Anaerobic Digestion

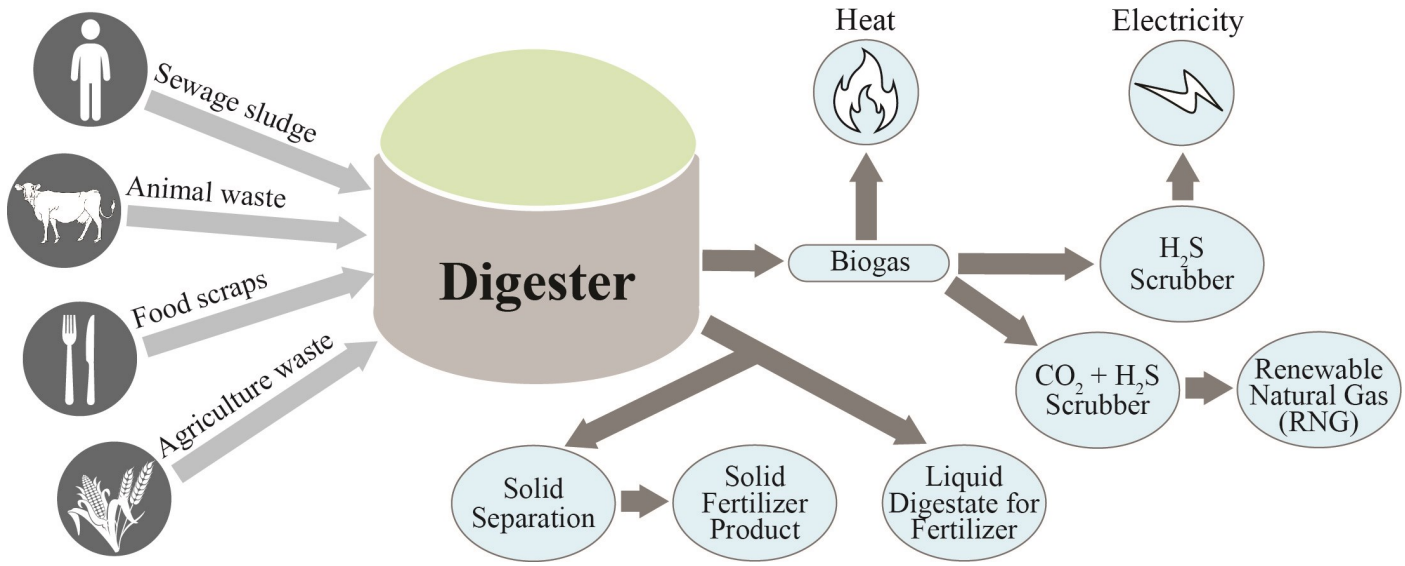

Diagram of the inputs and outputs of an anaerobic digestion bioenergy production system.

Anaerobic Digestion Background

Anaerobic digestion (AD) is a technology that transforms waste into renewable energy while reducing greenhouse gas emissions. During anaerobic digestion, *biogas* is produced from naturally occurring microbes that break down biodegradable material inside a sealed, oxygen-free reactor called a digester. AD can process a wide range of feedstocks, such as food scraps, manure, crop waste, or sewage sludge. With rising concerns about odors and greenhouse emissions from manure and food waste, the use of AD processing allows farmers to greatly reduce or eliminate these odors and greenhouse gas emissions. Additionally, the AD process produces renewable bioenergy and a fertilizer that is odor-free and pathogen-free, allowing valuable nutrients and organic matter in waste to be used to grow crops and offset the use of chemical-based fertilizers.

Anaerobic digestion involves three biological steps:

1. **Hydrolysis:** Bacteria convert complex materials into soluble carbohydrates, fats, and proteins.
2. **Acidogenesis:** Bacteria convert the soluble compounds into short-chained organic acids.
3. **Methanogenesis:** Bacteria (called methanogens) utilize the organic acids to produce biogas, which has >50% methane.

The process is similar to digestion inside a person's stomach, where bacteria metabolize our food. The process of anaerobic digestion is sensitive to several variables, including pH, oxygen concentration, and digester temperature. The digester temperature is usually mesophilic (35-38°C or 95-100 °F) or thermophilic (55-60°C or 130-140 °F), the reactor is free of oxygen, and the pH is between 6.8 and 8.

Definition of Biogas

One of the valuable products of AD is biogas. Biogas is the mixture of gases produced by the microbial decomposition of organic wastes in anaerobic digestion systems. It is composed of 50-75% methane (CH_4), 25-50% carbon dioxide (CO_2), 3-4% water vapor, and trace

Upright anaerobic digester at a dairy farm in Stuttgart, Germany. Photo: Stephanie Lansing

gases (<1%) that may include hydrogen (H_2), ammonia (NH_3), hydrogen sulfide (H_2S), and carbon monoxide (CO).

Methane is the primary energy component in biogas, with the energy content related to the amount of methane it contains. Biogas can be used directly for heat and electricity production (after removing H_2S using H_2S scrubbing technology to protect the broiler or electric generator from corrosion). Biogas may also be upgraded to renewable natural gas (RNG) with >99% CH_4 by adding more advanced scrubbing technologies that remove all other gases present in the biogas.

