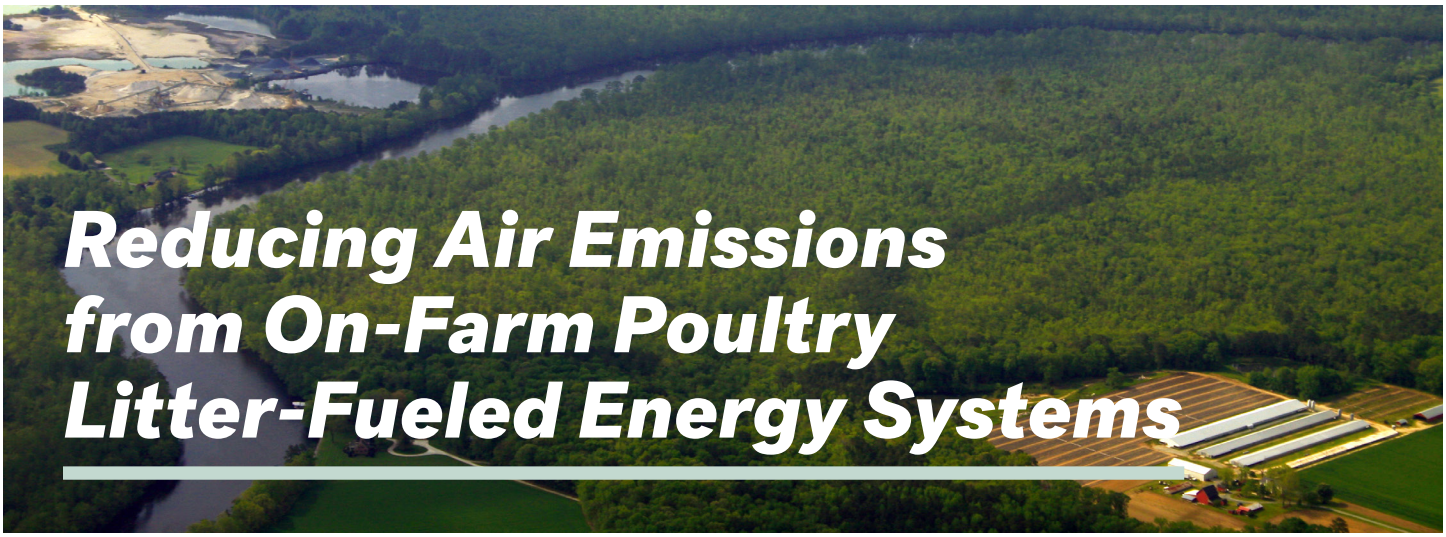
Sustainable Chesapeake



Reducing Air Emissions from On-Farm Poultry Litter-Fueled Energy Systems

Background:

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 (figure 1). In these areas, the amount of manure and associated nutrients produced may exceed local crop fertilizer demands. 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.

This project builds on findings from the **Farm Manure-to-Energy Initiative**, a regional partnership effort launched in 2012 and funded by the USDA, U.S. EPA, the National Fish and Wildlife Foundation, the Keith Campbell Foundation, the Blue Moon Fund and Agua Fund 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. The Initiative found that:

- Technical performance varied considerably between technologies.
- While all technologies successfully integrated with propane-fueled poultry house heating systems, the amount of heat produced varied with poultry litter fuel quality.
- Because of the high potassium content of poultry litter, air emissions of particulate matter were concerning. The team recommended vendors work to improve emission control systems.
- Results suggested that, although not as concentrated, poultry litter co-products are feasible as a substitute for commercial fertilizer products for row crop production.
- A simple financial analysis, considering just capital costs and energy-cost savings, suggested that farm-scale systems can have a positive return on investment (ROI). Farmers repeatedly observed and reported the trend toward reduced propane use while the systems were running. This saved money for the growers and reduced their carbon footprint.

