Appendix H

Financial Assessment of the Farm Manure-to-Energy Initiative

Prepared by the Environmental Finance Center, University of Maryland

Provided to Sustainable Chesapeake and partners of the Farm Manure-to-Energy Initiative with funds provided by the National Fish and Wildlife Foundation

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Contents

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1. Introduction

The Environmental Finance Center at the University of Maryland (EFC) was part of a collaborative project to investigate the use of innovative technologies that produce energy from the conversion of poultry litter. These technologies are of particular interest for protecting water quality in the Chesapeake Bay region, in that they provide alternative uses and markets for excess poultry litter that, if applied to farmland in excess of crop needs, can reach local waterways through stormwater runoff.

The coalition conducted the Farm Manure-to-Energy Initiative between 2012-2015, working with five farms in the Chesapeake region to implement and evaluate the use of thermal technologies to produce energy from poultry litter. The coalition, under the organizational umbrella of the National Fish and Wildlife Foundation, included the following partners: Sustainable Chesapeake; Farm Pilot Project Coordination, Inc.; Virginia Cooperative Extension; Virginia Polytechnic University (VA Tech); Lancaster County Conservation District; University of Maryland Center for Environmental Science; Eastern Shore Resource Conservation & Development Council; and the International Biochar Initiative. Funders included the National Fish and Wildlife Foundation, Chesapeake Bay Funders Network, USDA Conservation Innovation Grant Program, and U.S. EPA's Innovative Nutrient and Sediment Reduction Program.

The purpose of the Farm Manure-to-Energy Initiative was to evaluate the effectiveness and performance of thermal manure-to-energy technologies that use excess animal manure or poultry litter (comprised of manure, bedding, and feathers) to produce electricity or heat for animal housing on farms in high-density animal production areas of the Chesapeake Bay watershed. The evaluation included technical, environmental, and financial performance of the systems. The role of the EFC was to provide a financial assessment of the investment at each host farm.

It is important to note that the even when technical problems resulted in failure of the thermal technologies to deliver heat or electricity throughout an entire flock cycle, there were periods of successful energy production that reduced the use of propane for heating the poultry houses. While the data 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.

Farmers also observed improved bird health (weight gain, decreased foot disease, and lower ammonia levels). Although this project did not seek to correlate bird health performance with the technology, farmer testimonials indicate that bird health benefits are worth future investigation.

While the cost balance provides an overview of the costs associated per farm, it does not fully characterize all farm labor and costs. The propane reduction estimates in this assessment were calculated using the data available to demonstrate the type of energy offset analyses that will be needed in future assessments, when the technology runs for a sufficient duration of multiple flock cycles at a farm.

The experience at these five host farms offers various pieces of a puzzle that help define the benefits of thermal manure-to-energy systems at the farm level. While no one farm currently offers this information, the five farms collectively allow for a preliminary characterization of costs associated with installing and operating such systems. All farmers have exhibited willingness to communicate with the EFC and its partners to conduct this assessment; however, privacy issues and farm administration duties affected some data availability, compounded with relatively short durations of continuous run-time of the technology during flock cycles. Host farmers also demonstrated a high degree of commitment to the assist the technology vendor in seeking system success.

The host farms included:

- **Windview Farms**, Port Treverton, PA, owned by Morrell "Mac" Curtis. Windview Farm has historical data for the use of manure-to-energy technology for consecutive years prior to a fire in May 2014. This data demonstrates long-term operation and maintenance of this technology once the learning curve has leveled out. Windview Farm experienced success with its previous technology, but the system was undersized and design of the heat delivery system was not optimized. Hence, the system did not demonstrate as large a savings in propane offsets as would be expected. The newly installed technology is sized appropriately for the amount of poultry litter generated and the poultry house needs; the new system should demonstrate increased savings and offer important information during upcoming cold weather seasons.
- **Farm B**, Lititz, PA. Farm B offers detailed electricity and propane savings for short-term running of the thermal technology during part of two flock cycles. The energy-efficient poultry houses and high-performance boiler and heat delivery system offer a glimpse of cost performance for high-end monitoring, heat delivery, and vendor technology capacities.
- **Mark Rohrer Farm**, Strasburg, Lancaster County, PA. Mr. Rohrer demonstrates side-by-side in-situ energy comparisons with two poultry houses adjacent to a manure-to-energy system, run by his brother. The geographic proximity allows for a comparison of houses with and without manure-to-energy technologies, including the energy offsets in similar climatic conditions. Mr. Rohrer's transition from conventional to organic chickens, as well as his transition from conventional to solar energy, make the data comparison challenging for pre-technology to post-technology energy offsets. However, this is also ameliorated by using his brother's adjacent farm for comparison.
- **Mike Weaver Farm**, Fort Seybert, WV. Mr. Weaver's farm demonstrates technology similar to that at the Mark Rohrer Farm. While the technology did not operate continuously during the flock cycles, there is some flock data and propane offset information available to further characterize the potential for energy offsets at an energy efficient farm. Mr. Weaver provided decommissioning costs.

- **Riverhill Farm**, Port Republic, VA. Owned by Glenn Rodes, this farm provided an example of expended time and energy on air permitting for the manure-to-energy technology. The permitting experience is transferable to future generations of host farmers if they are in a non-attainment air quality area, or in Virginia, where permit compliance requires farmer time and fees. Mr. Rodes grows turkeys, and the moisture content of turkey litter challenged the original construction of the technology. The boiler was replaced with a new system by a different manufacturer. This farm offers more information on air quality data and capital costs; however, data on energy offsets was not available at this time for inclusion in this assessment.

The experiences of these farms show that implementing manure-to-energy technologies is still a challenge. Learning curves in design, installation, and operation are often substantial, pointing to the importance of services and subsidies provided by the public sector in the wider adoption of this technology.

Additionally, the unique circumstances and varied experiences of each of these farms raise questions about the ability to construct meaningful general cost ranges (capital and operational) that determine financial impacts of the technology on a farm's bottom line. At the same time, these experiences illustrate the willingness of farmers to test new technologies with the potential to generate positive environmental and economic impacts.

An additional component of this financial assessment is the financial value of the ash co-product that is generated by the manure-to-energy system. The ash has potential value as a crop fertilizer. Mark S. Reiter, Ph.D., a crop and soil specialist with the Eastern Shore Agricultural Research and Extension Center of Virginia Tech compared poultry litter and poultry litter ash in terms of market prices. Based on a series of field trials, his research suggests that poultry ash may have some promise as a fertilizer even when taking into account variability in fertilizer prices and nutrient values over time. Based on the five-year average retail fertilizer value for nitrogen, phosphorus, and potash, Dr. Reiter identified a wide range in the potential sale value of poultry fly ash ($0 to $463 per ton). As a point of comparison, poultry litter is either being given away or sold at prices typically in the range of $8 to $20 per ton. In the event future market assessments indicate a lack of targeted users, disposal costs should be included under the $0 per ton value scenario. Dr. Reiter also asserts that ash is microbially benign and offers high value market potential.

It is important to note that an extensive amount of market development and infrastructure is needed to support the emergence of poultry litter ash as a revenue source for farmers. These efforts should include: a thorough market analysis; education and outreach on the use of this new value-added product; a transportation analysis on the logistics of bringing this product to market; and a more comprehensive database to develop a basis for the cost of the ash. For example, the basis for the nutrient value should include additional field trials and laboratory analysis on a larger composition of ash samples from multiple poultry litter farms, with ash produced under consistent litter combustion rates. Future market analysis needs to consider the potential end-market value as well as the cost of marketing, packaging, and transportation, all of which impact the potential net revenue received by the farmer but does not necessarily reflect the net revenue available to farmer (or quantify if there is a net revenue to farmer).

2. Assessment Purpose

The purpose of the financial assessment is to measure the cost balance for each host farm. The EFC focused on estimating the costs for the life cycle of the technology at the farm sites. These costs are based on performance assessments of technologies obtained through farmer interviews and data collection on-site. However, because of the timing of installation and, in some cases, technical or vendor issues with performance, data was limited. Because of the limited timeframe for operational data collection, the cost balance does not capture the full value of life cycle costs and equipment aging.

This financial assessment does not include the revenue-generating opportunities of the nutrient-dense ash or biochar, which can be cost-effectively transported long distances or used to replace imported commercial phosphorus for fresh-market vegetable production. The laboratory analysis and field trials of the co-products were conducted side-by-side with this financial assessment. However, as previously discussed, Dr. Reiter's work suggests that ash or biochar from thermal manure-to-energy technologies has the potential to generate revenue and should be considered if markets are developed for this nutrient-dense material. Development of end-user markets will also facilitate phosphorus and potash recycling and should address transport of excess nutrients to regions of the country reliant on commercial fertilizer.

3. Farm Costs

This section summarizes farm costs for each host farm, including:

- A description of the farm
- Capital costs (infrastructure, installation costs, and permitting)
- Routine operations and maintenance costs (including regular maintenance)
- Fate of the poultry litter pre- and post- installation of manure-to-energy technology as available
- Energy costs:
  - Electricity and propane offsets listed during technology run-times
  - Weather conditions and integrator allowances
- Overall farm revenue, including the footprint of poultry production within the context of the overall farm revenue

3.1 Blue Flame Boiler Heating System at Windview Farm

3.1.1 Farm Description

Windview Farm is located in Port Treverton, Snyder County, PA. The farm includes two broiler houses that produce approximately 440,000 anti-biotic free broiler chickens per year for Sullivan's Natural. Each building consists of a 10,000 ft^2 section and a 20,000 ft^2 section, for 30,000ft^2 per building, or 60,000 ft^2 total. The farm hosts six to seven flocks per year with an average flock cycle of 40 days. Broilers are grown to varying weights depending on market demand.

3.1.2 Infrastructure costs, Installation Costs, and Permitting Costs

Note: Famer time was calculated at $34.89 per Bureau of Labor and Statistics, modified rates March 2015 (http://www.bls.gov/oes/current/oes119013.htm).

Windview Farm previously had a Blue Flame boiler, first fed with turkey litter and then broiler litter, provided through farmer funding and a grant from the National Fish and Wildlife Foundation. The system operated for five years, but an electrical fire in May 2014 damaged the system beyond repair.

With support from the Farm Manure-to-Energy Initiative, a new Blue Flame boiler and heating system was designed and installed by Total Energy during the spring and summer of 2015. Funding from the Farm Manure-to-Energy Initiative helped make system improvements, based on lessons learned. Given the timing of installation, no flocks were heated using the new technology during the performance assessment period. However, historic data was available on propane savings from the previous system. Mr. Curtis, the farm owner, also offered the lessons learned from past experience: how upfront costs and the learning curve shape a farmer's perspective, as well as the typical operation and maintenance costs incurred while the system was running.

The previous boiler that was destroyed by fire cost approximately $140,000. Infrastructure costs are still being incurred from that system, including payments of $1,100 per month on a mortgage for the equipment. The Farm Manure-to-Energy Initiative provided capital costs for the new technology installation totaling $41,500. The technology vendor and an insurance settlement for the system damaged in the electrical fire provided the remainder of the boiler costs.

Construction of a concrete pad includes 12x26 or 312 square feet for the pad under the hopper shed and 20x30 or 600 square feet under the burner building. The total concrete pad covers 912 square feet. Materials and construction costs were estimated to be $4,350 from the farmer.

Farmer labor is a significant portion of the upfront construction and installation costs as well as troubleshooting. For example, Mr. Curtis estimates that to install the boiler and lay 2,600 feet of pipe, dig ditch, and tear out tubing, he contributed 12 hours per day for 6 days a week for 2.5 months. This totals 72 hours per week for 10.86 weeks or 781.92 hours. Using a rate of $34.89 for a farmer, the initial labor is valued around $27,280. Troubleshooting time plus hardware for fittings, etc., not covered by budget was estimated between $17,000 to $18,000, or an average upfront cost of $17,500.

