Financial Feasibility of Alternative Animal Waste Management Demonstration Projects in Maryland


University of Maryland Environmental Finance Center
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Cover photos (clockwise from upper left): poultry litter fluidized bed combustion system at Double Trouble Farm (credit BHSL); demonstration of Days End Farm's mobile composter (credit EFC); anaerobic digestion and nutrient capture system at Millennium Farm (credit Planet Found Energy Development); structure housing the site-built composter at Glamour View Farm (credit David Kann).

About the Environmental Finance Center

The Environmental Finance Center (EFC) at the University of Maryland is part of a network of university-based centers across the country that works to advance finance solutions to local environmental challenges. Our focus is protecting natural resources by strengthening the capacity of local decision-makers to analyze environmental problems, develop effective methods of financing environmental efforts, and build consensus to catalyze action. EFC works to equip communities with the knowledge and tools they need to create more sustainable environments, more resilient societies, and more robust economies. The Environmental Finance Center is housed within the School of Architecture, Preservation and Planning.

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I. Introduction

The Maryland Department of Agriculture's Animal Waste Technology Fund (AWTF) provides grants for demonstration projects of innovative technologies for managing animal manure. These technologies are expected to improve on-farm waste management, enhance water quality, and create new revenue streams for farmers in the form of cost savings and marketable byproducts.

In its first AWTF grantmaking cycle (2014), MDA awarded three grants to support the installation of four manure management projects on Maryland farms: (1) $388,310 to **Green Mountain Technologies, Inc.** to install a mobile compost system at Days End Farm Horse Rescue in Howard County and a site-built compost system at Glamour View Farm in Frederick County;[1] (2) $970,000 to **Biomass Heating Solutions Limited, Inc.** to install a fluidized bed combustion system at Double Trouble Farm in Dorchester County,[2] and (3) $676,144 to **Planet Found Energy Development** to build an anaerobic digestion and nutrient capture system at Millennium Farm in Worcester County.[3]

The former two projects involve composting animal waste (manure, used bedding material, etc.) to transform it into a stable and usable end product. The latter two projects turn waste into heat, energy, and various byproducts through combustion and anaerobic digestion, respectively. All of these technologies are relatively novel, especially in the United States, though the manure-to-energy technologies are particularly nascent and are undergoing considerable testing and refinement. As a whole, these new technologies face an evolving landscape in terms of the regulatory, political, and financial factors that will affect their profitability and their adoption on Maryland farms.

The Environmental Finance Center was asked to evaluate the financial feasibility of the four pilot manure management projects, and to assess each technology's potential transferability to other farms in the state. This report presents summary findings from EFC's farm-scale financial feasibility assessments (Section II). It also reviews policy, regulatory, and other drivers that might affect the economic viability of the manure management technologies (Section III). The final section (IV) offers recommendations for supporting the success and adoption of alternative manure management projects throughout Maryland. Full farm-scale financial feasibility assessments can be found in the Appendix.

Summary of findings

Overall, the demonstration of these technologies as implemented on the host farms did not exhibit strong financial feasibility – defined as the simple payback period on the investment being less than the

[1] Maryland Department of Agriculture. June 2016. "Maryland's Animal Waste Technology Fund Grant Recipient Profile: Green Mountain Technologies, Inc." Available: http://mda.maryland.gov/resource_conservation/counties/GreenMountain.pdf
[2] Maryland Department of Agriculture. November 2014. "Maryland's Animal Waste Technology Fund Grant Recipient Profile: Biomass Heating Solutions USA." Available: http://mda.maryland.gov/resource_conservation/counties/BiomassFactSheet.pdf
[3] Maryland Department of Agriculture. September 2014. "Maryland's Animal Waste Technology Fund Grant Recipient Profile: Planet Found Energy Development." Available: http://mda.maryland.gov/resource_conservation/counties/PlanetFound.pdf

useful life of the technology. An exception is the Days End composting project, which does result in annual cost savings and is likely to produce a payback period that is shorter than the technology's anticipated useful life. This suggests that other farms in similar situations might invest in the technology with a reasonable expectation of recouping the investment. The Glamour View Farm composting project demonstrates the potential for financial feasibility if monetized environmental benefits are included, i.e. the value of avoided environmental damage from field stacking manure (the pre-technology status quo on the farm).

Based on available information and one-year initial performance periods, it appears that the two manure-to-energy projects generate cost savings and revenue for their host farms, but that net revenue is not sufficient to overcome project costs. In the case of the Millennium Farm anaerobic digestion and nutrient capture system, this result is not surprising, as the project was designed with the primary purpose of testing and refining the technology, rather than creating a financially viable standalone operation. The operator's goal is to replicate the system at a significantly larger, more profitable scale.

The other manure-to-energy project, a fluidized bed combustion system at Double Trouble Farm, currently appears to result in about $2,500 in annual losses. However, this result could be reversed in the case of several plausible scenarios: a longer performance period for the pilot project reveals that chicken health and growth rates improve (as has been in case in European applications of the technology); the sale price for raw poultry litter drops in light of new state regulations that limit the amount of litter that can be applied on soils that are over-enriched with phosphorous; and/or the farm is compensated for pollution reductions via an active nutrient trading system or other means.

Details about each of the four financial feasibility assessments can be found in Section II and the Appendix.

Expanding the scope of analysis beyond the individual farm scale, an important consideration is that each alternative manure management technology achieves ancillary public benefits that cannot necessarily be internalized to the host farm's finances. Chiefly, by converting raw manure into useable, saleable byproducts (most of which may be marketed outside the Chesapeake Bay region), the technologies reduce the potential for agricultural nutrient pollution to local receiving waterbodies. Further, because the projects are built and operated with private capital in addition to public subsidy, they achieve water quality benefits at a significantly lower cost to the State than projects funded through public dollars alone.

The alternative manure management technologies' profit-generating potential sets them apart from many traditional agricultural best management practices.

While the technologies do not yet demonstrate strong profitability across the board, their profit-earning potential sets them apart from many traditional agricultural conservation best management practices.

As the technologies are refined and improved, their associated costs (for construction, operations, materials, etc.) can reasonably be expected to decrease. Simultaneously, revenue can be expected to increase as markets for novel byproducts develop. As profitability improves, so will the impetus for private sector partners to engage and invest in the technologies. Given these considerations, continued State subsidy in demonstration of such projects may be warranted, especially until the technologies are improved enough to become financially self-sustaining.

II. Financial Assessments of On-Farm Demonstration Projects

For each of the four farm projects assessed, EFC created a full cost balance model that contrasts pre- and post-technology costs and revenue across a range of categories: capital, labor, operations and maintenance, materials and services, energy, monetized environmental costs, and byproducts. These numbers were used to determine the project's financial feasibility, defined as the simple payback on the investment as being less than the expected useful life of the technology.

To demonstrate how changes to key inputs and assumptions could affect project feasibility, EFC conducted a comparative scenario analysis for each project, with variations in each scenario's inputs and assumptions resulting in varying amounts of cost savings (or losses), as well as differing payback periods. Each farm assessment also includes a discussion of key factors affecting transferability of findings as well as conditions that would improve the financial feasibility of future applications of the technology. Below are summaries from the four farm assessments. The full assessments are included in the Appendix.

Days End Farm Horse Rescue, Howard County

Days End Farm is a horse rescue and rehabilitation operation located in Howard County. In 2015, Green Mountain Technologies installed an in-vessel composting system at Days End to process manure and used bedding material from the 40 horses housed in enclosed stalls at the farm. These horses produce a total of 1.6 tons of waste per day, all of which must be cleaned from stalls and disposed of. Prior to installing the composter, Days End had been landfilling this waste at a cost of $40 per ton. Landfilling manure is not uncommon among recreational horse farms, because horse manure is typically nutrient-poor and does not have high value as a fertilizer.

The new composter at Days End Farm processes about 300 tons of waste per year – or nearly half the total waste that Days End had previously been landfilling. The key expected benefit of this alternative manure management technology is cost savings from avoided landfill fees. Secondary benefits relate to the finished compost product, which may be used as a bedding substitute to offset costs and/or which could potentially be sold as a soil amendment.