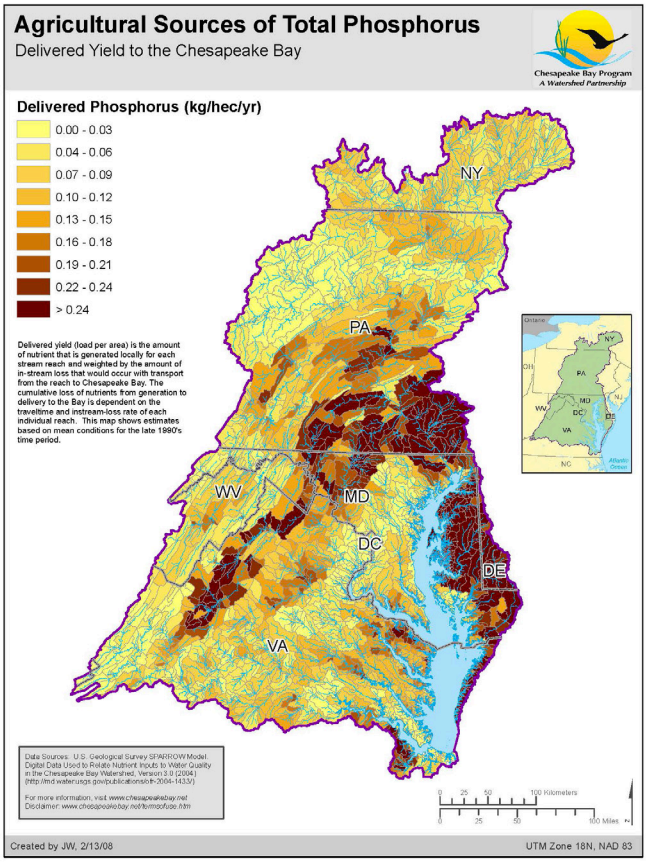


Figure 1. Areas of the Chesapeake Bay with the highest concentration of animal production are associated with the highest loading rates for phosphorus.

Goals and Objectives:

Guided by findings from the Farm Manure-to-Energy Initiative, the goal of this project was to improve environmental performance for two farm-scale poultry litter-to-energy technologies with a track record of reliable technical performance on two farms in Pennsylvania: the Organilock Bio-Burner 5000 and the Triple Green Energy boiler. Specifically, project objectives were to:

- Reduce particulate matter air emissions by 70%
- Expand markets for poultry litter fertilizer co-products
- Share information with farmers and technical service providers in the region

Project Location

Demonstration projects were located in Snyder County (the Klingler Family Farm in Selinsgrove, Pennsylvania) and Lancaster County (Earl Ray Zimmerman Farm in Ephrata, Pennsylvania).

Klingler Family Farm

Mr. Klingler (figure 2) grows boilers on a six week cycle with single-flock litter. Two 0.5 MMBtu/hr hydronic heaters (Model BB 500) manufactured by Organilock were installed in 2015 and used to provide heat for two 24,000 square foot poultry houses. He mixes fresh wood shavings from a local wood manufacturer to completely replace litter between each flock. He also mixes fresh wood shavings with poultry litter for use as a fuel in the BioBurner 500 hydronic heating system. In 2019, Mr. Klingler switched to using exclusively propane to heat the poultry houses, due to a disruption in wood shavings supply and a reduction in propane prices.

Figure 2. Mr. Klingler, owner of Klingler Family Farm in Snyder County, Pennsylvania.

Earl Ray Zimmerman Farm

Mr. Zimmerman grows certified-organic boilers in two poultry houses (24,000 square feet each) on a six week cycle (figure 3). He uses hot water heated by a Triple Green Energy boiler system to provide heat to two poultry houses and the farm machine shop. Like Mr. Klingler, he also completely replaces litter between each flock. For bedding, he typically uses a top layer of wood shavings year round, either with a base of wood chips in the summer, or with a base of biomass miscanthus grass in the colder months.