Differences between Natural Gas and Biogas

Source and Renewability:

- **Natural gas** is a fossil fuel composed of >99% CH_4 extracted from underground fossil fuel reserves. As a finite resource, the underground reserves where it is extracted will eventually be exhausted. It is a non-renewable energy source produced over millions of years.
- **Biogas** is produced during AD from decomposition of organic waste materials by microbes in the time span of hours or days. AD processing can produce biogas continuously, making it a source of renewable energy from biomass feedstocks. Biogas is primarily composed of CH_4 (>50%) and produced from renewable feedstocks, such as agricultural waste, food scraps, animal waste, and sewage sludge, which can be regenerated within a short time frame.

Carbon Footprint:

- **Natural gas** is extracted, transported, and burned for energy. Methane is a potent greenhouse gas that can leak during natural gas extraction and transportation. When burned for heating or electricity, the CH_4 in natural gas is transformed into additional atmospheric CO_2 that contributes to global warming.
- **Biogas** is also burned for heat or electricity production, with CH_4 transformed into CO_2 by the combustion process. When renewable feedstocks, such as food waste and manure, are used in anaerobic digestion, this CO_2 is not additional CO_2 but represents the release of previously sequestered CO_2 during photosynthesis. Avoided CH_4 emissions occur when manure and food scraps are processed in anaerobic digesters. The CH_4 that would have been otherwise naturally formed and released in open lagoons or landfill storage is captured, renewable energy is generated, and global warming potential is significantly reduced.

Uses for Biogas Produced from Anaerobic Digestion (AD)

- **Electricity** is generated when biogas is combusted to power a generator or a combined heat and power (CHP) system, where the captured heat can also be used to heat the anaerobic digester and meet other nearby heating needs.
- **Heat** is generated from the direct burning of biogas. It can be used for cooking, industrial processes, or to generate steam.
- **Renewable Natural Gas (RNG)** is created when biogas is upgraded to >99% CH_4, where the RNG can be injected into a natural gas pipeline or used in any natural gas installation.
- **Vehicle Fuel** is formed when the biogas is compressed and upgraded (on-farm or at a central location) using advanced CO_2 scrubbing technology to at least 80% CH_4. If the biogas contains 80 - 95% CH_4, a vehicle manufactured to run on upgraded, compressed biogas will be needed. If the biogas is upgraded to >99% CH_4, also known as RNG, any vehicle designed to run on compressed natural gas can be used.

Covered lagoon anaerobic digester at Kilby Farm in Cecil County, MD. Photo: Amro Hassanein

Generating Income from Anaerobic Digestion (AD)

- **Electricity, heat, RNG, and vehicle fuel** sales can generate revenue based on direct use or sale. The electric sale price can depend on whether the energy is used on-site to offset energy use or sold to an electric or natural gas company, with the rates negotiated between the electric company and the operator based on state law.
- **Fertilizers** from AD include the effluent that can be used directly as a liquid fertilizer. The solids can also be separated from the liquid fertilizer and sold as a solid fertilizer product, with similar nutritional and soil conditioning benefits to compost. Separated liquids can be used directly on fields as a fertilizer or the nutrients can be extracted from the liquids through advanced processing and sold separately.
- Farmers and/or AD operators can receive **tax credits** from federal, state, or local sources for renewable electricity or renewable natural gas produced from AD, with rates depending on the relevant federal, state, and local policies.
- **Renewable Fuel Standard (RFS) and Renewable Energy Credits (REC)** are used in federal and certain state energy trading programs. The RFS and REC values are based on the renewable identification numbers (RINs) given, which take into account the expected greenhouse gas emissions reduced based on the type of biomass feedstock digested.
- AD operators can receive **tipping fees** from manufacturing, businesses, or entities that generate organic waste and pay AD operators to receive the organic waste and process it using digestion.
- AD operators can receive **carbon offset credits** as AD processing decreases greenhouse gas emissions by reducing CO_2 and CH_4 emissions. AD systems decrease CH_4 emissions by capturing and processing manure or food waste and reduce additional CO_2 emissions through renewable energy production that offsets fossil fuel energy use. AD operators can sell the carbon offset credits through private transactions or credit aggregators.

Conclusion

Anaerobic digestion is a technology that transforms biomass into renewable energy and beneficial fertilizer while reducing odors and greenhouse gas emissions. During anaerobic digestion, biogas is produced from naturally occurring microbes that degrade biomass inside a sealed, oxygen-free reactor, called an anaerobic digester. Anaerobic digesters can process a wide range of waste, such as food scraps, manure, crop waste, or sewage sludge. The products of can provide additional revenue sources to farms through electricity or RNG sales, tipping fees, and/or tax credits.

Contact Information

For more information on the Animal Waste Technology factsheet series and the Maryland Animal Waste Technology assessment submitted to the Maryland Department of Agriculture go to https://go.umd.edu/AWTF

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