EFC's financial feasibility assessment found that based on available information, the GMT composter at Days End can be considered cost effective, as the simple payback period on the investment is expected to be less than the technology's useful life (15-20 years). The compost system will result in approximately $9,600 in annual cost savings, which produces a payback period of 13.8 years relative to the initial $132,000 capital investment (see Table 1). This result excludes any benefit from selling compost, since a local Howard County ordinance prohibits the sale of compost within the county, as well as any environmental benefits, and it is highly sensitive to the assumption that landfilling (at $40 per ton) is the next best animal waste management option.

Table 1. *Days End Farm compost system cost assessment results (see full assessment in the Appendix for inputs and assumptions)*

	Pre-Technology	Post-Technology	Balance ***(positive indicates cost savings or revenue)***
Labor costs ($)	548	1,077	-529
O&M, materials, and services costs ($)	25,212	14,796	10,417
Energy costs ($)	0	329	-329
Byproduct revenue ($)	0	0*	0
Sub-total	*$14,080*	*$4,521*	*$9,559*
			Summary
Capital costs			$132,161
Annual cost savings			$9,559
Simple payback on investment			13.8 years
Return on investment			7.23%

* While Days End Farm had anticipated being able to sell the finished compost product, a Howard County ordinance currently prohibits the sale of compost, so this assessment assumed no byproduct revenue.

Changes to key inputs and assumptions would change project feasibility. For example, if Days End were able to sell finished compost, this would introduce a new revenue stream and improve the payback period. On the other hand, if the farm had previously been managing manure with a more cost-effective method than landfilling (such as on-site composting with manual turning or land application by a cooperating farmer), this would translate to reduced cost savings and a longer payback period.

Regarding transferability of this technology to other farms in the state, it appears that in-vessel composting will be more financially feasible if (1) the farm's default manure management approach is landfilling or another costly approach, as is most likely to be the case at horse farms, farms that do not need or cannot use manure on their own land, and/or areas with a weak manure market; (2) the finished compost can be sold as a soil amendment or used on the farm; and/or (3) the farm is able to take advantage of subsidized interest rates to finance the project, such as those available through Maryland's Low Interest Loans for Agricultural Conservation program.

Glamour View Farm, Frederick County

Glamour View Farm is a dairy operation in Frederick County with 180 Holstein and Jersey cows. In 2015, Glamour View partnered with Green Mountain Technologies to install a composting system housed within a permanent structure on the farm. GMT's Earth Flow system automates mixing, aeration and moisture control, making it more efficient than manual composting. The composter processes about 500 tons of manure per year – representing animal waste and bedding material from the heifer segment of the operation, which includes about 60 cows. Finished compost is intended to be sold as a soil amendment, but the farmer could also elect to use some or all of it on-farm as a fertilizer or bedding material substitute.

The main benefit of this system is the production of a byproduct that has value on-farm and/or for sale (compost commands a higher price than raw manure). But the composter also makes the management of wet manure at Glamour View more efficient by decreasing the moisture and weight of the material, making transport easier and less expensive. It decreases the volume of material added to the farm's manure treatment lagoon, reducing electricity needs as well as wear-and-tear on lagoon components. It also reduces the amount of manure that must be stockpiled on a farm field, which is not an optimal management option given the potential for nutrient runoff into nearby streams and/or reduced productivity of cropland near the stockpile site.

EFC's financial feasibility assessment found that the project results in cost savings of about $3,000 per year, but that the simple payback period exceeds the life of the technology (25 years). However, to the extent the market or the state values decreased nutrient runoff from field-applied manure (via nutrient credit trading, public subsidy, etc.), and the farm can generate additional revenue, the project financial balance improves drastically. Solving for conditions whereby the simple payback of the project is equal to the useful life of the technology, then the project could be considered cost effective if the value of preventing raw manure from being field-applied were $12/ton or greater. Under these conditions, the total annual cost savings (internal and external costs) would be $8,968 (see Table 2).

Table 2. *Glamour View Farm compost system cost assessment results (see full assessment in the Appendix for inputs and assumptions)*

	Pre-Technology	Post-Technology	Balance *(positive indicates cost savings or revenue)*
Labor costs ($)	2,167	633	1,533
O&M, material, and services costs ($)	2,005	3,511	-1,506
Energy costs ($)	7,216	6,274	941
Byproduct revenue ($)	$0	2,000	2,000
Sub-total	*$11,388*	*$8,418*	*$2,970*
Monetized environmental costs ($)	6,000	0	6,000
			Summary
Capital costs			$219,106
Annual cost savings + revenue			$8,968
Simple payback on investment			24 years

The project's financial outlook changes as key inputs change. Namely, higher manure input to the composter (so that it is processing its full capacity of 1,300 tons per year) and a higher dollar value for the finished compost (market value estimates range from $10 - $18 per ton) both yield a better payback. Additionally, if Glamour View were to use compost as a bedding substitute for the shaved wood product it currently purchases, there is significant savings potential. On the other hand, if during pre-technology the farmer had been deriving value from raw manure from either on-farm fertilizer use or sale to other farmers, annual cost savings opportunities decrease and the project's payback period increases.

Regarding transferability of this technology to other farms in Maryland, many of the same factors apply as in the Days End discussion. It appears the technology would be more feasible (though not necessarily feasible) if: (1) the farm's default manure management strategy yields little revenue and/or incurs significant costs, as is likely to be the case for farms in areas with a weak or unstable manure market, such as horse farms statewide and dairy farms in areas subject to PMT regulations; (2) the finished compost can be sold as a soil amendment or used to offset bedding costs on the farm; (3) the farm is able to take advantage of subsidized interest rates via the Low Interest Loan for Agricultural Conservation to finance the project; or (4) the technology were to become eligible for cost share assistance via the Maryland Agricultural Water Quality Cost Share Program, or if it were to be designated an eligible generator of credits via the state's Nutrient Trading Program, which would compensate farmers for preventing raw manure from field application. See the Appendix for a more complete discussion of these issues.

Double Trouble Farm, Dorchester County

Double Trouble Farm is a poultry operation in the Eastern Shore county of Dorchester. The farm partnered with Biomass Heating Solutions Limited to install a fluidized bed combustion system (FBC). This system converts poultry litter to heat and electricity through a combustion process aided by upward-blowing streams of air, which creates a turbulent mixing of gases and solids. The system became operational in late 2016 and processes 1,000 tons of poultry litter per year (with capacity for up to 3,300 tons per year).

Expected benefits include energy to heat four poultry houses, which offsets the need for purchased propane. While the system at Double Trouble is not large enough to viably take advantage of net metering, larger systems are expected to be capable of producing excess energy that could be converted to electricity and sent back to the grid to offset the farm's electricity costs. An additional expected benefit – of both the Double Trouble Farm system and future systems – is the production of a high-phosphorous and high-potassium ash byproduct. The sale of this product not only produces revenue for the farmer or vendor, it enables much of the nutrients found in poultry litter to be captured and sent outside the Chesapeake Bay region, a boon for local water quality. Another initial expected benefit of the technology was improved growth rates and feed conversion efficiencies for poultry raised in houses heated by the FBC system (which produces a dryer, healthier heat compared to propane and allows for increased ventilation which reduces ammonia levels in the houses). This benefit has been achieved in European applications of the technology, but flocks raised via Double Trouble's system to date have not demonstrated statistically significant altered growth rates or feed conversion rates.

Based on available information a short performance period, the FBC system at Double Trouble Farm appears to result in $2,503 in annual losses for the farmer and/or vendor (see Table 3). This is due largely to an increase of roughly $22,000 in operations, materials and services costs, as well as lost proceeds from the sale of raw poultry litter at a price of $18 per ton. Favorable to the project's bottom line are revenue from byproduct sales, as well as an approximately $30,000 net decrease in the energy line, due to avoided energy costs plus revenue from the sale of renewable energy credits. However, for the project to be considered cost effective, it would need to yield an additional $110,000 in net cost savings and revenue, through increased poultry weight gain, net metering, sale of nutrient trading credits, and/or monetized environmental benefits.

