Promising Manure-to-Energy Technologies For the Chesapeake Bay Watershed

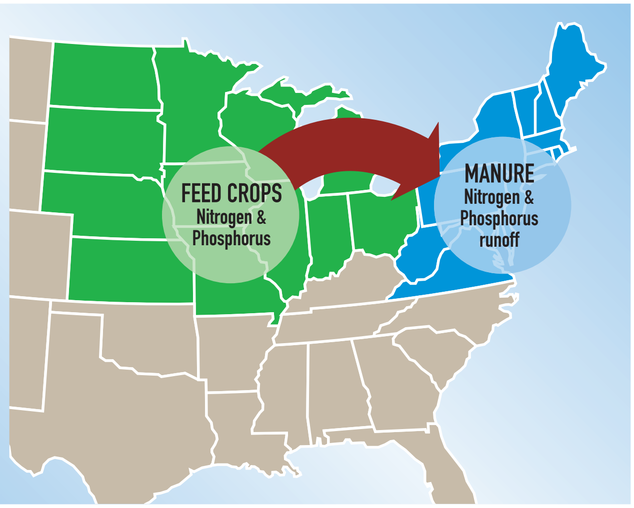
A TECHNOLOGY SUMMARY · SEPTEMBER 2011

INTRODUCTION

Animal manure (including both livestock manure and poultry litter) has traditionally been used as a source of fertilizer and a soil amendment. Applied appropriately, manure is a valuable fertilizer that adds nutrients as well as organic matter to soils, improving both fertility and soil quality. However, in concentrated animal-production regions around the country and in the Chesapeake Bay watershed, land application of nutrients from manure and chemical fertilizers often exceeds the nutrient requirements of locally grown crops, resulting in an excess of available nutrients in total. These excess nutrients add to the pollution load accumulating in the Chesapeake Bay watershed unless means are found to either export manure and litter to nutrient-deficient regions or employ alternative uses for the material.

Broken Nutrient Cycle

The one-way flow of nutrients from the Midwestern states into the Chesapeake Bay watershed has modified the natural nutrient cycle. It is estimated that 17 percent of the total nitrogen load (49 million pounds) and 26 percent of the phosphorus load entering Chesapeake Bay is derived from livestock and poultry.



(Chesapeake Bay Program Model 4.3)

CHALLENGES FOR MANURE-BASED NUTRIENTS IN THE WATERSHED

Exportation of manure to end-users outside of high-density production areas is limited by the fact that manure is less concentrated than commercial fertilizer and can pose material handling problems for a grower. Consequently, transportation costs limit the distance manure can be transported and still be economically competitive with inorganic commercial fertilizer. However, it is still feasible to move manure to end-users outside of high-density production areas, including these options that are currently utilized in the Chesapeake Bay watershed:

1. Transport raw manure locally in short enough distances to minimize hauling costs and remain competitive with commercial fertilizer.
2. Provide government/industry subsidies for the transport of manure to increase the distance it can be hauled, to control transport costs and allow it to remain economically viable.

GLOSSARY

ANAEROBIC DIGESTION: the use of bacteria in an oxygen-free environment to convert organic carbon into methane. The methane can then be captured and used to fuel a generator.

BIOCHAR: A form of charcoal produced by certain thermochemical processes. Instead of being used as a fuel, biochar can be used as a soil amendment to improve carbon sequestration and retention of nutrients.

BIO-OIL: a type of tar produced when biomass is subjected to thermochemical treatment. It is usually higher in oxygen than traditional hydrocarbon fuels, but can be combusted or gasified to fuel a generator.

BTU: British Thermal Unit, a measure of the energy value of a fuel. One BTU is equivalent to the amount of energy needed to raise the temperature of one pound of water one degree Fahrenheit.

COMBUSTION: The burning of material at a high temperature in a high-oxygen environment.