Obtaining permits for air emissions involved minimal farmer time. The new installation of air equipment costs were estimated by Farm Pilot Project Coordination Inc. (FPPC) as $14,500 (including support from Dr. Mike Buser of Oklahoma State University for emissions control design support). Mr. Curtis estimated he spent 2-4 hours (used 4 hours times $34.89 = $104.67 or $105) in support of obtaining air permit approval. There was unaccounted time spent by Denise Bechtel of the Small Business Development Center (Bucknell office in Lewisburg). Without help from the Small Business Development Center, the farmer's time on air permitting would have increased costs. The Small Business Development Center spent an estimated 80 hours to write the grant proposal that funded the first boiler and investigated air permitting (per conversation with Mac Curtis, September 2015). If Mr. Curtis was the sole source of permitting advocacy and grant writing, his time for 80 hours would be valued at $2,773.60 at the BLS rate of $34.89/hour.

Laboratory analysis of air sampling and ash contents were performed during the fall of 2015. Based on availability of data, the following is estimated as laboratory costs. Poultry litter ash and air sampling laboratory analysis were estimated by FPPC as $16,364 for three farms (Curtis, Rodes, and Farmer B), therefore an estimated one third or $5,454 was considered expended in analysis from Virginia Tech, Clemson, and Brookside.

Costs for poultry litter analysis were $419 per sample (Clemson and Brookside). This does not include data collection, which farmers typically would not be expected to do. In other words, data collection costs incurred by the project team supported information gathering beyond what an individual farmer would be required to do on his or her own. It is important to note that one sample is sufficient for federal permitting and does not constitute routine laboratory costs anticipated in the future.

A summary of the costs is provided below.

Windview Farm Cost-Share Contributions			
	Miles	Hours	Cost
Labor*			
Mac Curtis: 12 hours per day, 6 days per week, for 2.5 months		720	$16,294
Infrastructure			
Original system investment, re-invested in this project			$140,000
Over-budget, out-of-pocket expenses			$17,500
Cost to re-build hopper			$400
Mileage**			
Travel to Lancaster County Conservation District for manure-to-energy meeting (Jan. 2015)	160		$92
Travel for purchase of supplies and equipment (spring/summer 2015)	120		$69
Total			$174,194

* Volunteer Cost Calculation Notes: Farmer volunteer time valued at Independent Sector PA volunteer time estimate at $22.63 (http://www.independentsector.org/volunteer_time).
**Mileage calculated at federal rate for 2015 at $57.50.

3.1.3 Routine Operations and Maintenance Costs

Regular maintenance, when the system was running smoothly, averaged 45 minutes per day ($26.17) or $183 per week hauling four bucket loads of litter to the hopper to burn. In colder weather, average maintenance was about one hour per day or $244.23 per week ($34.89/hour/day). Occasional additional maintenance was required due to a stone in the auger; however, preventive removal of stones from litter minimized stone remediation. The initial learning curve for running the manure-to-energy burner the appropriate way involved modulating the dial from low to high demand. That depended on the litter and the weather; after a few months, Mr. Curtis said that it was fairly low maintenance. This initial learning time is not accounted for with Mr. Curtis. A steep learning curve and higher farmer input is mostly what we see with the other host farms, due to the duration of experience with the technology.

Mr. Curtis cleans out the poultry houses between flocks, which is required by his integrator and by the thermal manure-to-energy technology vendor, Total Energy. As such, this effort is presumed the same with and without manure-to-energy technology; therefore, no additional costs are anticipated from litter clean-outs. The University of Georgia Extension provides detailed cost savings on litter bedding and costs for machine clean-outs; however, these were not applied since the activities remained the same with and without the manure-to-energy technology (http://extension.uga.edu/publications/detail.cfm?number=B1267).

It is important to note that, due to the high cost of replacement litter, most growers remove only the top portion of the litter between flocks (called "cake-out" or "crust-out"). Whole-house litter removal is typically done once every 2 to 5 years. So for most poultry growers, a whole-house clean-out between every flock would be considered an additional cost.

3.1.4 Fate of Manure (pre- and post-manure-to-energy technology)

The farm produced 400 tons per year of manure when growing turkeys; now, with broilers, they produce approximately 375 tons per year. Prior to installing manure-to-energy technology, poultry litter was land applied on the home farm (40 acres) and rented land (100 acres) and sold off the farm. It was applied at varying rates, depending on the farm's nutrient management plan and whether corn or beans were planted, which occurred in alternate years. The volume was approximately 2 tons of manure applied per acre when growing corn or 280 tons of manure in total. The remaining manure was sold at a rate of $8 per ton (current rates are now $10/ton). Since manure is applied on alternate years, the remaining manure for sale varies from $960 to $3,200 annually, based on the $8 per ton rate. The revenue generated on selling manure during corn years is estimated as $960 per year for the remaining 120 tons sold at $8 per ton. The revenue generated for manure sold during bean planting years is estimated as $3,200 per year because no manure is applied and all goes to sale. Therefore, an average $2,080 per year is generated from sale of manure (based on a corn plus bean year). This estimated average revenue is not presumed to be available for farmers who burn litter for energy; it needs to be accounted for when calculating the savings from propane as a loss of revenue.

3.1.5 Energy Costs

Electricity and propane costs listed during technology run-times

Mr. Curtis described significant propane savings during his years with the manure-to-energy system. The manure-to-energy technology on Windview Farm burns approximately 320 tons per year, leaving none for sale. Any remaining litter, if available, was used on crops. Future modeling of financial performance of the manure-to-energy technology should account for loss of revenue from manure that was burned instead of sold. Additional detailed energy assessments are provided in Section 4.

While the loss of revenue for manure sold is $2,080 a year (on average), Mr. Curtis estimates that he saved more than 90 percent in his propane bill using poultry litter for energy over the recent few years.

Energy trends were based on years of propane and electric bills. In general, Mr. Curtis indicated propane prices have dropped, but were more than $3 per gallon when he began running the manure-to-energy technology. He has four 1,000-gallon tanks at the poultry houses that hold up to 3,200 gallons total (80 percent is full capacity to allow room for off-gassing). Mr. Curtis estimated that he used 3,500 gallons of propane in 2014. The savings in propane is realized when the integrator provided a stipend for propane; the stipend was not needed for propane and was therefore a source of revenue. The amount of propane offered varies per flock, based on the time of year. Mr. Curtis received a stipend for gas allowance from the integrator during 2012 through 2015, while he used the manure-to-energy system to generate heat and therefore decrease his propane use. In 2012, he received $41,100 as a propane stipend; in 2013, he received $34,650; in 2014, he received $41,700; and, as of July 2015, he received a propane stipend of $10,200. Because his propane bills were less than the stipends, he was able to earn the revenue using the litter burning technology as described below.

Integrator Gas/Electricity Allowance as Income

The integrators pay an allowance for both gas and electricity based on average grower usage in the geographic area. These allowances exceeded the propane bill and became a source of income. In 2012, the electricity allowance from the integrator was also a small income.

It is important to note that the integrator told Mr. Curtis that because he does not actually pay such high gas bills, his allowance should be reduced (personal communication between the EFC and Mr. Curtis, September 2015). Mr. Curtis contends that it would be unfair to penalize him for having technology that allows him to save on propane. Future implementation of manure-to-energy technology needs to consider whether or not integrators may lower the gas allowance and thereby null the propane savings.

Propane

In 2012, Mr. Curtis spent $5,558.99 on 3,716.6 gallons of propane, and his net income from the propane stipend was $35,541.01. In 2012, he spent $7,554.80 on electricity, and his stipend was $10,672; therefore, Mr. Curtis was able to receive the remaining $3,117.20. By burning litter, Mr. Curtis earned an additional $38,658.21 from the savings on his integrator allowance stipends. In 2013, Mr. Curtis spent $6,446.56 for 5,261.7 gallons of propane, which translated to an earned income of $28,203.44 from the allowance ($34,650.00 – $6,446.56).

In May 2014, Mr. Curtis lost his manure-to-energy boiler in a fire. Therefore, his use of propane was higher and his earned amount from the gas allowance was slightly less than the previous two years. In 2014, Mr. Curtis spent $14,348.74 for 8,987.9 gallons of propane, which translated to an earned income of $27,351.26 from the gas allowance of $41,700.00 ($41,700.00 - $14,348.74).

Electricity

Trends in electricity usage for the past few years are primarily observed by the Curtis family. No electric bills were available for 2013 or 2014. Mr. Curtis noted that electricity was usually higher when using the manure-to-energy system (2012 was an exception). The electric fee is based on pounds of birds (as a stipend by the integrator to the grower). The electric rate is the same per flock. Electricity also runs the pumps for the water wells. No other water use is a cost, per se. The grower is responsible for all washing of the fans, inlets, and stove between flocks and the building once a year. The farm labor for this was not accounted for because the farmer performs these tasks whether or not manure-to-energy technology is running.

3.1.6 Weather conditions

The on-farm use of propane for heating was reviewed in light of the weather patterns, based on the NOAA National Center for Environmental Information, with the statewide ranking of average temperature data reviewed monthly for Pennsylvania (based on historic data from 1895 to 2015). In general, the period between January and April 2012 was much warmer than normal to near normal. October through December 2012 was near normal, below normal, and much above normal (varied greatly) for Pennsylvania. In 2013, NOAA reported January through February as normal, March below normal, and April above normal. The cold weather months later in 2013 had near normal temperatures for October and December, while November 2013 was much below average. The NOAA database characterized January and February of 2014 below average temperature and March as much below average. The April and May 2014 temperatures were near average. Later in 2014, the NOAA database indicated that October and December had above average temperatures, while November 2014 was below average. In 2015, NOAA recorded below average and much below average temperatures for January through March.

3.1.7 Overall Farm Revenue

Windview Farm revenue consists of income from the birds, income from the 40 acres, and income from selling poultry litter. Corn can generate $12,000, and manure can generate $3,395, plus $257 in hay. In summary, poultry is 95 percent of the total farm revenue. The estimated total farm revenue was calculated from data on the settlement sheets for 2012, 2013, 2014, and part of 2015. During 2012, Mr. Curtis earned a $94,876.80 flat fee for growing poultry per pound. With the additional integrator stipends for gas, electricity, litter, and bonuses, his total income in 2012 was $180,158.71. Based on Mr. Curtis' assertion that poultry represents 95 percent of the total farm revenue, his proportioned total farm revenue for 2012 was estimated as $189,166.64. During 2013, he earned a $97,566.80 flat fee for growing poultry per pound. With the additional integrator stipends for gas, electricity, litter, and bonuses, his total income in 2013 was $177,786.87. The total farm revenue was calculated using the 95 percent proportion of revenue from birds and was calculated as $186,676.21. During 2014, he earned a $103,012.28 flat fee for growing poultry per pound. With the additional integrator stipends for gas, electricity, litter, and bonuses, his total income in 2014 was $190,894.02. The total estimated farm revenue for 2014, using the proportion of 95:100 for poultry-revenue to total farm revenue, was estimated as $200,438.72. From January through July 2015, Mr. Curtis earned a $44,359.80 flat fee for growing poultry per pound. With the additional integrator stipends for gas, electricity, litter, and bonuses, his total income in 2015 as of July was $66,416.01.

3.2 Ecoremedy Gasfier Demonstration at Farm B

(Name of farmer and farm redacted, per farmer request.)

3.2.1 Farm Description

Farm B is located in Lititz, PA. It has four poultry houses producing organic poultry broilers using a manure-to-energy system to provide heat.

3.2.2 Infrastructure costs, Installation Costs, and Permitting Costs

The following funding totaled $957,987 for the infrastructure of a manure-to-energy boiler and heat delivery system. Of the $957,987, $441,487 was from the farmer and vendor, as partner match ($247,969 from Enginuity Energy LLC, $183,518 from Ecoremedy Energy Technologies, and $10,000 from Flintrock Farm). The farmer also obtained funding from the Pennsylvania Natural Resource Conservation Service Environmental Quality Incentives Program totaling $150,000. The balance was funded via private funds from the National Fish and Wildlife Foundation in collaboration with the Chesapeake Bay Funders Network, which provided $366,500 through the Farm Manure-to-Energy Initiative.