Table 3. *Double Trouble Farm FBC system cost assessment results (see full assessment in the Appendix for inputs and assumptions)*

	Pre-Technology	Post-Technology	Balance *(positive indicates cost savings or revenue)*
Labor costs ($)	2,773	3,057	-284
O&M, materials, and services costs ($)	2,000	24,343	-22,343
Energy costs ($)	30,727	1,703*	29,024
Byproduct revenue ($)	18,000**	9,100	-8,900
Sub-total	*$17,500*	*$18,632*	*-$2,503*
			Summary
Capital costs			$2.73 M
Annual cost savings + revenue			-$2,503
Simple payback on investment			Infinite
Return on investment			N/A

* Includes revenue from the sale of renewable energy credits. ** Includes revenue from the sale of unprocessed poultry litter.

Various alternate scenarios yield improved profitability. These scenarios include the ability to realize proceeds from net metering, the sale of nutrient trading credits, reduced market value for unprocessed poultry litter, and accelerated growth rates for poultry raised via the FBC system. While all of these scenarios generate annual net revenue (rather than annual losses as in the base scenario), none generates revenue sufficient to produce a payback period less than the technology's useful life. Improved bird health does come close, with a payback period of 31.3 years, just over the vendor's upper-range estimate of the technology's lifespan (20-30 years). Combining *all* the revised inputs does produce a scenario in which annual net revenue (around $118,000) would be sufficient to recoup an initial $2.73 million investment within 22.9 years.

Considering future applications of FBC technology on other farms in Maryland, profitability seems more likely if (1) new Phosphorous Management Tool regulations have their anticipated impact of depressing the market value for raw poultry litter over the long term (i.e. within 15 years); (2) future FBC systems are sized appropriately to generate excess electricity and realize revenue from net metering; and (3) future systems are able to capture most or all of the technology's revenue-generating opportunities (REC sales, byproduct sales at a strong market rate, accelerated poultry weight gain, etc.), as demonstrated by the scenario analysis.

Millennium Farm, Worcester County

Millennium Farm is a four-house poultry operation and grain producer located on Maryland's Eastern Shore in Worcester County. In 2014, Millennium partnered with Planet Found Energy Development (PFED), a startup manure management technology company based in Maryland, to install a pilot-scale anaerobic digestion and nutrient capture system (AD + NCS) at the farm. Funded in part by an AWTF grant, this system uses a combined heat and power generator to convert poultry litter into methane gas that can generate heat and/or electricity. The system became operational in spring 2017. Though designed to process 1,200 tons of poultry litter per year (3.3 tons per day), the system is not yet operating at full capacity but rather is processing about one ton per day.

The facility is a pilot-scale system primarily designed to test and refine the technology, so that it can be replicated around the region at a significantly larger scale. In future scaled-up systems, primary expected benefits include the production of energy that can be used for heating and cooling and/or for the production of electricity that can net metered in order to save costs. Additionally, this and future projects may generate revenue from the sale of renewable energy credits and nutrient trading credits.

Another primary benefit – of both the pilot system and future scaled-up systems – stems from the nutrient capture element, which partitions out the primary nutrients found in poultry litter into three by-products: a soil amendment, a potting soil, and a high-phosphorous fertilizer. These products may be sold to markets outside the Chesapeake Bay region, benefitting regional water quality and generating revenue for the farmer. The soil amendment product may also be used by local farmers to replace poultry litter as fertilizer, as the new product is lower in phosphorous than raw litter and provides some of the soil health benefits realized from poultry litter. This is especially important in light of new state regulations which limit the application of phosphorous on certain cropland with high risk of phosphorus movement. The potting soil byproduct can be sold to nurseries and other markets.

EFC's financial assessment findings are consistent with the fact that the AD + NCS facility at Millennium Farm was not originally intended to demonstrate financial feasibility, but rather to test and refine the technology. Based on current operational capacity and a short initial performance period, the pilot project appears to result in annual losses of $123,377 (see Table 4). Again, however, the project was not designed to be financially self-sustaining at its existing pilot scale.

Table 3. *Millennium Farm AD + NCS system cost assessment results (see full assessment in the Appendix for inputs and assumptions)*

	Pre-Technology	**Post-Technology**	**Balance *(positive indicates cost savings or revenue)***
Labor costs ($)	5,648	48,000	-42,352
O&M, materials, and services costs ($)	-1,825*	96,000	-97,825
Energy costs ($)	58,000	58,000	0
Byproduct revenue ($)	0	16,800	16,800

Sub-total	*$61,823*	*$185,200*	*-$123,377*
			Summary
Capital costs			$1,832,137
Annual cost savings + revenue			-$123,377
Simple payback on investment			Infinite
Return on investment			N/A

* Includes value of poultry litter as on-farm fertilizer ($9,125) minus O$M, materials and services costs.

Profitability of future applications will depend on the system being scaled up in size and input capacity. Planet Found Energy Development has developed various models for future iterations of the pilot AD + NCS system, all of which are significantly larger than the pilot. One such model is a 1.5 MWh facility designed to process 50,000 tons of poultry litter per year, with input coming from multiple farms throughout the region. While capital costs increase under this scenario, revenue also increases significantly, through the sale of byproducts as well as an operations contract with the host entity (projected to be a public agency such as a college or university, which could benefit from significant energy cost savings). This model demonstrates profitability and would also benefit water quality in the region by removing an estimated 305,262 pounds of phosphorous from previously-land applied poultry litter and generating a marketable byproduct.

Beyond size of the system, there are other important factors affecting adoption of AD + NCS technology throughout Maryland. Chief among these is state nutrient management regulations which require farmers to transition to using a new Phosphorous Management Tool (PMT). This is discussed in detail in the following section, but generally, PMT can be expected to depress the value of raw litter as fertilizer in regions where the soils are over-enriched with phosphorous, and thereby to drive demand for alternative technologies. Additionally, the ability for vendors (and/or host entities) to increase revenue through state subsidies, a robust byproduct market, the sale of nutrient trading credits or other means would augment the technology's adoption potential.

III. Key Policy and Regulatory Drivers Affecting the Financial Feasibility of Alternative Manure Management Projects

For farmers to employ alternative manure management strategies such as composting or manure-to-energy, these new approaches must be more profitable than the standard management practices. A number of factors play into this calculation, including the market value of raw manure, the marketability and value of alternative byproducts such as compost or soil amendments, and the farm's individual labor capacity. But regulatory and policy factors have the potential to affect this calculation as well. Below is a brief discussion of key regulations, policies, incentives, and programs that may impact the economic feasibility of alternative manure management technologies in Maryland.

Regulations governing how manure is managed

Historically, Maryland farmers have had two main options for managing animal manure produced on their farms (1) apply it as fertilizer on their own land or (2) sell or barter it to another farm or other receiving entity that can put it to use. Alternative manure management technologies present another option – transforming manure into other products for use or sale. Several key regulations and programs related to manure management in Maryland may affect the profitability of employing these new technologies.

Maryland's **Nutrient Management Law** (COMAR §8-801),[4] created by the Water Quality Improvement Act of 1998, governs the amount, timing, and placement of nutrients – including manure – on farm lands, with the goal of sustaining crop yields and preventing excess nutrients from adversely affecting water quality.[5] Under this law, Maryland farmers grossing $2,500+ a year or livestock producers with 8,000 pounds or more of live animal weight are required to develop and follow nutrient management plans, which are based on scientific guidelines and specify how much fertilizer, manure or other nutrient sources may safely be applied to each crop.[6] Any farm that uses animal manure as part of its operation is additionally required to implement manure management practices related to storing, stockpiling, and handling animal manure in order to minimize the potential for nutrient loss, improve nutrient use efficiency, and properly time manure application.[7] These rules apply to operators that import manure as a source of fertilizer as well as to those that export animal manure or waste.