GASIFICATION: The reaction of organic material at a high temperature with a controlled amount of oxygen and/or steam to produce a gas. The gas can then be used as fuel for a generator.

GRID: The inter-state network of electricity generation, transmission and distribution.

PYROLYSIS: the decomposition of organic matter under high temperatures in the absence of oxygen, often under increased pressure.

TORREFACTION: a mild form of pyrolysis, carried out under atmospheric pressure, to reduce the water content of biomass and concentrate the energy value in a solid product.

3. Transform the manure to a form that is more nutrient-dense to facilitate the cost-effective transport of nutrients longer distances out of watershed.

Transport is costly and logistically challenging for liquid manures from swine or dairy operations because of low nutrient-to-weight/volume ratios. Poultry litter has less moisture and can be transported longer distances, but without incentives it is difficult if not impossible to move it far enough out of the watershed. While there are government/industry subsidized transport programs, it is widely recognized that subsidized transport is not a sustainable or cost-effective long-term solution to managing excess nutrients in high-density production areas.

Manure-to-energy technologies – the subject of this paper – produce both fuel and a concentrated nutrient-rich material that can help to fulfill the third option above. In this way, bio-energy from manure can help meet farm and local energy needs and help redistribute nutrients as well.

MANURE-TO-ENERGY TECHNOLOGIES

In simplistic terms, there are two primary processes for extracting energy from animal manures: biological and thermochemical. The relative pros and cons of both technologies are described below, from both an energy production and nutrient handling perspective.

1) Thermochemical Processes

Thermochemical processes encompass a range of technologies including combustion, gasification, pyrolysis and torrefaction. In addition to heat, thermochemical processes can produce a range of different, potentially valuable byproducts including liquid bio-oils, diesel fuel, and combustible gas, as well as nutrient-dense biochar and ash. All thermochemical processes can reduce nutrients, but vary widely in their effectiveness and their cost.

Pros

- Phosphorus and potassium are more concentrated in the ash or byproducts, making transport out of the region more economical.
- Some systems convert most of the nitrogen to inert N_2 gas that has no environmental impact.
- Some systems are more scalable for farm use than others.
- Well-suited to use dry material such as poultry litter.

Cons

- Air emissions of nitrogen (primarily NO_x), especially from combustion, require additional treatment at additional cost.
- Systems must be designed to accommodate the unique properties and variable nature of manure.
- Not well-suited for high-moisture dairy or swine manure slurries without an additional solid separation pre-treatment (adding to the cost of the process).

Thermochemical processes vary in terms of the amount of oxygen required, the operating temperature of the process, and the composition and characteristics of the byproducts including type and concentration of nutrients. All thermochemical processes concentrate phosphorus and potassium in the ash or biochar byproduct, although concentration of these nutrients varies depending on the process, operating parameters and system design. Most thermochemical processes convert nitrogen in the waste material to nitrogen gas, the composition of which is largely dependent on the amount of oxygen in the process.

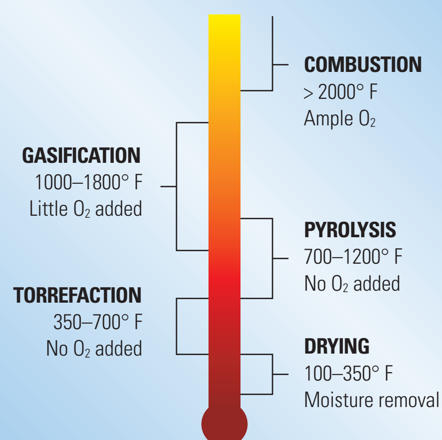
In general, combustion requires oxygen and operates at a higher temperature than gasification. Pyrolysis, torrefaction and gasification processes are usually operated with minimum oxygen.

