SMALL-SCALE MANURE DIGESTERS: POTENTIAL FOR ON-FARM HEAT AND ENERGY

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Anaerobic digesters for animal manure and other organic substances can address several challenges facing a farm. Guy Roberts has studied digester options for small-scale dairies that may resolve issues of:

- Odor control
- Resources lost to the environment, particularly nutrients lost in field application.
- Diversification of crops grown and fuels demanded.

Anaerobic digesters take inputs of cow manure (or other feedstocks, as outline below) into a heated, anaerobic environment. Naturally occurring bacteria will degrade the volatile solids (VS), releasing a combination of carbon dioxide (CO_2) and methane (CH_4) that may be burned/ combusted for energy production. Digestion does not reduce the nutrients in the manure, although it may alter the form of the nitrogen (more ammonia) and phosphorus (more ortho-phosphate). Digestion kills common pathogens and eliminates odor.

Digesters can use a variety of feedstocks, although some require more pre-treatment than others (as a general rule, the more readily biodegradable the material going in, the better) and some are not approved for field application on food crops. Potential substances for digestion include:

- *Manure*: Manure can be in slurry form (approximately 12% solids for cow manure) or separated with the liquid portion digested.
- *Spoiled Silage and Hay*
- *Bedding:* Short fibers work best
- *Biomass crops*: Sugars in green crops convert more quickly to biogas
- *Food / Food Waste*: High fiber contents can cause digester problems.

Anaerobic digesters come in three basic types:

- *Covered Lagoon*: A cover traps gas emitted from anaerobic manure lagoons, but it is a poor quality system.

- *Plug Flow*: In this design, the manure moves as a plug through the digester. A drawback is that manure requires a relatively high, 20-day, retention time, but an advantage is that the system is simple to operate.
- *Fixed Film*: These digesters require separated manure and use only the liquid portion. They have a higher efficiency than the plug flow, and lower retention times, but work with fewer volatile solids so the overall energy conversion is comparable to plug flow.

Guy bases his design on the plug flow system.

Smaller dairy farms demand electricity in a quantity disproportionate to their size. Analysis at the University of Wisconsin compares the per-cow electricity demands of different scale farms. A 200-cow dairy annually uses 689 kWh/cow, a 200-cow dairy uses 276 kWh/cow and a 400-cow dairy uses 262 kW/h per cow. The small dairy example, which is larger than many of Vermont's small dairies, uses more than twice as much electricity per cow as its larger counterparts. The electricity savings from using an anaerobic digester therefore might be particularly significant for this group.

A rough way to calculate how much electricity a dairy could produce with anaerobic digestion is to assume 12% solids going into a digester (unseparated cow manure slurry) with 80% of these solids volatile solids. Each pound of volatile solids can yield 13 cubic feet of biogas. Assuming a 25% efficiency in converting biogas to energy, a cubic foot of biogas produces about 600 BTU or 7800 BTU for every pound of volatile solids. Adding the average manure production for cows into this equation and converting to kilowatts, a rough estimate for generator capacity is 11 kW for small dairies and 20-30 kW once a farm reaches 200 cows.

Electricity alone may not be the optimal use for energy from anaerobic digesters. The digesters provide a constant power output, but a farm's electricity demands vary over the day and over the season.

One option for small dairies is to net meter onto the grid. In this scenario the grid functions as a storage system; a farm puts electricity onto the grid when it doesn't need it and can take that same amount back out again (at no cost) when they do need it. Farms cannot earn money by

consistently providing the grid with more energy than they consumer – the best that can happen is an electric bill reduced to zero.

Another option for farms is to use the anaerobic digester energy for functions other than electricity. Heat is a common energy use from digesters. Energy will usually go into maintaining the digester temperatures, but can also heat farm buildings and washwater. Absorptive refrigeration can use the biogas for chilling.

Guy's own digester design considers how a farm can get maximum benefits from all anaerobic digester products. Guy connects a greenhouse with a digester composed of plug flow tubes scaled to 15 cows each. The greenhouse can use heat and the liquid manure for hydroponic plant production. The advantages of this system include removing energy costs, improving manure storage and nutrient management through a contained ecosystem, odor control, and increased opportunities for value-added agriculture. Disadvantages include labor requirements of managing both a dairy and greenhouse operation (although partnerships between two separate businesses could reduce labor concerns), capital requirements, and incurring new pollution issues (ammonia).