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[4] Maryland Code §8-801. *Maryland Nutrient Management Law.* Available: http://mda.maryland.gov/resource_conservation/Documents/NM_Law.pdf

[5] Maryland Department of Agriculture. 10/29/2014. Press Release: "MDA Awards $970,000 for New Manure Management Technology Project; Farm Partners with Irish Co. with Support from Mountaire." Available: http://news.maryland.gov/mda/press-release/2014/10/29/mda-awards-970000-for-new-manure-management-technology-project-farm-partners-with-irish-co-with-support-from-mountaire/

[6] Maryland Department of Agriculture. Fall 2015. *Farming with Your Nutrient Management Plan: A Comprehensive Guide to Maryland's Nutrient Management Regulations and Requirements.*

[7] Maryland Department of Agriculture. *Maryland Nutrient Management Manual.* Available: http://mda.maryland.gov/resource_conservation/Pages/nm_manual.aspx

Farmers that are compelled to operate under a nutrient management plan are required to submit an annual implementation report to the Maryland Department of Agriculture by March 1st of each year, summarizing their nutrient use and management during the previous calendar year.[8] They also are required to complete a soil test at least once every three years, and farmers who use manure must have it analyzed for nutrient content at least every other year.[9] Additional requirements within the Nutrient Management regulations deal with issues such as establishing no-fertilizer setback zones near streams, limiting livestock access to waterways, and refraining from spreading manure and other organic nutrients during winter months.

Importantly, Maryland recently adopted stricter guidelines governing the use of phosphorous on soils with high phosphorous levels. Regulations requiring the use of a **Phosphorus Management Tool** (PMT) took effect June 2015. They require farms with phosphorous-enriched soils to use the PMT when preparing nutrient management plans; this new risk assessment tool helps identify farm fields with environmental risks posed by soil phosphorus levels and farm conditions, and it provides farmers with requirements to reduce the risk of phosphorus runoff into nearby waterways.[10] Soils restricted by PMT are typically found on farms that have used manure or poultry litter as fertilizer for a long period of time. Maryland's Eastern Shore in particular contains a number of such fields; in Somerset, Wicomico, and Worcester counties, an estimated 70% of the land area is over-enriched with phosphorous and thus restricted in manure use.[11] MDA is applying a tiered implementation schedule, with the highest-risk farms required to begin transitioning to compliance with PMT requirements in 2018, and lower-risk farms to follow in subsequent years, with all farms fully implementing PMT requirements by 2022.

In addition to limiting how and where nutrients can be applied, regulations can affect the **market for byproducts** created through the use of alternative manure management technologies. Maryland's nutrient management law requires farmers to document the nutrient content of any product – including manure – that they land apply. Maryland state fertilizer product laws require products being sold in the state to be certified by the State Chemist to document content, meaning that farms must account for the nutrient content of the finished byproducts they use or sell. Local regulations can affect the alternative manure management market as well, such as the Howard County prohibition against the sale of compost, which removes a potential revenue stream for farmers in that county who could otherwise sell finished compost.

State programs affecting the manure management market

Several Maryland state programs affect the economics of manure management. Chief among these is the **Manure Transport Program**, which provides up to $18 per ton in cost share to ship manure to farms

[8] Maryland Department of Agriculture. Fall 2015. *Farming with Your Nutrient Management Plan: A Comprehensive Guide to Maryland's Nutrient Management Regulations and Requirements.*
[9] Ibid.
[10] Ibid.
[11] Louise Lawrence, Maryland Department of Agriculture. Interview with EFC, 7/14/16.

or alternative use facilities that can use the manure in an environmentally sound way.[12] Eligible participants are animal producers with high soil phosphorous levels or insufficient land to use manure in accordance with a nutrient management plan. Cost share rates are 20 percent higher for farms located on Maryland's Lower Eastern Shore, where the program will pay up to $.15 cents per ton per mile.[13] A related state program – the **Manure Matching Service** – connects farmers who have excess animal manure with nearby farmers or alternative use projects that can use the manure as a resource. Both of these programs make it easier and more affordable for farmers to ship manure to other farms or facilities in the state.

A third important program is the **Maryland Agricultural Water Quality Cost Share Program**, through which the state provides cost share incentives for the construction of best management practices (BMPs) on farms that improve water quality and provide public benefits but may not be cost-effective for farmers to install on their own. There are currently about 30 approved BMPs including practices such as planting streamside buffers and installing waste treatment lagoons. Farms with at least 15 animal units can receive grants to cover up to 87.5% of the cost to install such conservation measures, with a total cap of $150,000 for non-manure BMPs and up to $450,000 if manure BMPs are included. Currently, alternative manure management technologies such as manure-to-energy or composting are not eligible for funding through this program, which is a lost opportunity for incentivizing such practices.

Finally, a state program that has the *potential* to affect this market is the Maryland **Nutrient Trading Program** administered by the Maryland Department of Agriculture. An active nutrient trading market could incentivize alternative manure management technologies, by offering farmers a new revenue stream in the form of selling nutrient credits. These credits would be generated when the farmer implements an approved practice which reduces nutrient pollution at levels exceeding the farmer's own regulatory requirements.

Credit trading markets are still emerging throughout the Chesapeake Bay watershed. Pennsylvania and Virginia have relatively well-developed programs, with Pennsylvania's program explicitly including any practice that reduces land application of manure. In West Virginia, some ad hoc trades have occurred but the state does not have a statutory trading program. Maryland has a legislatively authorized trading program and regulatory guidelines, but no trades have been completed to date. Recently, the Maryland Department of Environment proposed nutrient trading regulations to address pollution from point sources, stormwater, and onsite septic systems, and the Department has been authorized by statute to use a portion of monies in the state Bay Restoration Fund to catalyze certain trades. These developments increase the likelihood of stepped-up trading activity in the future.

[12] Maryland Department of Agriculture. Manure Transport Program website. Available: http://mda.maryland.gov/resource_conservation/Pages/manure_transport.aspx
[13] Louise Lawrence, Maryland Department of Agriculture. Interview with EFC, 7/14/16.

A Manure Treatment Technologies Expert Panel convened by the US EPA Chesapeake Bay Program recommended that nutrient reductions from compost systems, thermochemical systems, and other technologies with verifiable nutrient reductions be approved for trading within the watershed.[14] However, each state must determine eligibility requirements for its own trading program, and Maryland has not yet specified eligibility for these technologies. Because Maryland's program has not seen trading activity to date and thus there is little market demand for credits, the Nutrient Trading Program currently represents a potential revenue source rather than an actual one.

Policies and incentives affecting the energy market

Two main types of energy policies have strong potential to interact with the market for manure-to-energy (M2E) technologies: renewable portfolio standards (RPS) and net metering regulations. Broadly speaking, these sets of policies serve to incentivize manure-to-energy projects by helping to improve the projects' bottom line. The laws generally do not impose additional costs on M2E operators and, depending on how the laws are structured and how the facilities are designed, they can generate costs savings and/or revenue for M2E projects.