In 2012, Mr. Zimmerman secured funding from Penn Vest and worked with Team Ag Inc. and Total Energy Solutions to install a 1.5 MMBtu/hr boiler manufactured by Triple Green Energy (Model TGF CGS-225). Mr. Zimmerman planted eight acres of

giant miscanthus (Miscanthus x giganteus), a variety of sterilized warm-season grass native to Asia, and harvests this during the winter as a lower-cost alternative to wood shavings for poultry bedding.

Figure 3. The Earl Ray Zimmerman Farm in Ephrata PA.

Brief Summary of Methods

Air Emissions:

John Ignosh and Dr. Jactone Ogejo (Dep. Biological Systems Engineering, Virginia Tech) led the air emissions testing component of the project and contracted with source emission testing companies, Reliable Emissions Measurements, Inc. (REM), Industrial Air Science (IAS), and Environmental Source Samplers, Inc. (ESS) to collect emissions data from the two technologies (figure 4). Source testing companies used EPA methods for air monitoring, with variations noted in source emission reports. Source emission testing focused on total particulate matter and opacity measurements. The first round of testing established a baseline of emissions that was used by vendors (Organilock and Triple Green Energy) to develop improved emissions control equipment. Subsequently, re-designed emissions control equipment was installed on the two participating farms. The project assessed emissions from each of the improved abatement systems during two periods, with the first results informing additional abatement system improvements evaluated during the second round of testing. Emission reductions were calculated as the percent change from the base case reference to the final abated values. Additionally, the project team evaluated a mineral product for use as a fuel additive during a series of tests with the BioBurner BB 500 base configuration. In addition to reducing particulate matter emissions, the new abatement systems modify other aspects of system performance relative to their base case, therefore, these results should be interpreted with this in mind. For more details please visit: **https://sites.google.com/vt.edu/bioenergy-emissions-abatement/home**.

Figure 4. Air emissions testing conducted with Reliable Emissions Measurements, Inc at the Earl Ray Zimmerman Farm on Nov. 12, 2020.

Co-product Marketing:

Dr. Mark Reiter and Dr. Clara Ervin (Virginia Tech) led efforts to convert ash from poultry litter-to-energy technologies into a commercially viable pelletized fertilizer product. Additionally, they developed a process that can be used to convert ash into pellets on-farm. In the summer of 2021, the team worked with Mr. Zimmerman to produce fertilizer pellets on the farm (figure 5). Mr. Zimmerman is currently refining the production system. Dr. Clinton L. Neill evaluated the financial feasibility and conducted a market analysis of farm-scale poultry litter ash fertilizer production, using Mr. Earl Ray Zimmerman's farm as a model.

OrganiLock has developed a series of solid and liquid fertilizer/soil amendment products developed in part from ash/biochar co-products of animal manures. They invested considerable time in developing markets for these products by attending trade shows and garnering earned media.

Additionally, the project team participated in a collaborative effort led by regional Land Grant University nutrient management specialists working in partnership with the USDA National Agricultural Statistics Service to survey farmers to identify

opportunities, and challenges, for using poultry litter and poultry litter co-products on their farms.

Figure 5. Poultry litter ash (on the left) has the consistency of talcum powder and is difficult to manage. In order to develop a form of fertilizer most farmers and home gardeners are familiar with, Virginia Tech researchers (Dr. Clara Ervin and Dr. Mark Reiter) developed a process to convert the ash to a granulated fertilizer (right).

Outreach and Education:

Because the project timeframe overlapped with the global pandemic, the project team invested in a series of videos to share information with farmers and technical service providers about the project.

