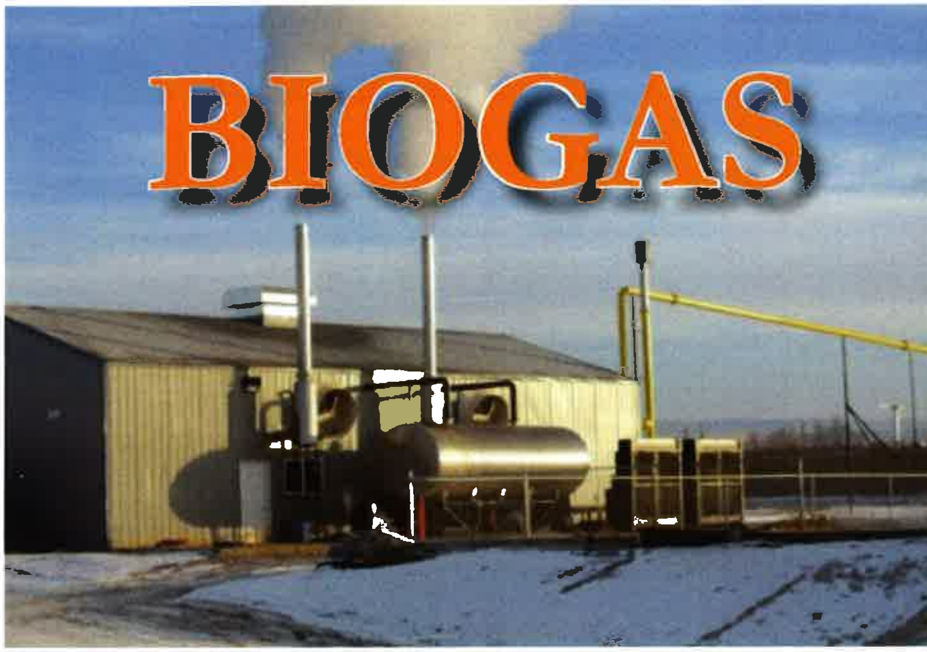
UNIVERSITY OF ALASKA FAIRBANKS

Alaska Center for Energy and Power



Large facilities benefit from the economy of scale, making them more efficient and profitable. The Vander Haak Dairy in Lynden, Wash., has a 600-kWh capacity.

Flammable methane pockets are located under winter lake ice. Dragos Vas and Katey Walter Anthony observe. Photo by Todd Paris/UAF

Biogas produced from the breakdown of organic material presents an attractive renewable fuel option for communities with excess organic waste. In recent years, biogas has gained attention due to the rising cost of energy and increased environmental regulation of the treatment of agricultural and municipal wastes, which are appropriate feedstocks for producing biogas.

Biogas in Alaska

In Alaska, biogas presents an attractive option for rural communities that have tremendous heating and fuel costs due to the remoteness of their location. Anaerobic digestion, which has been used for centuries in China and India and more recently in other parts of the world such as Europe and the United States, presents a potential solution to help meet Alaska's energy needs.

Biogas technology has the following advantages over other waste treatment practices:

- produces a clean alternative fuel
- provides a use for organic waste streams that may otherwise be released into the environment
- prevents the release of methane, a potent greenhouse gas, to the atmosphere
- creates valuable liquid and solid fertilizers as a bioproduct to enrich soils and enhance food crop production

Harnessing the energy potential of Alaska's natural resources.

Oil

Gas

Geothermal

Wind

Water

Biofuels

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Biogas is a flammable, methane-rich gas formed from the decomposition or breakdown of organic material by microorganisms in an oxygen-free environment. This form of decomposition is known as "anaerobic digestion" as it involves bacteria and archaea that metabolize sugars, proteins and other organic materials without using oxygen. These microbes are commonly found within the anaerobic rumens and digestive tracts of large animals, such as cattle and moose, and aid these animals in breaking down complex cellulosic material. As a by-product, the microorganisms release a large amount of methane. Similarly, methane-producing microbes can be found among anaerobic sediments of lake bottoms in Alaska and other "benthic" aquatic environments.

The product of anaerobic digestion (biogas) is a mixture of methane (CH_4, typically around 60% by volume) and carbon dioxide along with other trace gases. By mimicking the environment of an animal rumen or lake bottom, biogas can be produced in large, oxygen-free containers by feeding microbes a source of organic material.

Biogas can be stored, purified to form "biomethane" or burned directly in most conventional gas-powered devices for heat or energy production and compares favorably with many other fuel types.

Biogas (60% methane, uncompressed) — 80 Btu/gal (600 Btu/cu ft)

Natural Gas — (1,050 Btu/cu ft)

Propane — 91,500 Btu/gal (2,500 Btu/cu ft)

Diesel — 139,000 Btu/gal

Ethanol — 109,000 Btu/gal

Temperature

Biogas can be synthesized within a range of different temperatures. In fact, methanogenic microorganisms are classified based on the temperature range in which they live:

Thermophilic — Between 49°–57°C (120°–134°F)
Mesophilic — Between 20°–45°C (68°–113°F)
Psychrophilic — At or below 20°C (≤68°F), a potential for Alaska

Conversion of biomass to biogas is greatly accelerated at warm temperatures, falls off sharply at low temperatures and is almost nominal below 15°C (59°F). Most commercial and industrial biogas facilities in operation today maintain a stable temperature conducive to the specific microbial community that they utilize. Often this involves additional heat inputs to maintain high microbial metabolic rates and system performance.

Options for heating a digestion facility

Electric — In general, electric is considered the most expensive and least efficient way to heat an anaerobic digestion facility for the production of biogas. The energy content of the resultant gas is often less than the energy consumed in order to heat the reaction vessel.

