Farm Manure-to-Energy Initiative Final Report

Using Excess Manure to Generate Farm Income in the Chesapeake Bay Region's Phosphorus Hotspots

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Executive Summary

The Farm Manure-to-Energy Initiative was launched in 2012 to demonstrate and objectively evaluate manure-based energy systems operating on several private farms in the Chesapeake Bay region. As a collaborative multi-state effort, the Initiative included farmers in Pennsylvania, Virginia, West Virginia, and Maryland, with project management and support from foundations, nonprofit organizations, academic institutions, government agencies, and private businesses. Over the course of four years, thermal manure-based energy systems were developed and installed on five farms, and each was assessed for its technical, environmental, and financial performance.

Livestock manure contains valuable nutrients and organic matter that can improve soil fertility and promote healthy crop production when used as a fertilizer. For most animal operations, on-farm or local use of manure as a fertilizer is a standard practice and considered appropriately protective of water quality when manure is applied according to nutrient management plan recommendations.

However, managing manure to protect water quality can be challenging in areas where animal production is concentrated. In these areas, long-term application of manure to fields has resulted in high levels of soil phosphorus and increased risk of transport to surface waters through stormwater runoff. Because manure is bulky and costly to transport long distances, opportunities to sell excess manure for use on nutrient-deficient fields outside of high-density production areas are limited.

Demonstrations and Evaluation Strategy

The Farm Manure-to-Energy Initiative focused on farm-scale thermochemical (thermal) systems. Thermal systems generate energy while producing nutrient rich co-products (ash and biochar) that could be more easily transported out of nutrient-dense areas and sold elsewhere as fertilizer. Four thermal technologies were selected for demonstration on five farms in the Chesapeake region:

- Ecoremedy ® gasifier (designed and installed by Enginuity Energy, with continuing support from Ecoremedy Energy) on Flintrock Farm in Lititz, PA
- Global Re-Fuel (designed and installed by Wayne Combustion Systems) on the Mark Rohrer Farm in Strasburg, PA, and on the Mike Weaver Farm in Fort Seybert, WV
- Bio-Burner 500 (by LEI Products) at Riverhill Farm in Port Republic, VA

- Blue Flame Boiler (designed and installed by Total Energy Solutions) on Windview Farm in Port Trevorton, PA

Additionally, Farm Manure-to-Energy Initiative partners helped to develop and secure funding for a demonstration of the Biomass Heating Solutions Ltd. (Bhsl) technology on a farm in Rhodesdale, MD. Construction for this project is anticipated in the spring of 2016. Partners have also supported AHPharma Inc. efforts to demonstrate a pyrolysis thermal manure-to-energy system at their research farm in Tyaskin, MD.

Before installation, project partners worked closely with EPA Region 3 and state permitting agencies to determine permitting requirements for farm-scale systems in each of the Bay states. These conversations informed air emissions testing methodology and laid the foundation for the demonstration projects.

Each of the systems was evaluated for technical performance, environmental performance, and financial performance. Technical factors included the reliability of the system, how well the system integrated with the farm's existing heat delivery systems, and how well the technology succeeded in maintaining target temperature and relative humidity goals. To monitor environmental performance, project partners collected data on air emissions and documented the fate of nutrients as poultry litter moved through the system. Partners also evaluated the market potential of the ash and biochar co-product and compared its fertilizer value to raw poultry litter and traditional commercial fertilizers. Financial performance factors included the costs to install, operate, and maintain the system, and any reduced costs for propane or electricity.

Findings

Technical Performance

Performance varied considerably between the technologies. On one hand, the Global Re-Fuel technology failed to perform reliably and will need additional research and development before additional on-farm deployments. Alternatively, the Blue Flame boiler and Biomass Heating Solutions Ltd. technologies have been used successfully on poultry farms in the Chesapeake Bay region and Europe for up to 5 years. The Bio-Burner 500 and Ecoremedy gasifier are still in early phases of deployment. Additional data is needed on their performance before further deployments are recommended.