Results

Air Emissions:

- OrganiLock system:
  - **Mass Emission (lbs/hr)** – Reduced the total particulate matter mass emission rate (TPM - lb/hr) by approximately 34% (0.766 lbs/hr)
  - **Emission Concentration (gr/dscf)** – Reduced the emission concentration of total particulate matter by approximately 65% (0.566 gr/dscf @ 7% O_2), though with a higher flow rate
  - **Visible Emissions (%)** – Organilock reduced opacity by 72% to an opacity value of 11
  - A mineral fuel additive was tested at 2%, 5% and 10% blends which resulted in a 10%, 33%, and 61% reduction in the mass emission rate (lbs/hr) as compared to emissions from the original fuel used in the BioBurner BB 500 base configuration.
- Triple Green Products system:
  - **Mass Emission (lbs/hr)** – Reduced the total particulate matter mass emission rate (TPM - lb/hr) by approximately 97% (0.158 lb/hr)

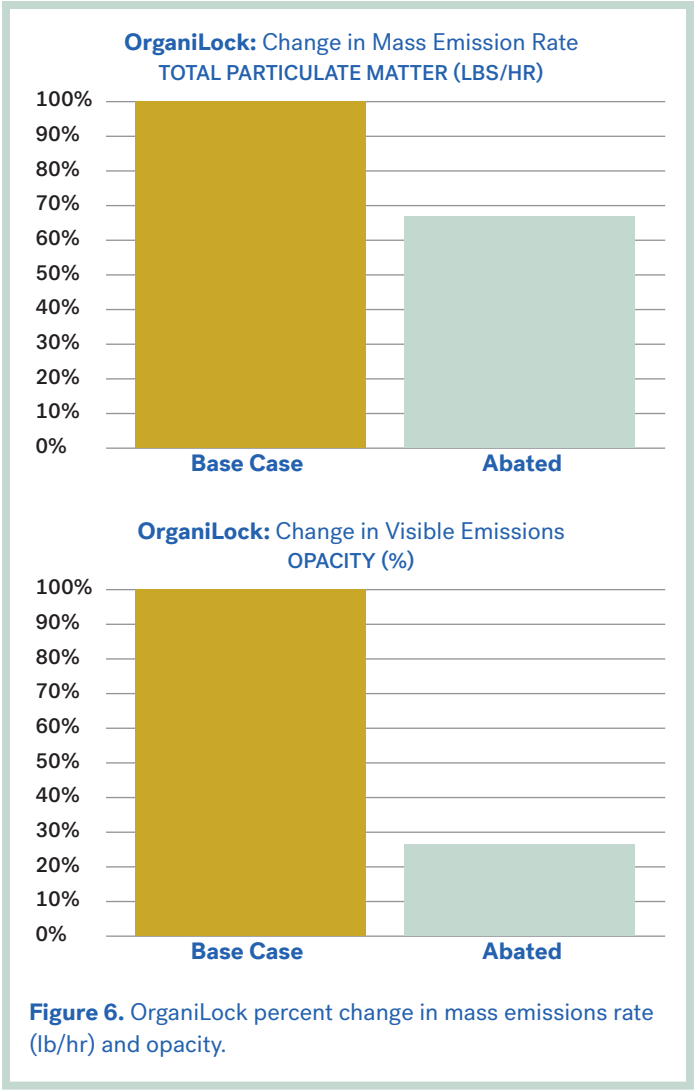
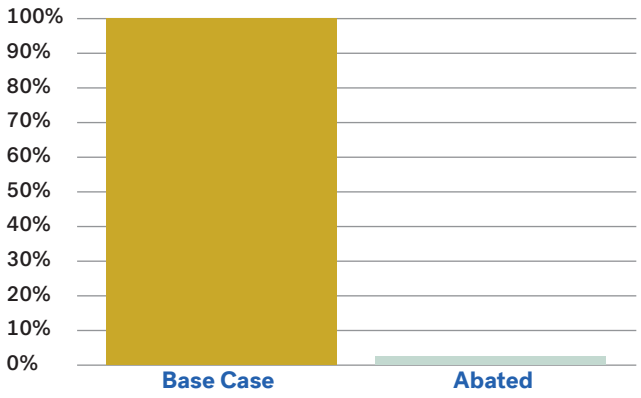


Figure 6. OrganiLock percent change in mass emissions rate (lb/hr) and opacity.