Heating exists for four poultry houses fueled by manure-to-energy technology. The poultry houses in place are not included into the capital costs; however, $53,000 in upgrades for energy efficiency are included in the capital costs. The poultry houses that are heated by the technology fuel include 243,000 cubic feet for Houses 11 and 12 and 170,500 cubic feet for houses 9 and 10.

Farm B had an existing concrete pad under the storage shed so no additional costs were incurred. The concrete pad under the hopper shed is located under the building. Farmer B said he put $200 into the concrete pad for capital costs. Estimated labor and materials to install an estimated 400 square feet for a concrete pad under the boiler shed concrete pad is $1,900 from the farmer plus his estimated $200, or $2,100 for labor and materials to construct the concrete pad under the hopper and boiler sheds, covering 400 square feet.

Obtaining permits for air emissions involved no farmer time. No water or stormwater permitting costs were associated with the project. Laboratory analysis of air sampling and ash contents are being performed during the fall of 2015. Based on availability of data, the following is estimated as laboratory costs. Poultry litter ash and air sampling laboratory analysis were estimated by FPPC as $16,364 for three farms (Windview Farm, Riverhill Farm, and Farm B); therefore an estimated one third or $5,454 was considered expended in analysis from Virginia Tech, Clemson, and Brookside. Costs for poultry litter analysis were $419 per sample (Clemson and Brookside). This does not include data collection, which no other farmer had to do since one sample is sufficient for federal permitting.

3.2.3 Installation Costs

Farmer B estimates he spent a total of 830 hours between 2012 through 2014 to help get the manure-to-energy system running. This was broken down at 10 hours per month from January 2012 through January 2013, 20 hours per month from February 2013 through December 2013, and 40 hours per month from January through December 2014. At the farmer labor rate of $34.89 per hour, total farmer time for installation is estimated as $28,960. Farmer time for up-front preparation included two trips to Lancaster Conservation District and two trips to the vendor in Mechanicsburg, PA. Famer time was calculated at $34.89 per Bureau of Labor and Statistics, modified rates March 2015 (http://www.bls.gov/oes/current/oes119013.htm). The farmer labor included above is a significant portion of the up-front construction and installation costs as well as troubleshooting. The time estimates from Farmer B include installing the boiler and laying pipe, digging ditch and tearing out tubing, troubleshooting time plus hardware for fittings.

The travel to the Conservation District is estimated as 0.5 hours travel plus a two hour meeting, which totals 2.5 hours for one meeting or five hours for both meetings. Travel gasoline at the IRS reimbursement rate for 2014 was 0.56 per mile, totaling $11.20 per trip or $22.40.

Distance to the vendor was 90 miles round trip, or two hours travel plus two hours per meeting for a total of four hours per meeting of farmer time. For two meetings, total farmer time was estimated at eight hours and gasoline for travelling 180 miles at the same rate is $110.80.

Total costs for four trips to prepare for the technology include $453.57 for 15 hours of farmer time and $133.20 for gasoline, or a total of $587.

3.2.4 Routine Operations and Maintenance Costs

(Includes regular maintenance when running smoothly.)

Farmer B estimates regular maintenance to be $5 per ton for the daily labor of moving litter to the boiler, or $8,000 (per his pro forma). Farmer B estimates daily labor of filling and checking the system to be 1.5 hours when it gets up and smoothly running, which would be $10,950 for 1,600 tons (per his pro forma). These were best-guest farmer estimates because the actual labor was heavy and the manure-to-energy technology did not run smoothly during the performance assessment period.

Farmer B cleans out the poultry houses between flocks to remove the top crust of the bedding. He changes the entire bedding and replaces litter on whole-house cleans-outs, which are conducted once every 12 to 18 months. Whole-house clean-outs cost $1,700 per house. For four houses to be cleaned out every 12 to 18 months, the cost is $5,100 annually. Farmer B used to be allowed to use spent horse stall bedding for litter; however, his current integrator does not permit that so it is an additional cost for him to do the whole-house clean-out and replace bedding. (Note: the additional four houses not using manure-to-energy technology likewise cost $5,100 annually.)

3.2.5 Fate of Manure (before and after manure-to-energy technology)

Farm B produces about 800 to 900 tons a year of manure with organic broilers (personal communication, Farmer B, September 3, 2015). Farmer B has 40 acres of cropland and uses about 2-3 tons of litter per acre per year to fertilize it, or 100 tons of litter (2.5 acres over 40 acres). The remaining 700 to 800 tons of litter, prior to implementing manure-to-energy technology, was sold to brokers at a rate of $9 to $10 per ton (current rate is $9 per ton). Prior to burning litter, this generated approximately $6,750 per year in income using an average of 750 tons of litter. The buyer would pick up the manure, so Farmer B incurred no disposal or hauling costs in the transaction. When the manure-to-energy technology is fully functional and running continuously, the loss of $6,750 per year should be reflected in the cost balance sheet.

It is important to note that this farmer sold his poultry litter ash to growers in Missouri.

This sale is a milestone, as it represents the first in interstate market sales and reflects the potential marketability of the fly ash. As presented in Section 1 of this report, market values for ash should be refined in future market assessments.

3.2.6 Energy Costs

(Electricity and propane costs listed during technology run-times.)

Propane

The boiler did not run for a sufficient duration to affirm long-term propane savings. However, Farmer B noted that he had decreased propane consumption while using the manure-to-energy system to heat one flock (for a portion of the flock cycle) from December 2014 through January 2015. The houses on the north hilltop use the heat from the manure-to-energy system, whereas the southern houses are heated by propane only. Based on propane bills from 2014 and 2015, the houses that were using manure-to-energy technology during a flock placed from December 5, 2014 through January 1, 2015 realized a savings of propane; however, without more data, it is a qualitative trend rather than a statistically significant savings. Farmer B indicated that during one week when the manure-to-energy system was running, he used $2.20 propane per pound of bird, versus $4.76 for propane per pound of bird for an average grower that same week. It is important to note that the manure-to-energy run time during that flock placement was about three weeks and did not run during the high heat time of initial placement for pre-heat or the first few days, when chick heating needs are most intense.

Electricity

The electricity is solar-generated. Under net metering, Farmer B has a refunded amount credited to his account for the solar production, or he gets a deduction if they use less than they generate. They are capturing most of the manure-to-energy heat offsets with the independent meter.

Additional electric not covered by this meter includes: three ¾ HP motors per house running all the time, or 12 motors running total for his four houses. Also, if Farmer B was running the system per the guidance of bird health advocates, he would be making more use of in-house fans, so the electricity meter on the manure-to-energy boiler alone does not quite cover the price difference.

Note: Farmer B estimates that his electricity use will be in the range of $7,000 per year because of the manure-to-energy system for four houses. The electricity data is not as specific as propane. Farmer B runs an inventory of propane used per flock but does not do the same inventory of electricity as he does for propane.

Integrator Gas / Electricity Allowance as Income

The integrators pay an allowance for both gas and electricity based on average grower uses in the geographic area.

3.2.7 Weather conditions

The on-farm use of propane for heating was reviewed in light of the weather patterns, based on the NOAA National Center for Environmental Information, with the statewide ranking of average temperature data reviewed monthly for Pennsylvania (based on historic data from 1895 to 2015). In general, the period from January through April 2012 was much warmer than normal to near normal. October through December 2012 was near normal, below normal, and much above normal (varied greatly) for Pennsylvania. In 2013, NOAA reported January through February as normal, March below normal, and April above normal. The cold weather months later in 2013 had near normal temperatures for October and December, while November 2013 was much below average. The NOAA database characterized January and February of 2014 below average temperature and March as much below average. The April and May 2014 temperatures were near average. Later in 2014, the NOAA database indicated that October and December had above average temperatures, while November 2014 was below average. In 2015, NOAA recorded below average and much below average temperatures for January through March.

3.2.8 Overall Farm Revenue

Farm B's overall revenue is generated by selling some manure that is not used on the fields and by running an averate of seven poultry flocks per year in eight houses. Annual poultry income was not disclosed.

3.3 The Mark Rohrer Farm

3.3.1 Farm Description

The Mark Rohrer Farm is located in Strasburg, Lancaster County, PA. Organic chickens are raised in two poultry houses, heated with manure-to-energy technology. Mr. Rohrer's brother, Todd Rohrer, has two poultry houses situated next door that do not use manure-to-energy technology.

3.3.2 Infrastructure costs, Installation Costs, and Permitting Costs

The Rohrer farm used the two existing poultry houses and a manure shed during the time hosting this technology. The hard infrastructure in support of the manure-to-energy system included the boiler, the shed for the boiler, the heat delivery system, air quality abatement equipment, and a concrete pad under the boiler shed.

The infrastructure for the manure-to-energy boiler and heat delivery system totaled $303,012. A subtotal of $181,512 was provided as partner match; this was based on $26,365 from the farmer and $155,147 from the vendor. The remaining was funded through a grant Farm Manure-to-Energy Initiative providing $121,500 in funding.

The vendor paid for materials and construction of concrete padding in the amount of $5,000. While no concrete pad dimensions or time estimates were available regarding farmer contribution, it is estimated there were no out-of-pocket costs borne by the farmer for the concrete pad. This estimate is based on the $4,350 paid by Mr. Curtis for materials and time to install a concrete pad under his boiler and hopper. For the purposes of this assessment, we assume that Mr. Rohrer's cost was a similar amount, covered by the vendor's contribution of $5,000. The vendor provided $17,500 for the shelter for the system.

Farmer labor is a significant portion of the up-front construction and installation costs as well as troubleshooting. For example, Mr. Rohrer indicated he paid $5,363 in out-of-pocket expenses and time for the initial installation. The fan ventilation system cost $50,000, paid for through a cost-share arrangement that also covered installation and equipment training.

Cost-share funding and the FPPC's contribution of $15,000 were used to fund the air pollution remediation equipment and installation.

There were no air emission permits, so no farmer time or permit fees were incurred. A contractor and FPPC performed initial and subsequent air pollution sampling, with no costs available at this time, as sampling was performed in September 2015. Future financial assessments should include air source sampling, laboratory analysis, and time for regulatory agencies, as required based on local and state regulations.

3.3.3 Routine Operations and Maintenance Costs

Note: Famer time was calculated at $34.89 per Bureau of Labor and Statistics, modified rates March 2015 (http://www.bls.gov/oes/current/oes119013.htm).

Regular maintenance was not experienced for a significant duration. The maintenance time incurred by the farmer to support the system was documented on farmer log sheets. Mr. Rohrer logged a total of 44 hours for maintenance and troubleshooting between September 28 and November 30, 2014. Mr. Rohrer's time during this period was estimated to be valued at $34.89 per hour or $1,535. This reflects the steep learning curve and higher farmer input exhibited during the duration of the technology run times.

Mr. Rohrer cleans out the surface litter of the poultry houses (a "crust out") between flocks. This effort is presumed the same with and without manure-to-energy technology; therefore, no additional costs are anticipated from litter clean-outs. The University of Georgia Extension provides detailed cost savings on litter bedding and costs for machine clean-outs; however, these were not applied since the activities remained the same with and without the manure-to-energy technology (http://extension.uga.edu/publications/detail.cfm?number=B1267).

3.3.4 Fate of Manure (before and after manure-to-energy technology)

The Rohrer farm did not provide data on the fate of manure before the manure-to-energy system was using litter to generate heat. It is assumed that the manure was used on their crops and not sold.

3.3.5 Energy Costs

(Electricity and propane costs listed during technology run-times. Detailed energy assessments are provided in Section 4 and in Appendix A.)