For Alaskans, who on average pay 16.61cents/kWh (15.25 cents/kWh industrial), electrical heating with the aim of biogas production is probably not feasible.

Hot water — Most biodigesters are heated by hot water. Waste heat recovered from large-scale biogas production is usually enough to maintain the desired temperature in the containment vessel.

Solar — In areas with adequate solar potential, solar radiation and solar hot water can be used as a heat source. In equatorial regions, solar gain is typically the main heating source for small, household-scale biogas digesters, but it is not a viable option for heating digesters year-round in Alaska due to the long, dark and cold winters.

Thermal mass — Since many of the microbes needed to produce biogas are sensitive to changes in temperature, increased thermal mass can help stabilize the system when heat input is not available or discontinuous. In general, biogas facilities that are larger in scale benefit from being less sensitive to environmental change and local weather patterns than smaller-scale projects. Water, sand, rock and earthen insulation can all be used to help maintain digestion efficiency and temperature environment.

How big should digesters be?

Biogas production can be carried out at any scale, including individual households, and is independent of facility size. Large facilities, however, benefit from the economy of scale, making them more efficient and profitable. Large facilities often have the capacity to

Large-scale anaerobic digestion applications

Municipal solid waste treatment plants

Water treatment

Landfill methane recovery

Dairy and swine waste management

Excess solid and organic waste is a major problem in rural Alaska communities and a potential feedstock for a biogas facility. Photo by Edda Mutter

closely monitor and control the reaction process. In many colder climates, the need to maintain a warm environment for biological reactions often limits anaerobic digestion to large-scale facilities since the mechanical and capital costs can only be justified for facilities that can process large quantities of organic material.

If the ultimate goal for implementing an anaerobic digestion reactor is the Btu rating of the biogas produced, then it is unlikely that small-scale facilities will be adopted in Alaska in any great number as they have been elsewhere in the world. However, small-scale projects may benefit communities that pair biogas digesters with other projects or services. For example, if waste heat can be recovered from other sources, such as boiler rooms, then the person(s) or community may contend that the additional benefits of anaerobic digestion for primary water treatment, reduction of nutrient/organic waste release into the environment, reduction of smell and production of fertilizer may help justify implementation of a biogas facility of any size.

For more information regarding anaerobic digestion, please refer to the EPA/DOE AgSTAR program: www.epa.gov/agstar/anaerobic/index.html.

Feedstock evaluation

The most important consideration prior to implementing an anaerobic digestion reactor is the available amount of feedstock material and resource evaluation. It is important that appropriate organic waste resources be identified before investing in an anaerobic digestion facility. Determining the annual amount and types of waste, as well as seasonal variation in materials that are likely to be processed, will help a great deal when designing an appropriate anaerobic digestion reactor.

The vast majority of biogas digesters in the world are small, household-scale digesters maintained by individual families. These digesters are typically able to harness enough energy to meet household cooking fuel needs by recycling organic waste streams (about 1 kg dry weight per day) into the vessel. However, these household digesters are located in warm climate regions where no additional energy inputs are needed in order to maintain the reaction process.

Bio-Terre Systems, Inc., Capacity 150 kWh
Eugene, Ore. — www.manuremanager.com

Common types of large-scale biogas facilities

There are multiple configurations for anaerobic digestion facilities. Most are defined by their size and level of mechanical input in order to maintain microbial communities.

- Batch and sequence reactors
- Continuous plug flow
- Covered lagoons
- Fixed film reactors

This student greenhouse project tested the available nutrient content of biodigester liquid effluent. Photo by Casey Pape

Inside the project Conex are six 1,000-L high-density polyethylene tanks that contain active microbial communities. The distended tanks illustrate active methanogenesis. Photo by Casey Pape

Anaerobic digestion technology observations

The Cordova students were able to grow food in a greenhouse using liquid fertilizer from the biogas digester. They observed that the additional benefits of liquid fertilizer as well as reducing the amount of discarded food waste at their school are still reasons to consider anaerobic digestion technology even in colder regions where biogas production efficiency is less than what is observed in warmer climates.

Case Study:
Cordova High School

Researchers at the University of Alaska Fairbanks are working with the Cordova Electric Cooperative and the Cordova High School Science Club on a joint research project to test the feasibility of small-scale anaerobic digestion in rural Alaska communities. This project was funded through the Denali Commission Emerging Energy Technology Grant program. The research is testing production efficiencies of different microbes at low temperature conditions typical in coastal Alaska.

The Cordova biogas project, part of the Emerging Energy Technology Grant, is located at Cordova High School. Photo by Casey Pape

Researchers constructed and maintained six 1,000-L anaerobic digesters using recycled high-density polyethylene Sucralose storage containers. Digester tanks were inoculated with microbes either from cow manure (warm-loving mesophiles) obtained from farms in Delta Junction or with sediments collected from the bottom of a lake in Fairbanks (cold-tolerant psychrophiles). The work is based on research by UAF Assistant Professor Katey Walter Anthony, who measures high rates of methane production by sediment-dwelling microbes living at near-freezing conditions in Alaska lake bottoms. The goal is to determine the potential for lake sediments as a source of cold-tolerant microbes to produce biogas energy at cold temperatures in Alaska.

Using food scraps from their lunchroom cafeteria, Cordova High School students demonstrated that psychrophilic microbes found in lake sediments in Alaska could produce large quantities of flammable biogas well below temperatures at which manure cultures ceased biogas production. To date, daily gas production rates as high as 345 L/day for a 1,000-L tank have been achieved. However, this is still well below production rates demonstrated among similar-scale anaerobic digestion reactors in the equatorial region, and has yet to be demonstrated as economically viable in Alaska at the household scale.

For more on the anaerobic digestion project in Cordova, please see www.cordovaenergycenter.org/.

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