  - **Emission Concentration (gr/dscf)** – Reduced the emission concentration of total particulate matter by approximately 96% (0.103 gr/dscf @ 7% O_2).
  - **Visible Emissions (%)** – Triple Green Products achieved a 98% reduction to an opacity value of 1.

Co-product Marketing:

- In August of 2020, the Virginia Tech team worked with Mr. Zimmerman to produce an on-farm poultry litter ash pellet, the first system of its kind in the region.
- On-farm production and sale of a 0-24-24 fertilizer granule poultry litter ash product is potentially profitable. Assuming sale at $0.75/lb, annual profits of nearly $8,000 are achievable. The home flower and vegetable garden market is the most promising market opportunity for on-farm poultry litter ash pellet sales.



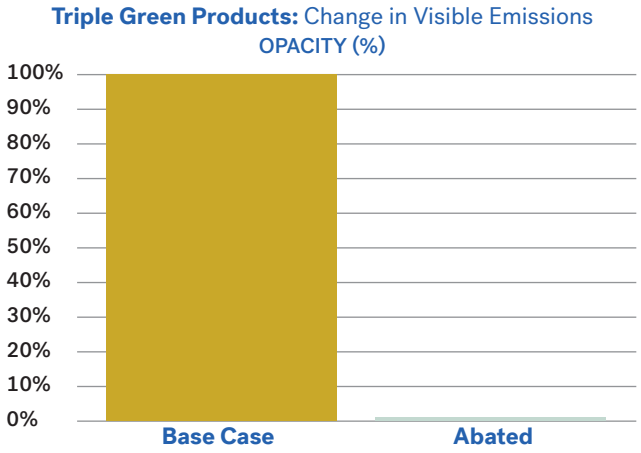


Figure 7. Triple Green Energy percent change in total particulate matter mass emissions rate (lb/hr) and opacity.

- Based on the analysis of poultry litter pellets produced at the Earl Ray Zimmerman Farm, Mr. Zimmerman now has a registered fertilizer product suitable for sale in Pennsylvania.
- The survey of potential poultry litter co-product end-users identified that while many farmers were interested in using poultry litter co-products, the greatest challenge for expanded use was lack of knowledge about the products.

Challenges

Air Emissions

- Triple Green Energy Products Cyclonic Filter System utilizes a filter media. While effective, overtime, due to the particulate matter loading, the filter media can tear or become clogged. On Mr. Zimmerman's farm, these filters need to be replaced between every flock. A commitment to the expense and time associated with regular filter media replacement is critical to achieving reliably low emissions.

Figure 8. Mr. Earl Ray Zimmerman (left) and Dr. Clara Ervin (right) making fertilizer pellets from poultry litter ash on the Earl Ray Zimmerman Farm in July, 2020.

- While these systems have potential, on-farm manure-to-energy systems do require considerable time and resources and may not be a good fit for each farm or farmer.
- Both participating farmers use single-flock bedding systems, which are still relatively unusual in the Chesapeake Bay region (fig. 9). Poultry farms using traditional bedding management systems crust out a portion of spent-bedding between each flock and only completely replace all bedding every few years (or longer). This traditional litter management approach will likely generate litter of lower fuel value that could impact heat generation and increase air emission challenges. Careful analysis of fuel value is needed before investing in any on-farm poultry litter to energy technology.
- Farmers utilizing poultry litter as fuel will need to self-determine that their litter meets EPA boiler requirements [**EPA NHSM Guide**].
- Availability and cost of litter as well as propane costs are important determinants for the financial feasibility of on-farm poultry litter-to-energy technologies. More research is needed to help determine where and when propane or poultry litter is a better fuel source for poultry house heating.