Propane

The average daily propane consumed by the Rohrer farm for the two months that the farm hosted flocks and the system was delivering heat was 55 gallons per day, compared to the estimated pre-technology use of propane of about 98 gallons of propane per day. This estimate was calculated by comparing his propane use to propane on an adjacent farm. For two flocks in a side-by-side comparison, Mark Rohrer's propane bill was $5,901.37 plus $136.02 in propane costs for running the system, for a total propane cost for two flocks of $6,037.39. This can be directly compared to the adjacent farm's propane bill of $8,009.76 for the same time period with two flocks. In theory, the data from the adjacent farm can emulate pre-technology conditions for Mark Rohrer. While the poultry houses are not identical, they are similar for the purposes of demonstrating trends in energy savings. This side-by-side comparison indicates a 25 percent reduction in propane use by Mark Rohrer for the time he was using the heat delivered by the manure-to-energy system.

Integrator Gas / Electricity Allowance as Income

No integrator for gas or electricity allowance from flock settlement was confirmed and was therefore not included in this assessment.

Electricity

Mark Rohrer's electricity cost for running the system was $404 for the duration of two flocks from September 28 through November 30, 2014. Other electricity data is extrapolated from the two flocks and presented in Section 4.

3.3.6 Weather conditions

Due to the geographic proximity, the weather conditions are similar to those of Farm B, described above.

3.3.7 Overall Farm Revenue

Mr. Rohrer has an estimated six flock cycles a year. No data was available on the income generated annually from the poultry, or what percent that constitutes of his overall farm revenue. Income presented on the flock settlement sheets from June through November 2014 indicated a net grower pay of $38,575.97. If doubled, the estimated annual net grower pay from poultry could be estimated as $77,151.94.

Data on total farm revenue plus the percentage of revenue generated from poultry compared to the total farm, while useful in future analyses, is sensitive in nature and was not easily secured from the farmers.

3.4 The Mike Weaver Farm

3.4.1 Farm Description

The Mike Weaver Farm is located in Fort Seybert, Pendleton County, WV. Mr. Weaver produces broilers conventionally in two poultry houses.

3.4.2 Infrastructure costs, Installation Costs, Permitting Costs

The infrastructure for the manure-to-energy boiler and heat delivery system totaled $297,647. A subtotal of $176,147 was provided as a partner match; this was based on $21,000 from the farmer and $155,147 from the vendor. The remaining was funded by leveraged grants through the National Fish and Wildlife Foundation's Conservation Innovation Grant number 33043 and partners.

Mr. Weaver had an existing concrete pad under the storage shed so no additional costs were incurred. The cost for the concrete pad under the hopper shed was not available, but estimated at $5,000 (based on the Curtis farm).

No environmental permitting costs, fees, or farmer time were expended in this project. Obtaining permits for air emissions involved partner support but no farmer time.

No water or stormwater permitting costs were associated with the project. The state issues a research permit for the project and did not have a cost.

3.4.3 Installation Costs

A ditch was dug for the pipe ductwork to delivery hot air to the two poultry houses. Farmer labor was not available.

There was no travel for permitting, vendor consultation, or to the regional Conservation District (no information was available for inclusion of these parameters, if applicable). No laboratory analyses costs were provided for ash or air sampling material.

3.4.4 Decommissioning Costs

Based on a cooperative agreement, dated December 17, 2013, between FPPC and Mr. Weaver, FPPC paid the farmer $12,000 for decommissioning of the equipment and hard infrastructure. This farm is the only host site with decommissioning data available.

3.4.5 Routine Operation and Maintenance Costs

(Includes regular maintenance when running smoothly.)

Regular maintenance data was not gathered to a large degree, given that the boiler, when running fairly routinely, was turned off during Flock 1, due to warmer weather and the size of birds (shut off after October 11, 2014). During Flock 1, the boiler ran 304 hours according to the FPPC data logger (farmer-logged hours indicated that the boiler ran 354 hours). Mr. Weaver's time was 32 hours and included tasks such as hopper feeding and boiler repair. The farmer hours were approximately 10 percent of the run-time hours.

Mr. Weaver cleans out the poultry houses between flocks. These activities do not change with burning litter in the manure-to-energy system. Per the farmer questionnaire, Mr. Weaver pays approximately $4,000 per house a year in ammonia treatment.

Mr. Weaver raises approximately seven flocks a year, with 14-day increments between flocks. Flock cycles typically run 38 days for 46,000 birds per house. Weaver removes cake litter between flocks. He does not totally clean out his houses. Each house has approximately 150 tons of litter. The remaining litter is stored in a shed beside the houses. Annual cost to replace bedding of wood shavings is about $4,000 a year.

Another operation and routine maintenance cost is to move litter into the shed for burning, using his front end loader. Mr. Weaver included that activity in his hours for 32 hours of Flock 1 and 22 hours during Flock 2, while the boiler was burning litter. There was no further breakdown of costs for this activity. The estimated farmer labor time from September 11 through December 1, 2014, was valued at $1,884 for 54 hours of farmer time at $34.89 per hour.

3.4.6 Run-times of Technology

The boiler ran for a portion of three flock cycles, as noted below.

- Flock 1, September 26 - October 11, 2014

  - During Flock 1, the system ran for a total of 304 out of 360 hours due to mechanical failures.
  - Farmer time to deal with the mechanical issues and routine hopper loader totaled 32 hours during flock 1, or roughly 10 percent of the run-time.
- Flock 2, November 16 - December 1, 2014.
  - During Flock 2, the boiler ran a total of 120 hours (per farmer log sheets) out of the 360 hours it was partially up, before being permanently turned off.
  - During Flock 2, farmer time was 22 hours or 18 percent of the run-time.
- Flock 3, January 11 - February 20, 2015.
  - During Flock 3, the boiler ran a total of 224.2 hours for House 1 and 228.2 hours for House 2, or an average of 226.2 hours during 960.

3.4.7 Fate of Manure (before and after manure-to energy technology)

Prior to burning litter as fuel for the boiler, some of the litter was applied to the land and some was sold. The amounts were not specified on the farm survey. No additional litter data was available.

3.4.8 Energy Costs

(Electricity and propane offsets listed during technology run-times.)

Mr. Weaver receives a stipend from the integrator for fuel. The amount received depends upon flock performance. Weaver uses liquid propane to fuel two houses, in addition to the heat generated from the manure-to-energy boiler. His current rate is $1.30/gallon. Mr. Weaver's annual fuel costs run $2,000 for the poultry houses. His poultry house has insulated walls and an insulated drop ceiling to maximize energy efficiency. His poultry house dimensions are 31,200 square feet each (624 feet by 50 feet). The brooding space is 312 feet by 50 feet or 15,600 square feet.

The manure-to-energy boiler did not run for a sufficient duration to affirm long-term propane savings. The boiler run-time was intermittent for three flock cycles. Also, most the heat was delivered during the early growth time for the flocks, when a curtain keeps the birds and heat at half-house conditions. Mr. Weaver noted that the half-house temperature difference is 3 degrees, while the full-house temperature difference is 5 degrees (email communication, August 24, 2015).

Air flow in the houses is managed by actuator controlled vents and exhaust fans set to run with average house temperature curves of Day 1: 86 degrees, Day 3: 84 degrees, Day 7: 82 degrees, Day 10: 79 degrees, and Day 14: 75 degrees, etc. The heated air from the boiler is pumped through underground ducts and enters the two houses.

Integrator Gas / Electricity Allowance as Income

The integrators pay an allowance for both gas and electricity based on average grower usage in the geographic area.

3.4.9 Weather Conditions

The on-farm use of propane for heating was reviewed in light of the weather patterns, based on the NOAA National Center for Environmental Information, with the statewide ranking of average temperature data reviewed monthly for West Virginia based on period of record (http://www.ncdc.noaa.gov/temp-and-precip/climatological-rankings/index.php?parameter=tavg&state=46&div=0&periods[]=1&month=2&year=2015#ranks-form). In general, in 2014, NOAA reported warmer than normal temperatures for October, much cooler than average temperatures during November, and temperatures near average during December of 2014. The NOAA database indicated average temperatures in January 2015, below average temperatures in February 2015, and much below average temperatures in March 2015. April and May 2015 were cooler than average.

3.4.10 Overall Farm Revenue

Mr. Weaver earns revenue from two flocks of 46,000 birds each, approximately seven times a year. He sells a small amount of manure. No other revenue was reported.

Mr. Weaver used approximately 554 gallons of propane to fire the furnace for both flocks (beginning in September and November 2014), with approximately 327 gallons of propane used on multiple re-fire start-ups during the week of November 16-23. He pays $1.36 per gallon of propane, so this amounts to $510 in propane for Flock 2 (November 11-23) and a total of more than $864 in two flocks.

3.5 Riverhill Farm

3.5.1 Farm Description

Riverhill Farm is located in Port Republic, Virginia. The owner, Glenn Rodes, grows about 280,000 turkeys per year in one turkey brooder and four grow-out houses. His costs include capital costs and air permitting. Due to a change in technology, no additional costs were tracked for this farm.

3.5.2 Infrastructure costs, Installation Costs, Permitting Costs

The equipment costs for Riverhill Farm represent capital costs for the manure-to-energy system originally in place, which are no longer at this farm. Therefore, the capital costs were not included for the heat delivery system. An LEI Bioburner eventually replaced the original system, in order to better combust the higher moisture content of turkey litter at Riverhill Farm, compared to broilers at the other host farms.

Riverhill Farm offers insight into air pollution permitting requirements. The host farm sites in PA and WV are free from air pollution permitting costs, to date. There was time provided by FPPC but no farmer time was estimated. Virginia offers a biomass test permit for air pollution compliance. No technology system to date has exceeded the test permit timeframe; therefore the permitting process is still unexplored for the long-term in Virginia. There was an air pollution research permit in WV, which did not have a cost.

4. Energy Assessments and Recommendations

4.1 Impacts on Energy Consumption and Costs from Manure-to-Energy Technology

The future success of manure-to-energy systems on individual farms primarily depends on a system's ability to compete economically with conventional forms of thermal and electrical energy. There are other potential benefits associated with manure-to-energy technology, including displaced manure transportation and management costs, and the sale of ash as nutrients; however, avoided energy costs are the factor that will determine whether or not on-farm manure-to-energy technology is feasible. Referencing the experience and energy records from farms participating in the manure-to-energy Farm Pilot Project, this section seeks to quantify the changes in energy use and costs resulting from the installation and operation of manure-to-energy systems on four of the five farms that participated in this project.

4.2 Overview of Poultry Farm Energy Use

In general, farms with the greatest energy use and greatest associated cost will have the most to gain by installing manure-to-energy systems and realizing avoided costs. It is critical to understand the baseline, pre-technology thermal and electrical energy load at a given farm in order to properly assess the feasibility of a manure-to-energy system in a specific setting. In the case of the Farm Manure-to-Energy Initiative, the installed systems delivered heat, not electricity. In turn, the focus of this financial analysis is on displaced costs for heat; however, there are also some notable changes to electricity consumption resulting from the switch to manure-based heat and its delivery and ventilation systems.

For these farms, the default heating fuel was propane. Its consumption was dependent on a number of factors. Table 1 characterizes each of these factors and the approximate relationship to the heat load, or the amount of heat and fuel needed to maintain poultry health.