All of the technologies successfully integrated with existing propane heating systems and provided heat to poultry houses. However, the amount of heat produced (and propane offset) varied by the technology and the fuel quality of the poultry litter. The two technologies that have the longest track record for successful on-farm use (the Blue Flame boiler and BHSL system) are deployed on farms that completely clean out poultry houses between every flock. Most farms in the Chesapeake Bay region limit whole-house cleanouts and instead remove the top layer of poultry litter from the house at the end of each flock. Two farms that converted to organic production during this project period experienced an increase in litter moisture after the conversion. In one case, litter moisture was too high for the Global Re-Fuel system to use as a fuel. While the Ecoremedy gasifier successfully used higher moisture litter as a fuel, the heat output was reduced.

For AHPharma, Inc.'s demonstration project in Tyaskin, MD, partners were not successful in locating a commercially available pyrolysis technology that was designed to integrate with a poultry house heating system that met the project's cost criteria.

Environmental Performance

Air emissions for the demonstration technologies were evaluated using a certified, third-party air emissions testing company to inform nutrient mass balance and permitting. For a pyrolysis technology developed by North Carolina State University (NCSU) proposed for demonstration in Maryland, partners conducted preliminary emissions testing for nitrous oxide and particulate matter to determine if the technology could meet Maryland emissions requirements. The technologies demonstrated a range of air emissions. Because of the high potassium content of poultry litter, most vendors will need to control particulate matter emissions. Particulate matter proved challenging for several of the vendors who were not able to demonstrate that the technologies would be feasible for installation in Bay states with low thresholds for particulate matter emissions. Two technologies (BHSL and the NCSU pyrolysis technology) demonstrated the potential to meet all Bay state permitting requirements. Four of the technologies (Global Re-Fuel, Blue Flame boiler, Bio-Burner 500, and Ecoremedy gasifier) require additional controls for particulate matter to meet permitting thresholds in Maryland. Three of the technologies (Global Re-Fuel, Blue Flame boiler, and Bio-Burner 500) require additional reductions in nitrous oxides (NOx). System tuning for NOx emissions was recommended as the next step prior to consideration of NOx emissions controls. Three of the vendors demonstrated that, despite the nitrogen content of poultry litter, farm-scale thermal systems can be designed as low NOx emissions technologies.

The nutrient balance assessment suggests that much of the reactive nitrogen in poultry litter (primarily organic nitrogen and ammonia) is converted into non-reactive nitrogen in the thermal process. Reactive nitrogen in air emissions from thermal manure-to-energy systems was compared with reactive nitrogen (ammonia) lost from land application via various strategies (injection, shallow disking, and surface application without incorporation). Findings suggest that technologies with the lowest reactive nitrogen emissions will result in less reduced reactive nitrogen loss to the atmosphere than recommended practices for reducing nitrogen loss through land application (injection and immediate incorporation with a shallow disk). The technology with the highest nitrogen concentration in air emissions still reduced reactive nitrogen loss compared to surface application without incorporation.

The nutrient balance for phosphorus suggests that almost all of the phosphorus in poultry litter is sequestered in the ash (both bottom ash and fly ash from emission control systems). However, there was some loss of phosphorus in the emissions associated with particulate matter.

The nutrient balance also illustrated challenges with quantifying the fate of nutrients in farm-scale systems. Two of the analyses suggest that there is more phosphorus in the ash and air emissions than in the poultry litter used as a fuel. Since there is no known mechanism for creating phosphorus in on-farm thermal manure-to-energy systems, it is likely that variability in the fuel feed rate, ash production rates, and nutrient content of the poultry litter contributed to the variability of the results.

Financial Assessment

The financial assessment process was limited by the length of the performance period. However a simple analysis, considering just capital costs and energy savings, suggest that farm-scale systems can have a positive return on investment (ROI), even when they are not performing well. For example, despite technical problems, the Global Re-Fuel system has the potential to generate a 34% ROI over a 15-year period (or 26% over a 10-year period). The Blue Flame System would generate a 49% ROI over 15 years (or 38% over ten years). This analysis did not take into account operations and maintenance costs, cost-share program contributions, or allowances provided by the integrator for propane or electricity purchases. These allowances, which are common for organic or antibiotic-free integrators, can have a considerable impact on the ROI.

Although the available data, which was limited by the duration of the performance monitoring period, did not quantify the generated heat in a way that statistically correlates the technology with reduced propane use, farmers repeatedly observed and reported the trend toward reduced propane use while the systems were running. This saved energy and money for the growers and reduced their carbon footprint.

