

Small-scale anaerobic digestion system technology

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Anaerobic digestion (AD) is a process that involves the breakdown of complex organic material by microorganisms in the absence of oxygen. It produces digestate that may be stored and land applied as fertilizer, and biogas that can be utilized to produce electricity and/or heat or upgraded to produce renewable natural gas (RNG). Renewable natural gas is also referred to as biomethane and may be gas pipeline quality or compressed natural gas (CNG) vehicle quality.

Typically, anaerobic digesters are used on a large-scale as a manure treatment and handling method for dairy farms where they more easily achieve economic feasibility. Small-scale anaerobic digestion systems have emerged as an available option for smaller farms. These small-scale digesters may intake manure and/or food waste and produce energy at the farm. Other benefits of AD¹ include reduced odor, pathogen reduction, and substantially reduced methane emissions.

Digester technology

Digesters with volumes below 200 cubic meters (about 53,000 gallons) are typically classified as small-scale². The capacity of small-scale digesters may vary, but they can intake as little as 25 tons or as many as 21,000 tons of organic material per year (including food waste and manure). On average, one lactating cow produces about 27 tons (6,570 gallons) of manure per year and one 970-pound heifer produces eight to nine tons (2,190 gallons) of manure per year³. Table 1 shows the mass of manure excreted per year by number of lactating cows.

The smaller digesters on this scale typically come prefabricated, or fully integrated and containerized⁴, and may be suitable for farms with less than 165 cows. They are installed above ground rather than in-ground. The smallest options (e.g., 25-ton yearly capacity) were originally developed to accept food waste, but can accommodate other forms of organic waste, including manure.

Options are also available for mid-size farms of 165 to 800 cows. These digester vessels are generally constructed on-site and may be located in-ground or above ground⁵.

Table 1. Average manure mass excreted per year by number of lactating cows.

Number of Lactating Cows	Manure Produced (Tons Per Year)
100	2,736
200	5,472
300	8,208
400	10,944
500	13,680
600	16,415
700	19,152
800	21,888

Energy utilization

Anaerobic digesters produce biogas, a mixture of methane, carbon dioxide, and other trace gases. The biogas output of small-scale digesters varies with digester size and composition of organic material input. For example, a digester that processes 2,580 tons of co-digested organic material per year, consisting of two-thirds manure and one-third food waste, can produce about 15 cubic feet per minute (cfm) of biogas⁶. Notably, food waste may have two to three times more energy potential per unit mass than manure, making co-digestion an effective method to increase energy output. This biogas output may be used in a combined heat and power (CHP) system to generate electricity and heat energy. The smallest CHP systems have a power capacity between 10 kW and 20 kW, using as little as three cfm of biogas.

Additionally, biogas may be upgraded to biomethane through carbon dioxide (CO₂) capture and removal. Pressure swing adsorption (PSA) systems are most suitable for small-scale digester systems to upgrade and condition biogas to biomethane. Biogas is pretreated and trace gases are removed before being delivered to a compressor. After this, the PSA is used to adsorb nitrogen (N₂), oxygen (O₂), and CO₂, producing biomethane. The smallest digesters may not connect to the natural gas pipeline grid for RNG injection as it is not cost-effective to upgrade to pipeline quality and cover grid interconnection costs. Instead, biomethane can be delivered directly to a vehicle fueling station, a boiler, or other combustion equipment that require a lower percentage of methane (lower BTU) in the gas.

Although PSA is typically used on small-scale AD systems to produce biomethane, other methods for biogas purification may be used. Membrane systems utilize filters with specific pore sizes to remove CO₂. Single-pass membrane systems are best for farms that produce smaller biogas volumes and may be used as onsite vehicle fuel. Minor volumes of oxygen and inert gases may be present that pass through the membrane. Multiple-pass membrane systems pass biogas through membranes several times and support larger biogas volumes. Solvent scrubbing utilizes a chemical solvent (e.g., amine) to remove CO₂ and hydrogen sulfide (H₂S). Water scrubbing, usually reserved for very large-scale systems, pressurizes biogas into water, allowing CO₂ to be adsorbed and methane to pass into the product gas stream. Table 2 outlines the biogas utilization type and associated minimum biogas input and energy output with available technology at the smallest scale.

Table 2. Biogas utilization type and associated minimum biogas input and energy output.

Biogas Technology	Minimum Biogas Input (cfm)	Energy Output (per hour)
CHP	3	10 kW
RNG	5	0.2 million BTU (MMBtu)
RNG (pipeline quality)	30	1 million BTU (MMBtu)

Summary

Technology options now exist to accomplish AD and energy generation from biogas on a small scale; however, the capital and operating expense must be carefully estimated to evaluate the economic feasibility for your operation. Visit the [Dairy Environmental Systems website](#) for more resources on AD systems and their economic feasibility.



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¹ Gooch, C.A. and P.E. Wright. (2018). Key Benefits of Anaerobic Digestion. Cornell PRO-DAIRY Dairy Environmental Systems Program. hdl.handle.net/1813/66954.

² Issahaku, M., Derkyi, N. S., & Kemausuor, F. (2024). A systematic review of the design considerations for the operation and maintenance of small-scale biogas digesters. *Heliyon*, 10(1). doi.org/10.1016/j.heliyon.2024.e24019.

³ ASABE. (2013). Manure Production and Characteristics (ASAE D384.2). ASABE, St. Joseph, MI.

⁴ www.chomp.energy/product-line.

⁵ agriculturaldigesters.com/small-scale-manure-digesters/.

⁶ blogs.dickinson.edu/farm/biogasproject/.