Table 1. Factors influencing heat load and fuel consumption in poultry houses

Determining Factor	Description of Impact
Poultry type (chickens vs. turkeys)	Chickens (including broilers and layers) and turkeys have variable growth rates and heating needs. The longer the life cycle and the smaller the bird, the greater the heating loads.
Market type (conventional vs. organic)	Feed is used as a substitute for warmer temperatures when raising conventional chickens. Due to the high cost of organic feed, this relationship breaks down for organic birds, which requires higher temperatures and more fuel use. Warmer poultry results in higher weight. Organic birds are correlated with increased water consumption. These effects were not assessed.
Number and age of birds	Larger, densely packed birds put off their own heat. As birds age, the indoor temperature requirements will decrease.
Building size and conditions	Larger buildings require more fuel to heat the available space. Poorly insulated buildings will lose heat faster through leakage. Also, houses frequently operate at a fraction of their size (e.g., half-houses, ¾-houses) through the use of barriers that concentrate the heated bird area and reduce the heat load.
Outdoor Temperature, Delta Temperate	The difference between the outside temperature and indoor temperature, which varies based on the factors listed above, is the biggest driver of heat load. Fuel use peaks during the winter months.
Humidity and ventilation	Humidity, and its relationship to the creation of ammonia, is critical to poultry health and profitability. Ventilation is necessary despite the fact that it expedites heat loss and increases energy usage.
Heating system, fuel, and efficiency	The heating system (including the design, fuel, and efficiency of the system) meets the heat load as it cycles through seasons and flocks. More efficient systems use less fuel to meet that heating load. Fuel type has an indirect impact; for example, "wet fuel" requires more ventilation.

Electricity is used for lighting, ventilation (e.g., fans), pumps, feeding systems, and as source power for heating systems (i.e., parasitic load). Electricity use varies with the efficiency of these systems and, of course, over daily and seasonal cycles. Electricity use on poultry farms is highest in the summer when tunnel fans are used to cool houses.

Manure-to-energy systems are expected to impact electricity usage by 1) generating parasitic load associated with starting and operating the heating system, which puts upward pressure on electricity use, and 2) potentially changing cold weather ventilation rates. Manure-to-energy systems avoid the need to burn propane, which is typically uses in-house heaters. Propane releases moisture, carbon dioxide, and carbon monoxide when burned, thus increasing the need for ventilation. With manure-to-energy systems, thermal conversion of manure occurs outside of the poultry house and the system delivers either hot air or hot water, thus reducing in-house generation of undesirable propane emissions byproducts.

Some farmers with manure-to-energy systems may choose to reduce ventilation in the cold weather season. However, other farmers may choose to increase cold weather ventilation for improved air quality. This approach has been recommended by poultry ventilation experts to improve bird health and growth. In cold weather, growers with propane heating systems must balance house air quality with propane use, as increasing ventilation also increases propane use. Growers with manure-to-energy systems will have more flexibility to improve air quality through ventilation in the cold weather months.

Efficiency as an Initial Investment: Prior to investing in manure-to-energy technology, farmers would be wise to focus on improving the energy efficiency of their farm operations. High-efficiency variable speed fans, insulation, LED lights, drop ceilings, and regular maintenance of heating systems can result in immediate energy and cost savings with very little cost, thereby further improving heat delivery with a new manure-to-energy system. The potential for cost savings and other financial metrics associated with an investment in manure-based energy will be inflated if a farm hasn't first invested in basic energy efficiency.[1] Further, reducing the heat demand in a poultry house through energy efficiency may reduce the size of the manure-to-energy system needed, thus reducing the installation costs. Energy audits can help identify which improvements are cost effective.

4.3 Manure-to-Energy Farm Initiative Energy Records

One of the objectives of the Farm Manure-to-Energy Initiative was to closely track participating farms across an array of metrics to accurately account for the costs and benefits accruing from manure-to-energy technology. Propane and electricity usage (pre- and post-technology), flock cycles, bird health, bird production, system run-time, temperature, and humidity are the most important metrics in terms of quantifying and understanding changes in energy use and costs. Ideally, high-resolution propane and electricity usage records would be available for an extended period of time, both before and after the installation of a manure-to-energy system. This would allow for a more accurate assessment of changes in energy use and costs and, in turn, a more accurate financial assessment.

[1] Czarick, M. 2009. *Reducing Poultry House Power Usage*. Presentation from the University of Georgia. https://www.poultryventilation.com/sites/default/files/presentations/power.pdf.

Table 2. Overview of energy records by farm

Farmer Name	Description of Available Propane Data
Mark Rohrer Farm	The Mark Rohrer Farm has metered data for the period from September 2014 through January 2015, along with detailed settlement sheets corresponding to two flocks produced during that period. The metered data corresponds to one house with manure-to-energy technology and one house without.
Windview Farm	Windview Farm has four propane tanks for two poultry houses. Available records from December 2011 though June 2015 indicate when the tanks were filled and the amount delivered.
Farm B	Farm B farm has 4 houses and a meter on each house for the period from December 2014 through May 2015.
Mike Weaver Farm	The Mike Weaver Farm has invoices for purchased propane for September 2014, December 2014, and January 2015. The rate of propane usage is unknown.

As Table 2 suggests, there are data gaps in the number of records over time, issues with data resolution, and uncertainty about how to account for changes in propane usage. For example, Windview Farm receives 5-7 deliveries of propane per year, which is pumped into tanks and used as needed to produce heat. There is no meter available to provide hourly, daily, or monthly estimates of propane use. Higher resolution propane data (i.e., propane use per day) enables tighter tracking and correlation to the factors driving propane use, including temperature, ventilation patterns, bird count, flock age, etc. By establishing the correlation between propane use and these factors driving propane use, it then becomes possible to attribute changes in propane consumption to either 1) manure-to-energy technology or 2) other factors that might be consider "noise."

There is some empirical evidence that manure-to-energy systems displace propane costs. Again, Windview Farm serves as a good example, as it has one of the few systems that ran consistently for more than two years. The farm had a manure-to-energy heating system that was installed in 2011 and ran until May 2014, when it was destroyed in an electrical fire. During its period of operation, Mr. Curtis had 3,717 gallons of propane delivered in 2012 and 5,262 gallons of propane delivered in 2013. In the fall and early winter of 2014, when the system wasn't available, 8,988 gallons of propane were delivered — a 70 percent increase compared to 2013. Also of note, Mr. Curtis received a gas allowance from his integrator totaling $41,100 in 2012, but only purchased $5,559 worth of gas. The difference between the allowance and the actual amount paid for gas, on the surface, suggests that the farm was using far less propane than would have been the case had the manure-to-energy system not been operational.

This and other anecdotes from farmers suggest the potential for manure-to-energy technology to displace propane costs. However, this is not a robust analysis of manure-based energy and its impact on costs. The remainder of this section focuses on overcoming the data gaps in energy records and using calibrated models to estimate the impact of manure-to-energy technology on energy use and costs.

4.4 Modeling Energy Use Across Manure-to-Energy Farms

A rudimentary model, based on primarily Mark Rohrer Farm data, was developed to overcome data gaps and provide a range of typical working assumptions. Data from the Rohrer Farm serves as a template for the model and contains details on the sub-modules summarized herein and is in the spreadsheet in Appendix A. It is important to note that the modeling exercise presented in this energy assessment is more detailed than commonly performed with sparse data; however, it demonstrates the level of assessment and predictions possible, given more comprehensive database for consideration in future assessments.

The purpose of the model is to create scenarios based on pre- and post- technology efficiency using variable run-times (40 and 95 percent run-times) to predict estimated energy savings. For the purposes of this report, the model is termed the On-Farm Propane and Manure-to-Energy Model. The objective of the On-Farm Propane and Manure-to-Energy Model is to estimate daily propane and electricity use as it relates to a period of past poultry production, to customize characteristics unique to specific farms, and to quantify changes in propane and electricity use resulting from the installation of a manure-to-energy system. The model enables direct comparison of energy patterns pre- and post-installation of a manure-to-energy system, and will summarize daily results across an entire year for long-term fiscal analysis. The model was developed in two phases: 1) estimate of daily energy use based on available data and testable assumptions, and 2) model calibration with actual propane and electricity data. The model, described in greater detail below, can be modified across different farms or as assumptions breakdown.

4.4.1 Temperature Differential (sub-module)

1. Collect data related to historic poultry production via settlement sheets including when flocks were placed and removed, the type of birds being raised (e.g., conventional broilers), and the number of birds placed.
2. Referencing the nearest airport weather station to each farm, pull daily minimum and average temperatures for each station.
3. Estimate the daily indoor temperature requirement based on the age and types of birds under the following assumptions:
    a. Default house temperature (no birds) = 65^0 F
    b. Organic poultry operation (weight factor) = $+12^0$ F (varies with calibration)
    c. Conventional poultry operation (weight factor) = -8^0 F (varies with calibration)

   d. Bird age < 7 days = 90^0 F, <14 days = 85^0 F, <21 days = 80^0 F, < 28 days = 75^0 F, <35 = 70^0 F, >35 = 65^0 F[2]

4. Note: The weight factor corrects for the higher fuel requirements (due to increased ventilation) of organic poultry relative to conventional. Also, the declining temperature requirements relative to bird age imply that the thermal output of birds (based on the number of birds) is correct (e.g., many birds at the end of a flock put off significant heat, and the barn doesn't need to be heated to as high a temperature).
5. Calculate the temperature differential based on the *minimum* daily temperature and the indoor temperature (see #3 above).

4.4.2 Ventilation and Heat Loss (sub-module)

1. Estimate average volume throughput of air (cubic feet per minute, CFM) based on bird age where average airflow (CFM) = 530 * flock age (days).[3]
2. Approximate hours of fan run-time per day based on assumption that peak estimated airflow of 25,440 CFM equates to approximately 24 hours of fan run-time. Hours of fan run-time are used to estimate electricity usage.
3. Insert dummy variable to correct for dryer heat produced when manure-to-energy combustion system is installed. If the system is installed, volume of air (CFM) is reduced by 15 percent (testable assumption).
4. Calculate heat loss from ventilation (BTUs/hr) = temperature differential (See temperature differential sub-module) * volume throughput * heat loss constant (1.08).

4.4.3 Total Heat Load and Loss (sub-module)

1. Estimate heat loss from floor = (square footage of floor * temperature differential) / insulation (R-value) of floor.
   a. Default R value of floor = .8
2. Estimate heat loss from ceiling = (square footage of ceiling * temperature differential) / insulation (R-value) of ceiling.
   a. Default R value of ceilings = 2
3. Estimate heat loss from walls = (square footage of walls * temperature differential) / insulation (R-value) of walls.
   a. Default R value of wall = 2
4. Calculate daily heat load (BTUs per day) = sum of items 1-3 above *plus* heat loss from ventilation (see ventilation and heat loss sub-module).

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[2] Relationship between bird age and indoor temperature and ventilation requirements derived from University of Georgia Winter Ventilation and Heating Tool.

[3] Ibid.

4.4.5 Propane Use (sub-module)

1. Daily propane use (BTUs) = daily heat load (See the heat load and loss sub-module) * 2 – efficiency of the existing heating system (e.g., boiler).
    a. Default is 80 percent efficiency boiler, meaning 10 BTU of heat load output requires 12 BTU of propane input.

4.4.6 Manure-to-Energy System Propane Impact (sub-module)

1. Estimate heat output from manure-to-energy system. Heat output = system capacity or size (BTUs/hr) * system efficiency * hours of daily operation (correcting for downtime to fill hopper).
2. Correct for annual maintenance and repair by assuming that every day of the year there is a given probability that the system is unavailable to operate.
    a. Default for a high performing system is a 5 percent probability that the system is down on any given day.
    b. Default for an intermittently operating manure-to-energy system (i.e., similar to the new Farm Pilot Project systems) is a 60-percent probability that the system is down on any given day.
3. Calculate net propane use. Propane use = heat load in poultry barn minus heat output from the manure-to-energy system. Assumes propane is used to make up shortfall in what manure-to-energy system is able to provide on a given day.