Thermochemical technologies that operate in high-oxygen environments, such as combustion, tend to produce nitrous oxides (NO_x). In contrast, technologies that reduce or eliminate oxygen in the process (e.g. gasification, pyrolysis, and torrefaction) tend to produce inert nitrogen gas (N_2). Inert N_2 has no environmental impact, but NO_x can form acidic droplets in the atmosphere that rain back down onto land and water. The US Environmental Protection Agency (EPA) estimates that atmospheric deposition of nitrogen accounts for up to one-third of the total nitrogen loading to the Chesapeake Bay.

Although all four thermochemical processes using animal manure have potential to reduce (concentrate)

Thermochemical Processes

Temperature and oxygen define the thermochemical processes as well as the products.

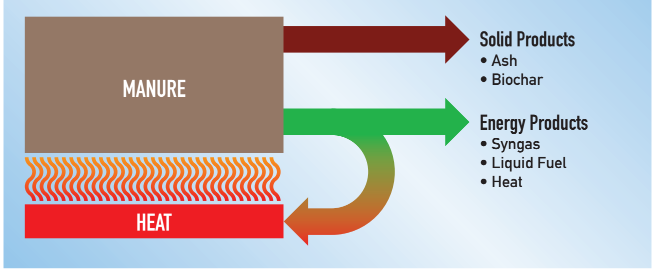


SOURCE: FARM PILOT PROJECT COORDINATION, INC.

or eliminate nutrients from reaching the Bay, all have challenges that currently limit their widespread use in farming, including high capital expense, lack of experience with using manure as an energy feedstock, and concerns about pollutants in air emissions. Although manure as a feedstock generally possesses about 5,500 to 8,500 BTU per pound on a dry matter basis, the use of manure or poultry litter as a feedstock for thermochemical technologies is still a relatively new phenomenon in American farming. Also, manure as a fuel can have variable properties or contain foreign objects, creating material handling problems and other difficulties that equipment suppliers have often underestimated. Finally, for farms that have developed manure-to-energy operations, there have been additional logistical and cost challenges with connecting to the power grid and rerouting electrical power lines.

Energy and Byproducts

Basic thermochemical process using manure as a feedstock.



2) Biological Processes

The principal biological processes used to break down waste involve anaerobic digestion, which is commonly deployed to convert the volatile waste solids into methane (commonly referred to as biogas). The anaerobic digestion process usually operates in a container and in the absence of oxygen. Composting, another valuable biological process, operates in an air environment but does not produce usable energy.

Pros

- Well-known with a long history of use to produce methane which can generate either heat or electricity, or both.
- If the methane is captured and converted to CO_2, the technology reduces significant amounts of greenhouse gas emissions.
- Used by some farm operations to control odors.
- Most of the nitrogen and phosphorous are retained in a sludge byproduct and can be used as crop fertilizer or transported short distances to other parts of the region.
- If solid separation methods are applied after digestion, the captured solids can be recycled as bedding for dairy farms or further processed for use as a soil amendment.
- Well-suited for high-moisture, dairy and/or swine manure slurries.

Cons

- Requires relatively large area for manure containment, and can be very capital intensive.
- Although reduced, the volume of nutrient-rich byproduct left after digestion is still significant in size, must be stored and managed as a wet nutrient source, and is not cost-effectively transported.

The biological process for producing energy from manure utilizes engineered systems that facilitate the growth of bacteria in an anaerobic (oxygen-free) environment. These bacteria convert the organic carbon in manure to methane gas. Methane gas from a digester can then be collected and used to fuel a generator, producing both electricity and heat. Alternatively, methane gas can be cleaned and added into existing natural gas distribution systems. The advantage of the anaerobic digestion process is that it is well known and, when used to produce heat or electricity, will also reduce emissions of methane, a greenhouse gas with a global warming potential 23 times that of carbon dioxide.

The greatest challenge facing widespread adoption of anaerobic digestion is that the process only reduces the content of organic carbon in the waste stream, and almost all of the nitrogen and phosphorus associated with the manure remains in the digester byproduct. Therefore, additional treatment and management of the liquid and solids associated with digester effluent are needed to facilitate material handling, transportation, and proper nutrient control.