Renewable portfolio standards (RPS) require that all suppliers that sell electricity source a portion of their energy from renewable resources. To comply with RPS regulations, load-serving entities must purchase renewable energy credits (RECs) from the market, with the proceeds going to facilities that generate energy from renewable sources such as solar, wind, biomass, and geothermal. Maryland's Renewable Portfolio Standard requires that twenty-five percent of the state's energy come from renewable sources by 2020.[15]

Key attributes of a state's RPS law that affect the manure-to-energy market include:

- ***Eligibility***. A state's RPS specifies which fuel sources are considered renewable and are therefore eligible to generate renewable energy credits. The key question as it relates to AWTF projects is whether animal manure including poultry litter is considered a renewable resource. Manure-to-energy is often discussed in tandem with biomass technologies or waste-to-energy technologies that use refuse or industrial byproducts such as black liquor (i.e., from pulp and paper manufacturing). Under Maryland's RPS, poultry litter incineration facilities are an eligible resource, as is gas produced from the anaerobic decomposition of animal waste or poultry waste.[16]
- ***Thermal qualification.*** In general, a facility must generate electricity to become eligible for renewable energy credits. However, as is the case with Maryland's RPS law, thermal-only facilities (i.e., those that generate heat but not electricity) are eligible to produce and sell renewable energy credits. Poultry farmers are generally concerned about the cost of natural gas

[14] Jeremy Hanson, Virginia Tech / Chesapeake Bay Program. Interview with EFC, 11/7/16.
[15] Maryland Public Service Commission. Renewable Energy Portfolio Standard Program. Accessed 11/27/17: http://www.psc.state.md.us/electricity/maryland-renewable-energy-portfolio-standard-program-frequently-asked-questions/
[16] Ibid.

or propane needed to heat poultry houses. For this reason, many farmers would presumably prefer to direct the thermal output of manure-to-energy facilities directly toward space heating rather than electricity generation. Thermal eligibility allows farmers to secure additional revenue while directing thermal output to an issue of greatest need. In May 2012, the Maryland legislature enacted an amendment to the RPS that granted eligibility to thermal biomass systems that primarily use animal waste.[17]

- ***Tiers and carve-outs*.** By placing eligible renewable technologies in different tiers or carve-outs, RPS law can protect or incentivize specific renewable energy technologies. For example, the Maryland Legislature created a carve-out for solar photovoltaic (PV) technologies, which ensures that load-serving entities must purchase at least a portion of their renewable energy credits from this technology. There is no known carve-out for manure-to-energy technologies.
- ***Timetable*.** The timetable for meeting RPS over time and across tiers drives demand for renewable energy credits. The timetable is set several years in advance and ensures escalating demand for renewable energy credits, and in turn, renewable energy-generating technologies. In 2016, Maryland's General Assembly approved a more aggressive RPS timetable than had previously been pursued.[18]
- ***Geographic constraints.*** The RPS law can be designed to restrict the purchase of renewable energy credits to a specific geographic area and thereby expand or contract the supply of credits available to load-serving entities. In Maryland, for example, renewable energy credits must be generated from a facility located within the transmission area of PJM Interconnection, a regional transmission organization that coordinates wholesale electricity transfer in the Mid-Atlantic as well as Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, and Tennessee. A larger area of eligibility expands supply and drives prices down for renewable energy credits. It may be possible to modify the RPS in a given state to require that renewable energy credits from a specific technology (e.g., M2E) must be purchased within a defined geographic area such as a watershed.
- ***Stability.*** State legislatures frequently revise RPS laws to expand on and clarify the attributes discussed above, among other changes. A state's RPS is an attractive target for various special interest groups (clean energy, environment, public health) who wish to advance their advocacy goals through changes to the RPS. For M2E proponents, it is important to be attuned to the potential for amendments to a state's RPS that could weaken the position of M2E. Most notably, an amendment could remove M2E technology from the list of RPS-eligible technologies. This potential to lose eligibility introduces an element of financial uncertainty for farmers and other operators and investors.

Net metering regulations require utilities to credit distributed (non-centralized) electricity producers for the electricity they sell back to the electricity grid. Net metering regulations can create additional

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[17] DSIRE. Renewable Energy Portfolio Standard. Available: http://programs.dsireusa.org/system/program/detail/1085

[18] Utility Dive. 4/7/16. "Maryland Senate passes 25% RPS in clean energy jobs bill." Available: http://www.utilitydive.com/news/maryland-senate-passes-25-rps-in-clean-energy-jobs-bill/417006/

revenue opportunities for farmers when an on-farm M2E facility generates more electricity than is used on the farm. The key attributes of a state's net metering regulations as they relate to farm M2E include:

- ***Eligibility.*** Net metering is only available to electricity-producing facilities, and in many states, there is a defined set of technologies that qualify. In Maryland, biomass and anaerobic digestion facilities are eligible. Unlike Maryland's RPS, the Maryland net metering regulations do not specifically name poultry litter incineration as an eligible technology.[19]
- ***Capacity limits and virtual aggregation.*** Net metering regulations typically include a maximum capacity size, above which the system will not be eligible to participate. In Maryland, the limit is two megawatts (MW). Similarly, Maryland regulations stipulate that the system may not produce more than 200 percent of the electricity consumed by a customer in a given year. For example, the typical home consumes around 12,000 kWh per year. To participate in net metering, then, a residential rooftop solar PV system should be sized to generate less than 24,000 kWh per year. Virtual aggregate net metering enables property owners with multiple meters to install a larger system, by allowing the 200 percent limit to be assessed against the sum or aggregate of all meters owned by a single entity. In Maryland, aggregate net metering is available to agricultural customers, non-profit organizations, and municipal governments. This is a boon for farmers and investors interested in farm-scale, electricity-generating M2E technology.
- ***Credit price.*** Depending on the net metering regulations, electricity-generating facilities may be credited at the retail or wholesale electricity rate. The higher retail rate includes the electricity supply, transmission, and distribution costs. The wholesale rate includes only the electricity supply. Across the country, utilities, regulators, and clean energy advocates are debating the merits of net metering regulations, with much of focus on the credit price. In Maryland, utilities pay at the higher retail rate, and once per year reconcile at the wholesale rate. Stability of net metering credit price is a major consideration in advancing M2E investment.

In addition to state RPS and net metering regulatory drivers, federal regulations affect the manure-to-energy market. In particular, federal air emissions standards under the Clean Air Act can increase operational costs for operators of manure combusting projects subject to the regulations. EPA's updated Clean Air Act rules classify manure as solid waste (rather than non-waste), which means that projects that burn this waste are considered incinerators rather than boilers and are thus subject to more stringent standards.[20] Prior to the rule update in 2011, manure used for power generation was considered a non-waste material. This shifting regulatory landscape creates uncertainty for would-be M2E operators.

Specific compliance standards and associated costs depend on the M2E project's location, and can vary widely state to state and even within a particular state. Federal National Ambient Air Quality Standards are administered by state governments, which are required to issue permits and bring any

[19] DSIRE. Net Metering. Available: http://programs.dsireusa.org/system/program/detail/363
[20] 42 U.S.C.A. §7401 et seq.

nonattainment areas into compliance. Of the Chesapeake Bay states, Maryland has the most stringent particulate matter emissions standards for combustion units of the size that might power an M2E facility, allowing a maximum annual average of 0.32 pounds of emissions per million BTU (lbs/MMBTU). Pennsylvania and Virginia have only slightly higher allowances, permitting emissions of 0.4 lbs/MMBTU and 0.6 lbs/MMBTU respectively. West Virginia is the outlier, allowing as much as 3.4 lbs/MMBTU of particulate matter to be emitted.

How regulations and policies affect economic feasibility of alternative technologies

Generally speaking, Maryland's RPS and net metering regulations support the financial feasibility and therefore the adoption potential of manure-to-energy technologies, by providing additional sources of revenue to entities (including farmers) that install these systems. To a lesser degree, Maryland's nutrient management regulations also provide an incentive for farmers to manage animal manure nutrients in innovative ways, in order to ease concerns associated with complying with the rules. This is especially true for farms subject to the PMT. Because these farmers will be limited in how much phosphorous can be applied to their land, they will have a strong impetus to find alternative uses for the manure produced on their farm. When the regulations for transitioning to PMT went into effect in 2015, they included a provision that nutrient management consultants were required to submit soil phosphorus Fertility Index Value (FIV) information to MDA for every field subject to NMP in the state every six years. Preliminary results indicate that every county contains some fields with high phosphorus FIV levels, but as mentioned above, the most serious issues are in the Lower Eastern Shore counties of Somerset, Wicomico, and Worcester, where an estimated 70% of the land area is enriched with phosphorous (defined here as >150 P FIV), compared to 20% for the state as a whole.[21]