Fertilizer Value of Ash and Biochar Co-Products

Field row crop trials and laboratory analysis were used to evaluate the fertilizer value of ash and biochar co-products produced from a range of thermal systems, including combustion, gasification, and pyrolysis technologies. The fertility value of thermal co-products was compared with commonly used commercial phosphorus and potash fertilizers (triple super phosphate and muriate of potash), as well as untreated poultry litter.

Results suggest that, although not as concentrated, poultry litter co-products are feasible as a substitute for commercial fertilizer products for row crop production. Trace mineral content of the bottom ash also met state requirements for fertilizers.

Nutrient densification varied between pyrolysis, gasification, and combustion systems: phosphorus was concentrated between 4-12 times its original density, potassium was concentrated between 3-13 times its original density, and sulfur was concentrated between 2-5 times its original density. Thermal technologies that operate at higher temperatures densified nutrients more than lower temperature technologies (such as pyrolysis).

The nutrient densification and value of this material as a fertilizer indicates that cost-effective transport out of high-density production regions of the Chesapeake Bay is feasible and that this material could provide a new source of revenue for poultry growers. Although additional work is needed to establish markets, ash co-products have the potential to provide new sources of revenue for poultry growers through the sale of excess farm nutrients. One transaction that occurred during this project demonstrated this potential through the sale of poultry litter ash – at market prices for the phosphorus and potassium content – to soybean growers in Missouri.

Lessons Learned

This four-year project generated many important insights on the potential of these thermal systems and the remaining challenges for more widespread success. Some of the key lessons learned are:

1) On-farm thermal systems are not a good match for every farm. They require considerably more management than propane heating systems and, depending on the farm, they may not be cost effective. On-farm thermal systems also require more time to operate, especially because the technologies are still in the early phases of commercial deployment.
2) The success of a particular technology on one farm does not mean that it will succeed on another farm. The characteristics of poultry litter vary significantly between farms, requiring farm-specific adjustments to the system. Success requires collaboration between the vendor and the farmer.
3) Poultry litter ash and biochar are valuable plant nutrients. Depending on the process, poultry litter ash contains in the range of 14 to 18% phosphorus fertilizer and 13 to 24% potash fertilizer. Plant availability of the nutrients also varies by process but is in the range of 80 to 100%.
4) To support regulatory compliance, vendors should be prepared to supply data on air emissions. In states with strict particulate matter emissions thresholds, advanced air emissions controls may be needed to trap and remove fine particulate matter when poultry litter is used as a fuel.
5) State rules vary significantly with respect to on-farm thermal poultry litter-to-energy technologies. Only two technologies identified through this initiative have the potential to meet permitting requirements for all the Bay states.
6) Initial capital expenditures for installing systems to heat poultry houses currently range from $87,000 to over $300,000 per house to install. As these technologies mature, prices will likely come down over time.
7) Costs vary significantly, but a face-value comparison may not be the best way to determine value. A comparison that normalizes the cost may be a better way to evaluate different technologies. For example, a unit such as dollars-per-BTU-

delivered is worth considering in addition to the total cost of the system. On-going operation and maintenance costs should also be considered.

8) Farm-scale thermal systems can improve cold weather ventilation and reduce relative humidity in poultry houses resulting in better in-house air quality and improved bird health. These potential production benefits warrant further investigation.

9) Organic poultry farms may offer the best opportunity for deploying farm-scale thermal systems. In the Chesapeake region, organic production requires 3 to 5 times more propane than conventionally produced poultry. If a thermal, manure-based system can reduce propane use and improve bird health and feed conversion, organic integrators may especially stand to benefit.

Next Steps

The Farm Manure-to-Energy Initiative identified both opportunities and challenges associated with these emerging technologies. Recommended next steps are as follows:

- Continue to support technology vendor efforts to improve emissions controls for deployment in all the Bay states. The project team is working with air emissions experts to recommend next steps for emissions control design and installation.
- Build on fertility trials to develop markets for poultry litter co-products that connect growers with ash or biochar to end users willing to pay a fair price for the nutrients.
- Continue to communicate results: partners will work with farm partners to host field day events when avian influenza risk is lower.

For More Information

- Visit the project website hosted by eXtension at www.extension.org/68455.
- View the video at www.extension.org/68455 (available in January 2016).
- Contact Kristen Hughes of Sustainable Chesapeake at kristen@susches.org.