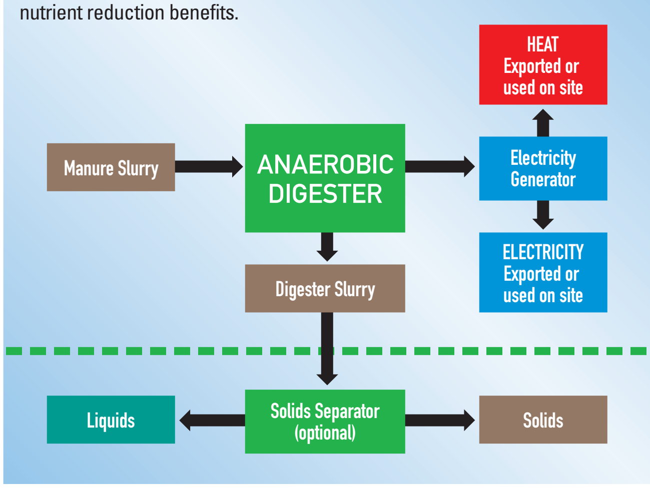
There are proposed processes that involve separation of the solid and liquid portions of the byproduct that may help address the nutrient handling challenge. One proposed process involves advanced separation systems that combine chemical additives along with physical separation. In this process, phosphorus can be removed from the liquid and transported cost-effectively (due to its dry form) off the farm to locations where phosphorus fertilization is needed. The nitrogen, however, remains in the liquid portion of the byproduct and must be managed with traditional methods such as lagoon storage and near-by land application.

The benefit of this approach is that the high-phosphorus solids can be more economically transported to end-users in need of nutrients than the original liquid manure. This approach also allows the farmer to use manure nitrogen to grow crops on the farm, even in soils with high phosphorus concentrations where a nutrient management plan would typically recommend little to no phosphorus applications. This would save the farmer the expense of having to import nitrogen fertilizer for on-farm crop production.

Anaerobic bacteria require wet environments and while there are some exceptions, digestion is not typically utilized for drier manures, such as poultry litter or feedlot manure. Digestion of drier manures requires the addition of water along with solid-liquid separation and liquid storage systems for the effluent. In addition, anaerobic digestion systems can be expensive and typically are not cost-effective for smaller operations. One exception to this general rule is a large, centralized poultry litter digester planned for Cumberland County in Virginia. The project is supported by local poultry growers and the Farm Bureau. Partners plan to sell electricity and digested solids and utilize the liquid effluent as a fertilizer on local crop land.

Basic Anaerobic Digestion System with Nutrient Removal

Anaerobic digestion alone does not address water quality concerns. Optional steps (shown below the dotted line) can be added to provide nutrient reduction benefits.



CONCLUSION AND RECOMMENDATIONS

For manures that are relatively dry, such as broiler litter or feedlot manure, thermochemical processes are favored, as the cost of removing large amounts of moisture is avoided. For high-moisture materials such as dairy or swine manure, anaerobic digestion has been the favored technology for producing energy. As noted above, while all these processes can effectively produce energy, their relative ability to contain or eliminate nitrogen and phosphorus varies widely. As state and federal governments look to promote the separate goals of agricultural viability, energy sustainability and nutrient reduction, technologies and systems that produce a combination of all three benefits should be favored.

Regardless of the manure-to-energy process employed, the cost-effectiveness of a project relies in large part on the availability of markets to utilize the nutrient and energy byproducts. Challenges remain for helping farm energy operations to connect to the electrical grid and sell their surplus electricity. Connection can be prohibitively expensive and technically challenging, and often depends on the willingness of utilities and their regulators to facilitate and incentivize the process. Additionally, widespread markets for the nutrient products have not yet been established, adding additional challenges for finding off-farm uses for captured nutrients that facilitate the transport of nutrients outside of high-density production areas

CREDITS

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