Alternative technologies could ease compliance with PMT, and in fact the regulations themselves contain a built-in incentive for farmers to pursue alternative technologies. The guidelines allow exceptions for farmers adopting MDA-approved alternative use technologies that reduce the phosphorus content in animal manure by at least 75%. These farmers may apply limited amounts of phosphorus to their lands.[22] This will apply primarily to manure-to-energy technologies, such as Millennium Farm's anaerobic digestion and nutrient capture system, which is able to separate out the nutrients found in poultry litter into several end products – some of which are high in phosphorous and could be marketed for alternative uses outside the region, and some with lower phosphorous content that could be land-applied on the Eastern Shore. While composting does not remove phosphorous, it does create a marketable product that can be diverted to other uses and markets. Additionally, by reducing the moisture content and overall volume of manure (by an estimated 50-60% for horse and dairy manure),[23] composting produces a drier and lighter product that is easier to ship or can be used as

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[21] Maryland Department of Agriculture. March 2016. "Preliminary Phosphorous Soil Test Results." http://www.mda.maryland.gov/documents/Preliminary-P-Data_03.2016.pdf

[22] Maryland Department of Agriculture. Fall 2015. *Farming with Your Nutrient Management Plan: A Comprehensive Guide to Maryland's Nutrient Management Regulations and Requirements.*

[23] Green Mountain Technologies. Email communication with EFC, 7/6/14.

a bedding material. The lower-moisture end product may also be eligible for field stacking, freeing up space in limited manure storage sheds.[24]

Beyond the regulations and programs discussed thus far,[25] a final significant driver should be mentioned: the U.S. EPA's **Chesapeake Bay Total Maximum Daily Load** (TMDL) requirements under the federal Clean Water Act. Enacted in 2010, the TMDL mandates levels of nutrient and sediment pollution reductions that must be achieved in each Bay state by 2025 in order to meet water quality standards.[26] The TMDL provides strong impetus for Bay states – including Maryland – to invest in cost-effective pollution reduction measures, so that pollution reduction targets are met on time and on budget. Because alternative manure management technologies offer profit potential and typically leverage private capital for construction and operations, they represent an efficient option for the State of Maryland as it seeks opportunities to invest in agricultural pollution reduction strategies.

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[24] It should be noted that the benefits of composting are more relevant for the dairy and horse industries than for the poultry industry, for a number of reasons. First, poultry litter is already fairly dry, meaning that there is less of a need to compost poultry litter, and also that it is not as cost-effective to do so. For litter to be effectively composted, farmers will need to add a source of moisture, which increases labor and input costs and potentially makes the operation less financially viable. Perhaps more important, though, is the fact that it is currently fairly profitable to sell raw poultry litter, especially considering the cost share incentives offered by the Manure Transport Program. In 2015, about 50,000 tons of poultry litter produced in the state were transported off originating farms to alternative uses, and only 2,000 tons were transported for land application. The alternative uses included the Perdue Ag Recycle pelletizing plant (now closed) and mushroom farmers in Pennsylvania, who use poultry litter as a growing medium. The market value for raw poultry litter in the Chesapeake Bay region has been estimated to range from $7.50[24] to $40[24] per ton, depending on local supply and demand. These market factors are likely to shift when full PMT management goes into effect in 2022; as additional farmers seek an outlet for litter, the market value of litter could decrease.

[25] This discussion of relevant regulations and programs is not meant to be exhaustive. Other local, state, and federal laws, programs and policies may also interact with the manure management market. State-level examples include Maryland's commercial fertilizer laws, sewage sludge management regulations, animal feeding operations guidelines, and water quality improvement strategies.

[26] US Environmental Protection Agency. December 2010. "Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorous and Sediment."

IV. Recommendations for Improving the Financial Feasibility and Adoption of Alternative Manure Management Projects

Based on financial assessments of the four AWTF pilot projects as well as the regulations and policies affecting these technologies, EFC offers the following recommendations for supporting future adoption of alternative manure management technologies on Maryland farms. With the exception of the last recommendation, which is targeted to local governments, all of these recommendations apply at the state level.

Continue State investment in alternative manure management technologies, including regionally-scaled facilities

Each of the alternative manure management technologies profiled in this report generate revenue for the host farmer and/or technology vendor. As discussed, in several cases this revenue is not sufficient to overcome added costs for construction, labor, materials, operations, maintenance, etc. over the useful life of the technology. However, the technologies' profit-generating potential sets them apart from many traditional agricultural conservation best management practices. This is significant, given Maryland's imperative to invest in cost-effective pollution reduction practices in order to comply with Chesapeake Bay TMDL mandates and meet other state water quality goals.

The State currently invests millions of dollars in nonpoint source pollution reduction efforts every year. In fiscal year 2016 alone, Maryland deployed $33.5 million to support water quality conservation practices on agricultural lands, preventing an estimated 3.1 million pounds of nutrients from entering local waterways.[27] With TMDL deadlines quickly approaching, the state needs to gain additional reductions in agricultural pollutant loads, especially reductions that can be achieved at a low cost-per-pound abated.

Given the ability of alternative manure management technologies to achieve water quality improvements at a lower cost to the public than comparable practices, they merit consideration for continued State subsidy.

Given the ability of alternative manure management technologies to achieve water quality improvements at a lower cost to the public than comparable practices (in part because they leverage private sector resources), these practices merit consideration for continued State subsidy. Support at this early stage of testing and refinement could be particularly valuable in helping these technologies become developed enough to be financially self-sustaining. As capital and operational costs come down, and as markets for the novel byproducts are established, these technologies will be increasingly

[27] Maryland Department of Agriculture. 2016. *Opening Doors for Maryland's Conservation Farmers: MACS 2016 Annual Report.* Available: http://mda.maryland.gov/resource_conservation/counties/MACS_FINAL.pdf

attractive to private investors. Though the projects do not yet represent a strong investment opportunity for individual farms, they very well may be a competitive investment alternative for the State over the long term.

It is important to note that while the first round of AWTF funding has focused on *farm-scale* demonstration projects, there may be value in extending future State support to *regional* facilities that utilize alternative manure management technologies.[28] For each of the pilot projects analyzed in this report, EFC's scenario analysis found that improved financial outcomes could be achieved through greater levels of manure input and/or larger-sized facilities. Scaled-up systems would be better positioned to realize efficiencies and economies of scale in operating the technology and producing outputs such as energy and byproducts. Further, while the alternative technologies do benefit their host farmers, the advantage of these systems extends beyond the individual farm scale. This is true from a water quality perspective, as has been discussed, but it could also be true for the broader farming community where a regional facility is located. The value of a community-scale system (composting or manure-to-energy) to individual area farmers would depend on how value is shared between the facility operator, the host entity (if applicable), contributing farmers, and farmers that purchase finished products. At a minimum, however, these facilities would offer farmers in the region a market for animal manure as well as readily available byproducts that can be used on-farm.

Consider offering tax deductions or other financial incentives to encourage desired technologies

If the State of Maryland wishes to jumpstart these and/or other alternative manure management technologies, direct subsidy via grants or other means is only one option for doing so. Another route would be to offer tax deductions or other financial incentives. Research indicates that farmers are in favor of income tax credits or deductions as a form of compensation for conservation activity, viewing them equally as appealing as direct payments.[29] The majority (82.7%) of Maryland farms are family-owned operations, rather than corporations or partnerships.[30] For family farms, any tax deductions are taken on personal income tax returns. Income tax deductions for expenses related to agricultural conservation practices are allowed at the federal level,[31] and in Maryland, purchases of eligible conservation equipment can qualify farmers to receive an income tax modification on their state tax return. Ensuring similar allowances for qualified alternative manure management practices could be built into the Maryland tax code.

Another option is to offer subsidized loans for alternative manure management projects themselves or for other farm financing needs (such as land or equipment purchases) when a desired conservation

[28] Such as MDA's 2016 award to Clean Bay Renewables, a regional scaled facility in Somerset County.
[29] Ibid.
[30] USDA Economic Research Service. "State Fact Sheet: Maryland." Updated 12/14/17.
https://data.ers.usda.gov/reports.aspx?StateFIPS=24&StateName=Maryland&ID=17854
[31] 26 C.F.R. § 1.175–2.

practice is embedded into the project.[32] Subsidized loans for agricultural best management practices are available through MDA's Low Interest Loans for Agricultural Conservation (LILAC) program, through which loans are backed by the state Water Quality Revolving Loan Fund and offered through participating lenders, typically at three to four percent below market rates.[33] Currently, all of the conservation BMPs eligible for cost-share assistance through the Agricultural Water Quality Cost-Share Program are also eligible for LILAC loans. Adding alternative management technologies to the list of eligible practices – and perhaps even offering a more deeply discounted rate for these practices – would likely increase their adoption potential.