Co-product Marketing:

- Equipment for manufacturing poultry litter pellets on farm is readily available, but needs more on-farm demonstration to determine the best fit. Mr. Zimmerman is currently working with a local manufacturer to develop improved fertilizer pellet equipment.

- Fertilizer registration in Pennsylvania (and many other states) must be renewed annually.
- Poultry litter and poultry litter ash are inherently variable products. Once sold as a fertilizer, the farmer and product must be similar to the labeled fertilizer rate or the farmer will be fined for non-compliance.

Figure 9. Both participating farmers completely replace poultry litter bedding between every flock. This is not a typical litter management practice in the Chesapeake Bay region. In addition, Mr. Zimmerman harvests biomass miscanthus grass as a bedding additive in the cold winter months. Collectively, poultry bedding and litter management practices affect the fuel properties of the poultry litter which can impact the potential performance of litter-to-energy technologies.

Summary of Outputs:

Videos:

What is it Like to Heat with On-farm Bioenergy? Energy Answers for the Beginning Farmer and Rancher
https://www.youtube.com/watch?v=tQAirjhxAs4

General Operation and Maintenance Considerations for an On-farm Poultry Litter-to-Energy System: A Farmer's First-Hand Experience
https://video.vt.edu/id/1_3nrpmniy

Experiences Selecting, Installing and Managing an On-farm Poultry Litter-to-Energy System: A Farmer's First-Hand Experience
https://video.vt.edu/id/1_cdnhswma

Poultry litter-to-energy fertilizer:
https://vimeo.com/496234743/244d4fedec

Publications:

Reducing particulate matter emissions from on-farm poultry-litter to energy technologies technical report and poster presentations: **https://sites.google.com/vt.edu/bioenergy-emissions-abatement/home**.

Fertilizer: The many forms you can use.
https://vtechworks.lib.vt.edu/bitstream/handle/10919/97654/SPES-187.pdf?sequence=1

Poultry litter ash as a phosphorus fertilizer for corn (links to poster and Extension publication):
https://scisoc.confex.com/scisoc/2017am/webprogram/Handout/Paper106071/C.Ervin_PLA_Poster_2017.pdf and **https://vtechworks.lib.vt.edu/handle/10919/103199**

Poultry litter ash physical and chemical characteristics that impact use as an alternative phosphorus fertilizer.
https://scisoc.confex.com/scisoc/2019am/meetingapp.cgi/Paper/118888

Granulated poultry litter ash acidulation and physical characteristics: **https://elibrary.asabe.org/abstract.asp?aid=52496**

Report on market analysis and financial feasibility of poultry litter ash fertilizer granules:
https://www.arec.vaes.vt.edu/content/dam/arec_vaes_vt_edu/eastern-shore/PL%20Ash%20Financial%20Feasibility%20and%203.29.21%20Marketing%20Final%20Report_v4_withSIMappendix.pdf

Poultry litter end-user survey results:
https://udspace.udel.edu/handle/19716/28836

Poultry litter-to-energy to fertilizer! Video showcasing Mr. Zimmerman's farm: **https://www.arec.vaes.vt.edu/arec/eastern-shore/programs/cses/manure-to-energy.html**

Potential Next Steps

The results from this project are promising. However, it is important to recognize that the success of these systems may not be replicable broadly. To further clarify what operations are a good fit for poultry litter-to-energy technologies, we recommend:

- Additional farm installations to confirm reduced air emissions can be achieved over the long-term, and to further demonstrate and evaluate technical and financial feasibility.
- Economic feasibility analysis that considers:
  - Cost compared to propane
  - Production/house maintenance costs compared to propane
  - Capital and operation and maintenance expenses compared to propane
  - Bird health and production goals compared to propane
- Performance of different sources of biomass (e.g. wood shavings, miscanthus grass) as poultry bedding, fuel characteristics, and fuel value requirements for operational success

Project Team:

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Triple Green Energy

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