." However, as of 2017, the EPA has not approved any producer requests to start generating e-RINs, despite biogas production already exceeding current transportation electricity demand.[43]

The Farm Bill[44]

Programs under the Farm Bill's Energy Title (IX) have been crucial for growth in the biogas industry. Under the 2014 Farm Bill, the USDA's Bioenergy Program for Advanced Biofuels provides payments to producers to promote the production of advanced biofuels refined from sources other than corn starch. The program currently receives $15 million per year in mandatory funding with $20 million available per year in discretionary funding through 2018.

The Rural Energy for America Program (REAP) provides grants and loan guarantees to agricultural producers and rural small businesses to promote renewable energy production and energy efficiency improvements. The program has mandatory funding of $50 million per year through 2018, and $100 million available in discretionary funds.

The Biomass Research and Development Initiative is a joint program between the USDA and DOE. With $3 million in mandatory funding through fiscal year 2017 and $20 million in discretionary funding through fiscal year 2018, the Biomass Research and Development Board awards grants, contracts, and financial assistance to projects that stimulate research and development of biofuels and bio-based products. However, these programs have consistently seen reductions in funding through the appropriations process.

With the help of over $500,000 in REAP grants and loans, Pennwood Farms was able to install an anaerobic digester in 2011. Bedding made from digestate saves the farm about $60,000 a year in bedding costs, and waste from the farm's 600 dairy cows produces more than enough electricity to meet on-site needs. Source: USDA

Other Agency Programs

AgSTAR is a joint program between the EPA, USDA, and DOE.[45] The program promotes the use of anaerobic digesters on livestock farms to reduce methane emissions from animal waste. The AgSTAR program supports the planning and implementation of anaerobic digester projects, and includes state and non-governmental partners.

The EPA's **Landfill Methane Outreach Program** (LMOP) encourages the waste industry to recover and use biogas generated from organic waste in landfills.[46] LMOP forms partnerships with communities, utilities, landfill owners, and other stakeholders to provide technical assistance and seek financing for landfill biogas projects.

Conclusion

Biogas systems turn the cost of waste management into a revenue opportunity for America's farms, dairies, and industries. Converting waste into electricity, heat, or vehicle fuel provides a renewable source of energy that can reduce dependence on foreign oil imports, reduce greenhouse gas emissions, improve environmental quality, and increase local jobs. Biogas systems also provide an opportunity to recycle nutrients in the food supply, reducing the need for both petrochemical and mined fertilizers.

Biogas systems are a waste management solution that solve multiple problems and create multiple benefits, including revenue streams. The United States currently has the potential to add 13,500 new biogas systems, providing over 335,000 construction jobs and 23,000 permanent jobs. However, to reach its full potential, the industry needs consistent policy support. Reliable funding of Farm Bill energy title programs and a strong Renewable Fuel Standard encourage investment and innovation in the biogas industry. If the United States intends to diversify its fuel supply and take action against climate change, it should strongly consider the many benefits of biogas.

This fact sheet is available electronically (with hyperlinks and endnotes) at *www.eesi.org/papers*.

Author: Sara Tanigawa
Editor: Jessie Stolark

The Environmental and Energy Study Institute (EESI) is a non-profit organization founded in 1984 by a bipartisan Congressional caucus dedicated to finding innovative environmental and energy solutions. EESI works to protect the climate and ensure a healthy, secure, and sustainable future for America through policymaker education, coalition building, and policy development in the areas of energy efficiency, renewable energy, agriculture, forestry, transportation, buildings, and urban planning.

---

[1] Fueling Economic Growth with Renewable Natural Gas. Coalition for Renewable Natural Gas and Energy Vision, 2016.
[2] Ground Water Contamination. EPA.
[3] Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. Environmental Health Perspectives, February 2007.
[4]Anthropogenic and Natural Radiative Forcing. Myhre, G., D. et. al, 2013. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker, T.F., et al. (eds)
[5] Biogas 101 Handout. American Biogas Council.
[6] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[7] Frequent Questions. American Biogas Council.
[8] Biogas 101 Handout. American Biogas Council.
[9] Meek, Brian, Avant Energy, "Powering Businesses, Homes and Vehicles with Waste," May, 2017
[10] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[11] Waste-to-Wheel Analysis of Anaerobic-Digestion-Based Renewable Natural Gas Pathways with the GREET Model. Argonne National Laboratory, September 2011.
[12] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[13] Sustainable Management of Food. EPA.
[14] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[15] Food Recovery Hierarchy. EPA.
[16] Sustainable Management of Food Basics, U.S. EPA, July 2017.
[17] Anaerobic Digestion of Food Waste. East Bay Municipal Utility District, March 2008.
[18] Overview of Greenhouse Gases. EPA.
[19] Landfill Gas Energy Basics. EPA.
[20] How Much Electricity Does an American Home Use?, U.S. Energy Information Administration, Oct. 2016.
[21] Animal Manure Management. USDA Natural Resources Conservation Service, Dec. 1995.
[22] Biogas 101 Handout. American Biogas Council.
[23] Overview of Greenhouse Gases. EPA.
[24] On Farm Biogas Production: A Method to Reduce GHG Emissions and Develop More Sustainable Livestock Operations. Animal Feed Science and Technology, June 2011.
[25] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[26] Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities. EPA, November 2011.
[27] Develop a Micro-Grid Using Energy Produced at Your Wastewater Treatment Facility. American Council for an Energy-Efficient Economy, 2016.
[28] Biogas 101 Handout. American Biogas Council.
[29] Renewable Energy Resources: Banking on Biosolids. National Association of Clean Water Agencies, 2010.
[30] 2016 Billion-Ton Report. DOE, July 2016.
[31] Biogas Opportunities Roadmap. USDA, EPA, and DOE, August 2014.
[32] Digestate Utilization in the U.S. BioCycle, January 2012.
[33] ABC Digestate Standard Testing and Certification Program, American Biogas Council.
[34] Use of Natural Gas, U.S. Energy Information Administration, Oct. 2016.
[35] Natural Gas Fuel Basics. DOE Alternative Fuels Data Center, April 2017.
[36] The Potential for Renewable Gas: Biogas Derived from Biomass Feedstocks and Upgraded to Pipeline Quality. American Gas Foundation, September 2011.
[37] Natural Gas Fuel Basics. DOE Alternative Fuels Data Center, April 2017.
[38] Natural Gas Fuel Basics. DOE Alternative Fuels Data Center, April 2017.
[39] Biogas Potential in the United States. National Renewable Energy Laboratory, October 2013.
[40] 2016 Renewable Fuel Standard Data. EPA, June 2017.
[41] Renewable Fuel Standard. DOE Alternative Fuels Data Center, May 2017.
[42] Serfass, Patrick, American Biogas Council, "Powering Businesses, Homes and Vehicles with Waste," May, 2017
[43] Analyzing the Impacts of a Biogas-to-Electricity Purchase Incentive on Electric Vehicle Deployment with the MA^3T Vehicle Choice Model. Oak Ridge National Laboratory, January 2017.
[44] Energy Programs. The 2014 Farm Bill.
[45] AgSTAR: Biogas Recovery in the Agriculture Sector. EPA.
[46] Landfill Methane Outreach Program (LMOP). EPA.