4.4.7 Electricity Use (sub-module)

1. Electricity use is estimated under the pre-technology, baseline scenario and the post-technology scenario. Only electricity used to operate the fans for ventilation and the electricity associated with parasitic load from the manure-to-energy technology is accounted for. All other end uses of electricity are assumed to remain unchanged with the introduction of a manure-to-energy system.
2. Electricity use from fans (kWh) = the number of fans * the wattage of each fan * hours of operation/ day (See # 2 under ventilation and heat loss).
    a. Default assumption is 8 fans at 150 Watts each.
3. Electricity use from parasitic load (kWh) is first derived by estimating hours of operating run time per day = heat output on a given day (see Manure-to-Energy System Propane Impact sub-module) / (system capacity * efficiency).
4. Total daily parasitic load = hours of run time * power load (Watts) of manure-to-energy system.
    a. Default assumption is 5,000-Watt power load for manure-to-energy system.

4.4.8 Model Calibration with On-Farm Energy Records

The On-Farm Propane and Manure-to-Energy Model assumptions and output can be modified on a case-by-case, farm-by-farm basis by calibrating the model results against actual on-farm energy records. The Rohrer Farm was used as the template for creating the model because it lent itself to calibration. (The Rohrer data template is provided in a spreadsheet in Appendix A.) For example, the Rohrer Farm has weekly propane meter readings and parallel bird production data. The Rohrer Farm also has the unique characteristic of having two nearly identical barns, one with a manure-to-energy system and one without. This makes a side-by-side comparison possible.

The calibration process is one of minimizing the difference between modeled results and actual energy records. The final calibrated model for the Rohrer Farm (Figure 1, Table 4) highlights the difference between the model and actual energy records.

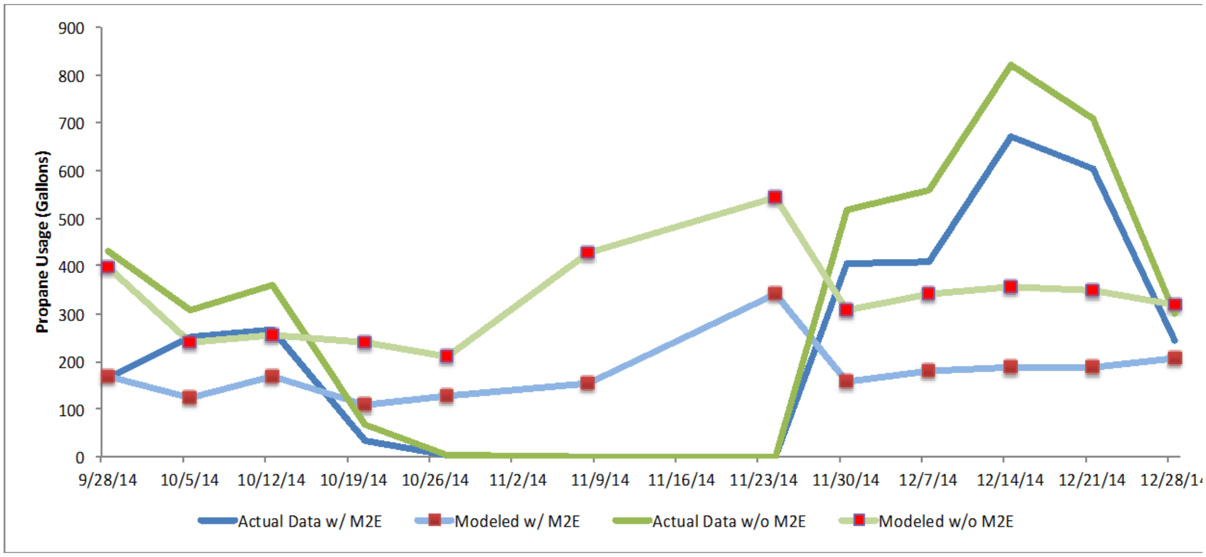

Figure 1. Modeled and actual propane use at Rohrer farm, with and without a manure-to-energy system

Table 4. Gallons of propane used, actual vs. modeled, with and without a manure-to-energy system

	Actual Data With Manure-to-Energy	Modeled With Manure-to-Energy	% Diff. With Manure-to-Energy	Actual Data Without Manure-to-Energy	Modeled Without Manure-to-Energy	% Diff. Without Manure-to-Energy
Flock 1	720.0	884.9	22.9%	1,173.2	1,775.8	51.4%
Flock 2	2,329.7	768.8	-67.0%	2,910.8	2,220.8	-23.7%
Sum	3,049.7	1,653.7	-45.8%	4,084.0	3,996.6	-2.1%

Model calibration works by adjusting the assumptions above so that the modeled energy consumption creates a better fit with actual energy records. For example, by adjusting the boiler efficiency, the R-value of insulation, the indoor temperature profile via the weighted factors for organic and conventional chickens, or any other number other factors, one can align the modeled energy use with actual energy records. In the case of the

Rohrer Farm, there is only a two-flock period of time where the settlement sheet and propane usage records align; therefore, this is the period against which the model is calibrated (Flock 1 between September 18 and November 8, 2014; Flock 2 between November 24 and January 2015). Granted, it is a relatively small sample size and there is a low degree of confidence around the model. The model can be further refined and calibrated with the aid of more high-resolution energy records, more time, and the inclusion of more variables.

4.5 Farm-Specific Assumptions and Results

The inputs, assumptions, and results of the model for all farms are presented below in Tables 5a and 5b. The first half of the table highlights the assumptions/available data that were input to each farm. These inputs drive the output in terms of propane and electricity used under different scenarios. There are three scenarios compared in the analysis below:

1) The "pre-manure-to-energy" scenario reflects the propane and electricity used prior to the installation of the manure-to-energy system. Propane use is expected to be higher than the post-manure-to-energy scenarios, but electricity use is lower in the pre-manure-to-energy scenario because there is no parasitic load from the manure-to-energy system.

- Note: Electricity totals under all scenarios include only electricity used to operate fans and the manure-to-energy system. They exclude other sources of electricity use, including lights, because these are assumed to be unchanged between the pre- and post-technology scenarios.

2) The "post-manure-to-energy intermittent" performance scenario reflects the propane and electricity used after the installation of the manure-to-energy system, but assumes that the manure-to-energy system has a 40 percent chance of being available on any given day due to frequent system repairs and troubleshooting.

- Note: The 40 percent figure comes from the Rohrer Farm during the second flock of manure-to-energy operation (November 24, 2014 through January 8, 2015), when the system ran about 40 percent of the time.

3) The "post-manure-to-energy high performance" scenario reflects the propane and electricity used after the installation of the manure-to-energy system and assumes that the system has a 95 percent chance of being available any given day.

Table 5a. Inputs and assumptions for Rohrer, Curtis, Farmer B, and Weaver Farms

	Global Re-Fuel at the Rohrer Farm (2014 Reference Year)	Blue Flame Boiler at Windview Farm* (2013 Reference Year)	Ecoremedy Gasifier at Farm B (2014 Reference Year)	Global Re-Fuel at the Weaver Farm (FY 15 Reference Year)
Poultry house size (gross square feet)	24,000	30,000	32,400	31,200 * .5 based on half-house = 15,600
Insulation (R-value)	Floor = .8; Ceiling = 2; Walls = 2	Floor = .8; Ceiling = 2; Walls = 2	Floor = 1.2; Ceiling = 4; Walls = 3	Floor = 1.2; Ceiling = 4; Walls = 3
Bird type + temperature weight	Organic (+12° F when flock in production)	Conventional (-8° F when flock in production)	Organic (+12° F when flock in production)	Conventional (-8 ° F when flock in production)
Number of flocks per year, average length	6.5 flocks, average of 47 days to maturity	6.5 flocks, average of 48.5 days to maturity	6-7 flocks per year	7 flocks, average 38 days to maturity
Sum temperature differences (indoor-outdoor), sum of daily min temperature (degrees Fahrenheit)	15,915 (15,190)	9,400 (15,007)	15,915 (15,190)	10,008 (14,082)
Propane boiler efficiency	70%	70%	88%	88%
Manure-to-energy capacity (BTUs/Hr)	500,000	135,000	132,000	500,000
Manure-to-energy system efficiency	85%	75%	85%	85%
Manure-to-energy power load (Watts)	5,450	1,000	10,000	5,450
Probability manure-to-energy is available on any given day	40% chance (intermittent scenario); 95% chance (high performance scenario)	40% chance (intermittent scenario); 95% chance (high performance scenario)	40% chance (intermittent scenario); 95% chance (high performance scenario)	40% chance (intermittent scenario); 95% chance (high performance scenario)
Number of fans, annual operating hours	8 fans, 3,061 hours	8 fans, 3,531 hours	12 fans, 3,061 hours	12 fans, 2,365 hours
Propane cost ($/Gallon)	1.6	1.2	1.2	1.06
Electricity cost ($/kWh)	0.12	0.104	0.12	0.12

*Note: There is no evidence to suggest that Windview Farm experienced technical problems that would result in intermittent performance.

Table 5b. Modeled energy usage and cost results for Rohrer, Curtis, Farmer B, and Weaver Farms

	Global Re-Fuel at the Rohrer Farm (2014 Reference Year)	Blue Flame Boiler at Windview Farm* (2013 Reference Year)	Ecoremedy Gasifier at Farm B (2014 Reference Year)	Global Re-Fuel at the Weaver Farm (FY 15 Reference Year)
Results – Propane Only				
Pre-manure-to-energy propane usage (gallons/year) @ cost ($)	12,942.6 @ $20,449.3	9,202.5 @ $11,227.1	9366.1 @ $11,239.4	3137.5 @ $3,521.9
Post-manure-to-energy propane usage (gallons/year) @ cost ($) Intermittent scenario	6,023.1 @ $9,516.5	4,904.2 @ $5,983.1	5,344.3 @ $6,413.2	1,860.7 @ $1,975.4
Post-manure-to-energy propane usage (gallons/year) @ cost ($) High performance scenario	474.9 @ $750.4	2,485.1 @ $2,982.1	1,140.2 @ $1,368.2	100.5 @ $106.7
Annual propane savings ($) % difference – intermittent scenario relative to pre-manure-to-energy	-$10,932.5 53% cost reduction	-$8,245.0 73% cost reduction	$4,826.2 43% cost reduction	$1,546.5 43% cost reduction
Results – Electricity Only				
Pre-manure-to-energy electricity usage (kWh/year) @ cost ($)	3,672 @ $440.7	4,237.5 @ $440.7	5,508.4 @ $661	4,258.3 @ $511.0
Post-manure-to-energy electricity usage (kWh/year) @ cost ($) Intermittent scenario	5,581 @ 669.7	6,140.2 @ $638.6	45,089.5 @ $5,410.7	3,696.3 @ $443.6
Post-manure-to-energy electricity usage (kWh/year) @ cost ($) High performance scenario	14,448 @ 1,733.8	7,584.8 @ $788.8	61,305.6 @ $7,356.7	4,140.6 @ $496.9
Annual electricity increase ($) % difference – intermittent scenario relative to pre-manure-to-energy	+ $229 52% cost increase	+$198 45% cost increase	+$4,749.7 700% cost increase	-$14.1 3% cost reduction
Results – All Energy (Propane + Electricity)				
Pre-manure-to-energy total energy cost ($)	$20,890.0	$11,667.8	$11,900.40	$4,032.9
Post-manure-to-energy total energy cost ($) Intermittent scenario	$10,186.2	$6,621.7	$11,823.90	$2,418.9
Post-manure-to-energy total energy cost ($) High performance scenario	$2,484.2	$3,770.9	$8,724.90	$603.5
Annual energy savings ($) % difference – intermittent scenario relative to pre-manure-to-energy	-$10,703.8 52% cost reduction	-$5,046.1 43% cost reduction	$76.50 <1% cost reduction	$1,614.0 40% cost reduction

*Note: There is no evidence to suggest that Windview Farm experienced technical problems that would result in intermittent performance.

4.6 Sensitivity Analysis

The energy modeling results suggest there are important differences across farms in terms of potential for energy and cost savings. What level of energy savings should a farmer expect given the characteristics of his or her farm? What types of farms should policymakers and vendors target as the most likely to find manure-to-energy technology cost effective? Should farm characteristics dictate how manure-to-energy technology is designed or how a particular incentive program is implemented?