Administer existing State subsidy and incentive programs so that they support desired technologies

Existing state subsidy and incentive programs may be amended so that they more effectively encourage alternative manure management practices. At a minimum, if the State seeks to encourage these technologies, existing programs should be evaluated to ensure they are not having the unintended consequence of *dis*-incentivizing desired technologies, by making it more profitable to continue using manure in more traditional ways.

Beyond that, programs could be modified to directly incentivize desired technologies. An example might be to preferentially target Manure Transport Program incentive funds to farmers that ship manure to eligible alternative use facilities. Or, Agricultural Water Quality Cost Share Program funds could be prioritized toward composting, M2E, or other desired projects (whether installed on an individual farm or if operated by groups of farmers on a more regional basis). This would reduce operators' out-of-pocket construction costs for such projects and encourage their adoption.

These adjustments may be made statutorily or administratively, depending on the program and the change. It would be necessary to determine the appropriate cost share or incentive rates, taking into consideration what level of incentive would – in combination with revenue from the sale of RECs, byproducts, selling back to the grid, and other sources – make a difference in project feasibility and encourage farmers to implement them. All of this would need to be balanced against the water quality improvements likely to be achieved.

Revise the Maryland Renewable Portfolio Standard to incentivize manure-to-energy

Maryland's RPS already supports alternative manure management technologies, by specifying poultry litter incineration, animal waste anaerobic decomposition, and thermal-only facilities as eligible REC-generators. Further support for M2E could be provided by amending the RPS to place these technologies in a carve-out, i.e. requiring load-serving entities to purchase a portion of their renewable

[32] Subsidized loans, credit enhancements, and other forms of financial incentives for conservation are discussed in the Environmental Finance Center's 2016 report *Financial Incentives for Water Quality Protection and Restoration on Agricultural Lands in Pennsylvania.*

[33] Maryland Department of Agriculture. 2015. "Helping Farmers Bridge the Cost-Share Gap: Maryland's Low Interest Loans for Agricultural Conservation." Available: http://mda.maryland.gov/resource_conservation/counties/LILAC.pdf

energy from projects that utilize the desired technologies. Or, the law could incorporate a geographic constraint that gives preference to renewable energy produced in high-priority watersheds, where alternative manure management would most efficiently achieve pollution load reductions in support of Maryland's TMDL targets and other water quality goals.

Promote nutrient credit trading

An active nutrient credit trading market would be a boon for alternative manure management technologies, in that it would provide a source of revenue for the pollution reductions these technologies achieve. To realize this potential, however, it will be necessary to jumpstart Maryland's dormant Nutrient Trading Program. One strategy that has been proposed to spur nutrient trading in the broader Chesapeake Bay region is the creation of a regional credit bank.[34] This bank would not only serve as a clearinghouse to facilitate nutrient credit trades; it would also stimulate the market by actively purchasing credits with public funds and/or with public-backed private investment.[35] Maryland could pursue a similar approach at the state level.

It is possible that the program will soon see stepped-up activity even in the absence of a statewide credit bank, given the recent developments at the Maryland Department of the Environment (MDE), discussed above. New MDE regulations governing credit-purchasers are scheduled to phase in beginning in 2018, and the ability of the Department to use Bay Restoration Fund monies to initiate trades could be a powerful catalyst for launching a more active marketplace.

To ensure that alternative manure management technologies in Maryland benefit from future nutrient trading, it will be necessary for the State to ensure that desired technologies are eligible to generate credits under Maryland's program. The EPA Chesapeake Bay Program and Bay area states have agreed that states should only trade reductions from practices that have been approved under the Chesapeake Bay Watershed Model. The Bay Program convened an expert technical review panel to calculate the nutrient credit benefits (pounds of pollution abated per year) that would accrue from alternative technologies. Based on the recommendations of this Manure Treatment Technologies Expert Panel, all compost and thermochemical systems would be eligible for inter-state trading within the watershed, as would technologies that generate verifiable nutrient reductions[36] (the Millennium Farm anaerobic digestion and nutrient capture system may be an example of the latter).

Drive the market for manure-to-energy and composting byproducts

Each AWTF-funded manure management technology profiled in this report generates at least one finished product that can be used on the host farm or sold to external entities. The use value and/or

[34] Chesapeake Bay Commission et al. January 2012. *Manure to Energy: Sustainable Solutions for the Chesapeake Bay Region.*
[35] Ibid.
[36] Jeremy Hanson, Virginia Tech / Chesapeake Bay Program. Interview with EFC, 11/7/16.

sale price of these byproducts is a key factor in the projects' profitability. While byproduct market development is largely a private sector consideration, it may be possible for public entities to drive the market by promoting or even requiring the use of composting and M2E byproducts in public projects. A 2012 report by the Chesapeake Bay Commission found that while some Bay states specify that compost material *can* be used in public projects, none mandated their use.[37] The Commission found that "States could do more to increase the market for manure-based compost and even biochar by promoting [their] use in public projects, especially those utilizing LID practices."[38] Even if public entities do not require the use of LID-supportive materials via regulatory means, they can encourage their use in both public and private projects via design standards, preferential purchasing policies, or other incentives.

Audit local land use ordinances for unnecessary barriers to alternative manure management practices

Local governments can play a role in encouraging – or conversely, inhibiting – the use of alternative manure management technologies. For example, local land use ordinances and zoning codes may disallow these technologies, by prohibiting certain land uses (such as manure incineration) either jurisdiction-wide or in certain zones. Or they may inadvertently limit the viability of alternative manure management applications, as in the case of Howard County's prohibition regarding the sale of compost, which reduces the profit potential of composting projects. Given the water quality and other benefits of these technologies, local jurisdictions may wish to consider auditing land use and other ordinances to identify and remove any barriers, intentional or unintentional, to the practices' adoption.

[37] Chesapeake Bay Commission et al. January 2012. *Manure to Energy: Sustainable Solutions for the Chesapeake Bay Region.*
[38] Ibid.

V. Appendix: Farm-Scale Financial Feasibility Assessments

The following pages contain financial feasibility assessments for each of the four AWTF-funded alternative manure management demonstration projects that EFC was asked to evaluate.

FINANCIAL FEASIBILITY ASSESSMENT:

In-Vessel Composting at Days End Farm, Howard County

Prepared for the Maryland Department of Agriculture by the University of Maryland Environmental Finance Center, November 2017

Background

The Maryland Department of Agriculture's Animal Waste Technology Fund (AWTF) provides grants for on-farm demonstration projects of innovative technologies for managing animal manure. These technologies are expected to reduce on-farm waste, improve water quality, and create new revenue streams for farmers in the form of cost savings and marketable byproducts.

Figure 1. Demonstration of Green Mountain Technology's in-vessel composting system at Days End Farm Horse Rescue.

Days End Farm Horse Rescue is a nonprofit, volunteer-based organization located in Howard County that cares for horses through rescue, rehabilitation, education and outreach. Founded in 1989, Days End shelters 80 to 120 horses annually, rehabilitating them and preparing them for adoption.[1]

In 2014, Green Mountain Technologies (GMT), a firm that designs and installs commercial-scale composting systems, received an AWTF grant to install an in-vessel Earth Flow composting system at Days End Farm to better manage animal waste (horse manure and used bedding material). The new system became operational in fall 2015. With a volume of 33 cubic yards, it is projected to process 300 tons of waste per year.[2] Because of the system's automated agitation and moisture control features, it is considered to be more efficient and effective than manual composting.