To answer these questions, it is important that individual farm characteristics be isolated and examined for their ability to influence energy outcomes. This section seeks to identify those key farm characteristics most likely to indicate significant energy savings as a result of manure-to-energy technology. To be sure, evaluating only energy outcomes is imprudent because manure-to-energy technology can influence a wide range of important outcomes, including bird health, production, manure management costs, and potential new revenue streams (e.g., ash or biochar co-products).

This section relies on sensitivity analysis to quantify and rank different farm characteristics for their ability to influence energy outcomes. Sensitivity analysis adjusts the value of individual variables incrementally while holding all other variables constant. The analysis focuses on the Rohrer Farm because it provided the most detailed data and yielded what we believe to be the most accurate model of energy use and costs relative to actual data.

4.6.1 Insulation

- *Findings*: A 25 percent increase in the R-value of poultry house insulation results in 10,518 gallons of propane saved per year under the post-manure-to-energy high performance scenario. The default R-values result in 12,468 gallons of propane saved per year under the post-manure-to-energy high performance scenario. **The 25 percent increase in R-value results in an 18.5 percent decrease in the amount of propane saved from the manure-to-energy facility**.
- *Discussion*: Farmers starting with a better insulated poultry house, with all other factors being constant, will have save less propane by switching to manure-to-energy. As a rule of thumb in nearly all sectors of the economy, energy efficiency is more cost effective than switching to renewable sources of energy. Energy efficiency investments targeting fans, lighting, and insulation, provided they don't impact bird health or performance, should be prioritized before manure-to-energy investments. Farmers and policymakers should be cautious of inflated propane saving projections simply because starting conditions are a poorly insulated poultry house.

4.6.2 Propane Efficiency from Existing Heating System

- *Findings*: A 25 percent increase in the baseline conditions of the boiler efficiency (87.5%) results in 10,706 gallons of propane saved per year under the post-manure-to-energy high performance scenario. The default boiler efficiency (70%) results in 12,468 gallons of propane saved per year under the post-manure-to-energy high performance scenario. **The 25 percent increase in boiler efficiency results in a 16.5 percent decrease in the amount of propane saved from the manure-to-energy system**.
- *Discussion*: Starting conditions are critical to understanding the potential for energy savings associated with manure-to-energy technology. The efficiency of a farm's existing heating system is no exception. Farms with older, inefficient heating systems (e.g., boilers, furnaces) appear to have more to gain from installing a manure-to-energy heating system relative to a farm with a newer, high-efficiency heating system. For farms that can rely entirely on manure-to-energy systems for their heating needs, the efficiency of the existing system becomes less important because of the complete fuel switch.

  However, for farms that will require supplemental heat from propane, it is important to understand the alternative investment of purchasing a new high-efficiency boiler. Either way, by assuming existing propane heating systems will be properly maintained or replaced regularly to ensure optimal efficiency, energy savings over the life of a project will be more conservative.

4.6.3 Bird Type, Temperature, and Heat Demand

- *Findings*[4]: By switching the temperature weight on the Mark Rohrer Farm from +12^0 F, representing an organic bird environment, to -8^0 F, which represents a conventional bird environment, there is a drastic change in heat demand and energy use. The organic bird temperature setting results in 12,468 gallons of propane saved per year under the post-manure-to-energy high performance scenario. In contrast, the conventional bird temperature setting results in 7,046 gallons of propane saved per year under the post-manure-to-energy high performance scenario. **The switch from organic to conventional birds results in a 77 percent decrease in the amount of propane saved from the manure-to-energy system**.
- *Discussion*: While there is significant uncertainty around the temperature weight given to organic and conventional birds (a topic that should be further tested in future studies), the results yield an anticipated outcome. All

[4] During the model calibration process, a weight was placed on the indoor temperature requirements whereby organic birds required +12^0 F of heat. In contrast, conventional birds required -8^0 F of indoor heat. This temperature setting reflects the fact that organic birds are kept in warmer environments (because it is less expensive than feeding) and are less densely housed. The weights were calibrated to align the Rohrer Farm and Windview Farm, respectively, and actual energy usage data.

else being equal, organic poultry operations consume more propane than conventional poultry operations because of the premium cost on organic feed and the fact that food and heat are close substitutes. A related finding is that colder climates require more heating, and it would stand to reason that poultry operations in these environments have more to gain in energy savings from manure-to-energy heating systems than peer farms in warmer climates.

4.6.4 Manure-to-Energy System Capacity

- *Findings*: A 75 percent decrease in the capacity of the manure-to-energy system (125,000 BTUs per hour) (BTUs/hr) results in 10,596 gallons of propane saved per year under the post-manure-to-energy high performance scenario. The default capacity of the manure-to-energy system (500,000 BTUs/hr) results in 12,468 gallons of propane saved per year under the post-manure-to-energy high performance scenario. **The 75 percent decrease in manure-to-energy capacity yields an 18 percent decrease in the amount of propane saved from the manure-to-energy system**.
- *Discussion*: The manure-to-energy system at the Mark Rohrer Farm was sized for two poultry houses and rated for 500,000 BTUs/hr. Mike Czarick, University of Georgia's poultry ventilation expert, describes the importance of ventilation in poultry houses, which is completely different than commercial building heating models.

  For the purposes of the model, the maximum heating demand over the entire year is 5.188 million BTUs per day or about 216,208 BTUs per hour on average. The Global Re-Fuel system at the Mark Rohrer Farm is 500,000 BTUs/hr, which is acknowledged in the model. This system serves two poultry houses totaling 48,000 gross square feet of space; however, the model is designed to recognize heat demand from one house. If the only space to be heated were the size of one poultry house, 250,000 BTUs/hr of capacity would suffice, factoring in ventilation and heat loss. Therefore, it is likely one needs 500,000 BTUs/hr of capacity to heat both houses.

4.6.5 Other Factors Warranting Further Exploration

- *Parasitic load from the manure-to-energy system:* In a high-performing system, the parasitic load of manure-to-energy systems should be closely correlated to the heat output of the system. On the farms where the technology is still being vetted, the heat output varied more than would be expected by the parasitic load as a result of litter moisture, technology efficiency, heat distribution system, and other factors. For example, a wetter litter results in reduced heat output. For some farms, the parasitic load was so significant that the electricity costs nullified any propane savings. Parasitic load associated with manure-to-energy systems is critical.

- *Electricity generation from manure-to-energy systems and/or other on-site systems*: Connected to the discussion on parasitic load, it is important to consider whether the manure-to-energy system generates electricity or, as in the case of Farm B and the Mark Rohrer Farm , there is on-site capacity for renewable electricity. If a farmer has access on-site renewable electricity and little or no cost, the impact of parasitic load electricity costs is diminished. Farms with on-site capacity to generate electricity will not experience the same changes in electricity costs as their peer farms without on-site generation capacity.

7. Summary

The EFC, as part of a coalition investigating the use of innovative technologies that produce energy from the conversion of poultry litter, prepared a cost balance summary and financial assessment. The purpose of the Farm Manure-to-Energy Initiative was to evaluate the effectiveness and performance of thermal technologies that use excess poultry litter (comprised of manure, bedding, and feathers) to produce electricity or heat for poultry housing on farms located within high-density animal production areas of the Chesapeake Bay watershed. The evaluation included technical and environmental performance of the systems, their potential for future use, and market opportunities (current and future) for both the energy generated and the nutrient-rich ash and biochar co-products. The experiences of these farms show that implementing these technologies is still a challenge. Learning curves in design, installation, and operation are often substantial, pointing to the importance of services provided by the public sector in the wider adoption of this technology.

Additionally, the unique circumstances of each of these farms raise questions about the ease and potential for using their varied experiences to construct meaningful cost ranges (capital and operational) that indicate financial impacts of the technology on a farm’s bottom line. At the same time, these experiences illustrate the willingness of farmers to test new technologies with the potential to generate positive environmental and economic impacts.

It is important to note that even when technical issues resulted in failure of the thermal technologies in delivering heat or electricity throughout an entire flock cycle, there were periods of successful energy production that reduced the use of propane for heating the poultry houses. While the data 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.

However, based on the ROI for some technologies, energy production alone will likely be insufficient to justify widespread adoption of manure-to-energy technologies from a financial standpoint. It is more likely that a combination of factors, including reduced energy costs, reduced need for nutrient pollution controls, and the added income from concentrated, lightweight ash co-product (once markets are established) will together move these technologies toward commercialization.

7.1 Return on Investment

Below are results of a return-on-investment (ROI) analysis that focused purely on infrastructure, capital costs, and energy savings.

Table 6. Return on Investment of Capital Costs by Energy Savings including comparison to present value (PV).

	Blue Flame Boiler at Windview Farm	Ecoremedy Gasfier at Farm B	Global Re-Fuel at the Rohrer Farm	Global Re-Fuel at the Weaver Farm
Cost				
Infrastructure Costs	$157,900	$957,987	$303,010	$297,647
Savings				
Electricity	-$198	-$4,749	-$229	$14
Gas	$8,245	$4,826	$10,932	$1,546
Annual Energy	$8,047	$77	$10,703	$1,560
PV (3%, 15 years)	$77,481	$741	$103,054	$15,020
PV (3%, 10 years)	$59,878	$573	$79,641	$11,608
Return on Investment				
15 years	0.49	0.00	0.34	0.05
10 years	0.38	0.00	0.26	0.04

Note: The reported capital costs in the table above may be higher than actual costs; however, no ROI shift would be anticipated unless there was a corresponding change in the energy savings.

The table above provides one way of measuring the ROI of the manure-to-energy technology. The ROI is the ratio of energy savings to capital investment and helps describe the extent to which the energy savings can offset the equipment costs over the operating life span of the technology. In the table above, the capital investment is not estimated to account for all costs of design and installation. It uses only infrastructure costs and excludes the cost of labor provided by the farmer and technical service providers. The ratio of labor costs to infrastructure costs ranged across the farms. It also assumes that the infrastructure costs were not financed but occurred as an up-front, lump-sum cost.

The return from this technology is based on the energy savings. The energy savings is the annual net of the change in electricity and gas. As demonstrated in this project, the manure-to-energy technology often significantly reduces gas costs, but tends to slightly increase the electricity costs. The savings are calculated as a net present value (NPV), which is the discounted stream of energy expenditure change aggregated over the operating life span of the technology. For illustrative purposes, the analysis conservatively assumes that the technology will operate for 10 or 15 years and uses a 3 percent discount rate. (As the discount rate rises, the NPV will fall.)

The table reports ROI over 10-year and 15-year time periods. Comparison of the ROI for 10 years versus 15 years illustrates how lengthening the operating life of the technology improves the ROI. Two of the farms have no ROI based on energy savings. However, the ROIs for Windview Farm and the Mark Rohrer Farm suggest that each dollar spent on the infrastructure generates between $0.34 and $0.49 in savings for a 15-year life of technology. With this basis for the ROI, it will improve as energy (gas) costs increase.

Another way to view the ROI is that the operational life of the technology would have to more than double in order for the energy savings alone to pay off the hard infrastructure capital costs. The results demonstrate why it is so critical that future analyses consider the multiplicity of benefits to gain a broader picture. The EFC recommends that, in the future, ROI analyses focus on flock health, whole-farm operations, and the social and environmental benefits gained from implementing manure-to-energy technology. For this reason, it is important not to focus on the value of co-products (ash and biochar) alone, and instead look at what the manure-to-energy technology does for farm operations and the greater community (which affects the role of public cost-share dollars).

It is important to note that these ROI calculations were based on short durations of the technology performing at four of the five the host farms. The assessment is based on the intermittent scenario of propane and electricity usage when the manure-to-energy technology is delivering heat 40 percent of the time on any given day. Obviously, under other scenarios where the technology is delivering heat for longer durations, the ROI will be better. Given technology performance of 40 percent of the time, Windview Farm and the Mark Rohrer Farm offer some return on the dollar invested. With the newly installed Blue Flame Boiler on Windview Farm, it is reasonable to assume that the ROI will be even more favorable in the upcoming cold months, based on the increased size (an improved match to litter generated) and improved heat delivery system.

This assessment is based on capital investment only and did not include integrator gas or electricity allowances, which are a significant source of income. For example, between 2012 and 2014, Windview Farm received a propane stipend from the integrator totaling over $117,000, far below actual propane bills. The income earned for propane and electricity will greatly impact the ROI. This calculation does not include farmer time, which can also influence the ROI. Farmer time varies for the intensive effort during the initial year and is presumed to level off after the learning curve. In summary, the ROI would change as one adds in more costs (debt if financed, labor, permitting, maintenance, and parts) and benefits (co-product value, deferred manure management costs, etc.).

7.2 Other Next Steps for Consideration

A reasonable next step is to create a tool (based on a model) that a farmer can use to plug in his or her farm data and determined if a specific manure-to-energy technology is feasible for their farm operation. This tool could analyze the amount of litter generated, insulation of poultry houses, energy bills, and policy drivers based on locations (such as net metering regulations, air quality permits, etc.) and discern anticipated farmer investments (in cost and time) and cost-share options for implementing the technology. The model could be created so that it could estimate the number of days it would need to run during cold weather for the farmer to break even, which technology vendors provide suitable systems, and other ROI influences such as market values for co-products (or if associations are available to help market the co-products).

In general, the technology appears promising and is expected to improve over time. The ROI highlights the importance of the role of public benefits. Other factors that need to be looked at more closely include: farmer time with consistent data to track and report time; quantification and influence of parasitic energy loads to run the systems; energy allowances form integrators (gas and electricity stipends as incomes and the likelihood of that continuing in the future); net metering and other offsets if electricity is generated; greenhouse gas credits such as those in the agricultural European market; and pay for performance income through which farmers are paid in accordance with science-based outcomes if that becomes a factor in the future.

Future financial assessments should also include the potential value of the ash and biochar co-products. Mark S. Reiter, Ph.D., a crop and fertility specialist with the Eastern Shore Agricultural Research and Extension Center of Virginia Tech, evaluated poultry litter and poultry litter ash in terms of market prices (see Appendix F of the final report). Based on a series of field trials, his research suggests that poultry ash may have some promise as a fertilizer even when taking into account variability in fertilizer prices and nutrient values over time. His research identified a wide range in the theoretical value of poultry fly ash ($299 to $463 per ton) based on 5-year average nitrogen, phosphorus, and potash commercial fertilizer prices. As a point of comparison, poultry litter is being given away or sold for up to $20 per ton (off the farm). In the event future market assessments indicate a lack of targeted users, the full disposal costs, including transporting and tipping fees of a landfill or monofill, should be included under the $0 per ton value scenario.

It is important to note that an extensive amount of market development and infrastructure is needed to support the emergence of poultry litter ash as a revenue-generating co-product for farmers. For example, it would be useful to explore the target amount of ash that could be produced with enough regularity to support a large, cost-effective market. Also, the basis for the nutrient value might include additional field trials and laboratory analysis on a larger composition of ash samples from multiple poultry litter farms, with ash produced under consistent litter combustion rates. Future market analysis needs to consider the potential end-market value, as well as marketing, packaging, and transportation costs to determine if sale of the ash has the potential to generate revenue compared to sale of untreated poultry litter.

Other factors for future consideration are as follows:

- Future modeling of financial performance of the manure-to-energy technology should account for loss of revenue from manure that was used as fuel instead of sold off-farm.
- Future implementation of manure-to-energy technology needs to consider whether or not integrators may lower the gas allowance and thereby null the propane savings.
- Decommissioning costs are an important factor that should be included in a full life cycle analysis of costs. Only the Mike Weaver Farm offered decommissioning data, based on a contractual agreement.

7.3 Energy Assessment Summary

Propane and electricity usage (pre- and post-technology), flock cycles, bird health, bird production, system run-time, temperature, and humidity are the most important metrics in terms of quantifying and understanding changes in energy use and costs. Ideally, high-resolution records of propane and electricity usage would be available for an extended period of time, both before and after the installation of a manure-to-energy system. This would allow for a more accurate assessment of changes in energy use and costs and, in turn, a more accurate financial assessment.

There is some empirical evidence that manure-to-energy systems displace propane costs. Again, Windview Farm serves as a good example, as it has one of the few systems that ran consistently for more than two years.

Due to data gaps in propane offsets from other farms, a model was developed using Rohrer farm data. The model offers ways to overcome the data gaps in energy records to estimate the impact of manure-to-energy technology on energy use and costs. The rudimentary model was developed to provide a range of typical working assumptions using the Rohrer farm as a template. The model contains sub-modules and is detailed in Appendix A. It is important to note that the modeling exercise presented in this energy assessment is more detailed than commonly performed with sparse data; however, it demonstrates the level of assessment and predictions possible, given more comprehensive database for consideration in future assessments.

The purpose of the model is to create scenarios based on pre- and post-technology efficiency using variable run-times (40 and 95 percent run-times) to predict estimated energy savings.

Model calibration works by adjusting the assumptions above so that the modeled energy consumption creates a better fit with actual energy records. For example, by adjusting the boiler efficiency, the R-value of insulation, the indoor temperature profile via the weighted factors for organic and conventional chickens, or any other number other factors, one can align the modeled energy use with actual energy records. In the case of the Mark Rohrer Farm, there is only a two-flock period of time where the settlement sheet and propane usage records align; therefore, this is the period against which the model is calibrated (Flock 1 between September 18 and November 8, 2014; Flock 2 between November 24 and January 2015). Granted, it is a relatively small sample size and there is a low degree of confidence around the model. The model can be further refined and calibrated with the aid of more high-resolution energy records, more time, and the inclusion of more variables.

7.4 Farm-Specific Assumptions and Results

Table 4 below displays propane use with and without the technology for actual and theoretical farms.

Table 4. Gallons of propane used, actual vs. modeled, with and without a Global Re-Fuel manure-to-energy system at actual and theoretical farms

	Actual Data with Manure-to-Energy	Modeled with Manure-to-Energy	% Diff. with Manure-to-Energy	Actual Data without Manure-to-Energy	Modeled without Manure-to-Energy	% Diff. without Manure-to-Energy
Flock 1	720.0	884.9	22.9%	1,173.2	1,775.8	51.4%
Flock 2	2,329.7	768.8	-67.0%	2,910.8	2,220.8	-23.7%
Sum	3,049.7	1,653.7	-45.8%	4,084.0	3,996.6	-2.1%

The model calibration adjusts the assumptions such that the modeled energy consumption creates a better fit with actual energy records. For example, by adjusting the boiler efficiency, the R-value of insulation, the indoor temperature profile via the weighted factors for organic and conventional chickens, or any other number other factors, one can align the modeled energy use with actual energy records. Given the small sample size, there is a low degree of confidence around the model; however, it is included as a demonstration of the potential for future with the aid of more high-resolution energy records, more time, and the inclusion of more variables.

8. Appendix A: Energy Models from the Mark Rohrer Farm

Table 8.1

Rohrer Farm: Cost Analysis per House for 2014			
		Run 40% of the time when heating is necessary	
	Base Scenario (See model)	Intermittent Run Scenario	High Performance Scenario
Gallons of Propane	12,942.6	6,023.1	475.0
Cost of Propane ($/gallon)	1.6	1.6	1.6
Sub-cost Propane Cost ($/year)	20,449.3	9,516.5	750.4
Electricity Used in kWh (Fans only)	3672.258296	3,119.4	3,119.4
Cost of Electricity ($/kWh)	0.1	0.1	0.1
Electricity Used in Thermal System (kWh) - Parasitic Load	0.0	2,461.5	11,328.7
Sub-Cost Electricity ($/year)	440.7	669.7	1,733.8
Total Energy Cost	20,890.0	10,186.2	2,484.2
Note about Propane costs: www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_SPA_DPG&f=W			

Table 8.2

Two-Flock Sample, Side-by-Side Comparison		
	Mark Rohrer Farm	Todd Rohrer Farm
Cost of Propane for Heating	$5,901.37	$8,009.76
Cost of Electricity Used for WC System	$404.69	$0.00
Cost of Propane Used for WC System	$136.02	$0.00
Cost of Labor for WC System	$517.00	$0.00
Total Operating Cost	$6,959.09	$8,009.76

Table 8.3

Rohrer Farm: Farmer Labor to Operate/Maintain System				
Date	Bird Age (days)	% of Time House is Open	Estimated System Run-time (hrs)	Farmer Time to Run/Maintain (hrs)
Flock 1	Pre-heat	50	0	0
9/18/2014	Birds placed	50	0	
9/28/2014	10	100	144	11.5
10/5/2014	17	100	12	8
10/12/2014	24	100	0	0
10/20/2014	32	100	0	0
10/27/2014	39	100	0	0
11/8/2014	50	100	0	0
Flock Total	**50**		**156**	**19.5**
Flock 2	Pre-heat	50	0	0
11/24/2014	Birds placed	50	0	0
11/30/2014	6	50	155	5.5
12/7/2014	13	50	120	7.5
12/14/2014	20	75	96	11.5
12/21/2014	27	100	48	3
12/28/2014	34	100	0	0
1/4/2015	41	100	0	0
1/9/2015	Birds out	100		
Flock Total	**41**		**419**	**27.5**

Table 8.4

Sensitivity Results			
R-Value	Pre-Technology Propane	Post-Technology Propane High Performance	Savings (Gallons of Propane)
Default R Values (.8 Floor, 2 Ceiling, 2 Walls)	12942.61918	474.9624334	12467.6567
25% Increase in R-value (1 Floor, 2.5 Ceiling, 2.5 Walls)	10783.63575	265.2731297	10518.3626
Percent Change	-20.0%	-79.0%	-18.5%
Boiler Efficiency	Pre-Technology Propane	Post-Technology Propane High Performance	Savings (Gallons of Propane)
Default Boiler Efficiency (70% Efficiency)	12942.61918	474.9624334	12467.6567
25% Increase in Boiler Efficiency (87.5% Efficiency)	11200.34352	493.9694646	10706.3741
Percent Change	-15.6%	3.8%	-16.5%
Bird-Type and Heating Demand	Pre-Technology Propane	Post-Technology Propane High Performance	Savings (Gallons of Propane)
Default Heat Differential (15,915 Degrees F)	12942.61918	474.9624334	12467.6567
Decrease Heat Demand per Conventional Birds (8,615° F)	7224.784594	177.9258165	7046.85878
Percent Change	-79.1%	-166.9%	-76.9%
Ventilation Rate	Pre-Technology Propane	Post-Technology Propane High Performance	Savings (Gallons of Propane)
Volume Throughput Rate (530 CFM * Age of Birds)	12942.61918	474.9624334	12467.6567
Reduced Volume Throughput Rate (397.5 CFM * Age of Birds)	12405.69367	515.0863815	11890.6073
Percent Change	-4.3%	7.8%	-4.9%
System Size	Pre-Technology Propane	Post-Technology Propane High Performance	Savings (Gallons of Propane)
Default Capacity (500,000 BTU/Hr)	12942.61918	474.9624334	12467.6567
75 % Decrease in Capacity (125,000 BTU/Hr)	12942.61918	2346.179622	10596.4396
Percent Change	0.0%	79.8%	-17.7%
Parasitic Load	Pre-Technology Electricity Usage	Post-Technology Electricity Usage High Performance	Increase (kWh of Electricity)
Default Parasitic Load (5,450 Watts)	0	10570.45164	10570.4516
25 % Decrease in Parasitic Load (4,087.5 Watts)	0	8042.78243	8042.78243
Percent Change	N/A	-31.43%	-31.43%