Expected Benefits

Days End's sheltered horses produce a total of 1.6 tons of waste per day (about 80 pounds per horse, for 40 horses kept in stalls rather than open fields).[3] All of this manure and soiled bedding material must be collected, transported and disposed of. Before installing the GMT composting system, Days End Farm landfilled this waste at a cost of $40 per ton. The new system is expected to defray 300 tons of animal waste per year (about 50% of total manure and bedding produced by sheltered horses)[4] and therefore reduce landfill costs, which is the primary expected benefit of this technology as deployed on Days End Farm. Secondary benefits relate to the finished compost product, which may be used as a bedding substitute to offset bedding costs (e.g., wood shavings) at the farm, and which could potentially be sold as a soil amendment.

Results: Financial Feasibility Assessment

The Environmental Finance Center (EFC) developed a full cost balance assessment for the GMT composter project at Days End. This assessment contrasts pre- and post-technology expenses and revenue across various modules including labor, operations and maintenance, materials and services, energy, capital costs, and byproducts. EFC developed this assessment through desktop research and interviews with the farmer, the vendor, and other specialists familiar with the technology.

Key finding: Based on available information, the GMT compost project as applied on Days End Farm will result in approximately $9,600 in annual cost savings, or a simple payback of 13.8 years relative to the initial $132,000 capital investment (see Table 1). The useful life of the technology is 15-20 years. This result excludes any benefit from selling compost (see Table footnote) as well as any environmental benefits, and it is highly sensitive to the assumption that landfilling (at $40 per ton) is the next best animal waste management option.

Table 1. *Cost assessment results for base scenario (see inputs and assumptions below)*

	Pre-Technology	**Post-Technology**	**Balance *(positive indicates cost savings or revenue)***
Labor costs ($)	548	1,077	-529
O&M, materials, and services costs ($)	25,212	14,796	10,417
Energy costs ($)	0	329	-329
Byproduct revenue ($)	0	0*	0
Sub-total	*$14,080*	*$4,521*	*$9,559*
			Summary
Capital costs			$132,161**
Annual cost savings			$9,559
Simple payback			13.8 years
Return on investment			7.23%

* While Days End Farm had anticipated being able to sell the finished compost product as a soil amendment, a Howard County ordinance prohibits the sale of compost within the county, so this assessment assumes no byproduct revenue. ** Includes $130,111 from AWTF grant award (excludes lab costs and Year 2 monitoring, evaluation and reporting) plus $2,050 out-of-pocket cost for Days End Farm for compost storage structure (e.g. hoop house).

Table 2. *Critical inputs, value, and corresponding notes*

Input Name	**Value**	**Note**
Animal waste input per year (tons/year)	292	Equals loading of .8 tons/day times 365 days/year. Higher degree of confidence after a longer performance period.
Tipping fee ($/ton)	40	Per interview with Days End Farm.
Sawdust for bedding ($/sqft)	.2	Per Tractor Supply Co.
Additional labor per year post-technology (hours/year)	530	Includes one hour per day to operate composter plus time to lay new bedding (which takes slightly longer than traditional bedding) @ $1/hour (low because Days End Farm relies largely on volunteer labor).
Percent reduction in volume from input to compost output	40%	Dependent on weather, etc. Higher degree of confidence after a longer performance period.
Value of finished compost ($/ton)	0	Howard County regulation prohibits sale of compost. See Bill No. 20-2014 [ZRA-149].
Annual O&M costs ($/year)	2,400	Per GMT interview; set at 3% of capital cost.

<u>Critical model inputs and assumptions</u>: The results for the base scenario are sensitive to inputs. In order of relative importance, the most important inputs include: the cost of landfilling as the next cheapest alternative, the total amount of animal waste managed by the composter per year, the value of compost as a marketable product, and the rate at which animal waste is converted to compost, among others (see Table 2).

<u>Scenario analysis findings</u>: The base scenario outlined above employs inputs for the Days End Farm financial model that may not be applicable to other farms looking to invest in composting technology. Namely, farms in Maryland counties other than Howard County might readily sell compost, which would introduce a new revenue stream and improve the payback period (see Scenarios A, B, D in Table 3). Likewise, it is important to question the assumption that landfilling animal waste at $40/ton is the next best animal waste management option (see Scenarios C + D in Table 3). While landfilling may be viable for smaller horse farms that can afford to avoid the hassle of managing manure, larger farms may find it necessary to deal with waste in a more cost effective way (e.g., on-site composting with manual turning or land application by cooperating farmer); this less expensive starting point would translate to lowered cost savings opportunity and a longer payback period.

Table 3. *Base scenario financial results plus four alternative scenarios with modified inputs*

	Scenario A $40/ton tipping fee + $30/ton for compost + manure input 350 tons/year*	**Scenario B** $40/ton tipping fee + $30/ton for compost*	**Base Scenario** See inputs above*	**Scenario C** $20/ton tipping fee	**Scenario D** $0/ton tipping fee + $30/ton for compost sale
Annual cost savings + revenue ($)	16,314	13,062	9,558	3,718	1,382
Simple payback (years)	8.1 < 20 useful life	10.1 < 20 useful life	13.8 < 20 useful life	35.5 > 20 useful life	95.6 > 20 useful life

* Shaded scenarios indicate a simple payback less than the useful life of the technology, a common measure of cost effectiveness.

Discussion: Transferability and Policy Considerations

The analysis above pertains specifically to Days End Farm. As discussed below, a number of factors affect whether these findings are transferable to other farms in the state, and whether investment in this composting technology will be cost effective on a given farm.

<u>Default manure management conditions</u>: While many dairy farmers see cow manure as a valuable resource, either as a source of nutrients for their own crops or as a source of revenue if it is sold to other farms, horse manure does not have the same nutritive value as a crop fertilizer. In addition, many small horse farms lack the capacity to manage manure onsite via alternatives to landfilling such as manual composting or land application. For these reasons, landfilling manure is fairly common in the recreational horse industry. However, if a farm has a cheaper default manure management option than landfilling – as is often the case for dairy and poultry operations which have a more robust market for raw manure – the cost savings of an in-vessel composting system would not be as significant.

<u>Value of byproducts</u>: The inability to sell finished compost is unique to the Days End Farm project analysis and other farms in Howard County. In other Maryland counties, a similar system would be

more likely to generate revenue from the sale of compost (See Scenarios A, B and D in Table 3, above). Again, it is important to consider a farm's default manure management technique and whether the operation can generate revenue by selling manure. This would likely be especially true for dairy operations, since cow manure has greater value as a crop fertilizer than does horse manure. The ability to sell compost and the market price of compost are secondary factors in importance relative to the cost (and revenue) associated with default manure management. Aside from compost's potential to be marketed as a soil additive, the final product may have value as bedding material for horses. Each ton of compost used as a bedding substitute saves approximately $4, or $1,200 over the course of a year with production of 300 tons of compost.

<u>Siting conditions and labor costs</u>: Capital costs and long-term operation and maintenance costs will be influenced by a candidate farm's starting conditions. In particular, electrical and support infrastructure may need to be installed in order to operate an in-vessel composting system, which would drive up the costs of installation. Conversely, if the system can be sited in a convenient location close to animal stables, a great deal of time and energy can be saved over the life of the project. Finally, a critical difference between the Days End Farm analysis and other farms is that Days End Farm relies largely on volunteer labor (at an assumed rate of $1 per hour). Based on an estimated 500 additional hours per year of labor to operate the technology – compared to the labor required to load and truck manure to landfill - if another farm had to hire and compensate an employee at $10 per hour, there could be an additional operating cost of $5,000 per year. Of course, this number will vary depending a farm's default manure management approach and its associated labor requirements.

<u>Cost share and other sources of revenue</u>: The capital costs related to installing a similar composting system could be reduced if this technology were to become eligible for financial assistance through the Maryland Agricultural Water Quality Cost-Share Program, which subsidizes best management practices for water quality management on farms. There are currently about 30 approved best management practices (BMPs) through this program, including practices such as planting streamside buffers, contour farming, and installing waste treatment lagoons. Farms with 15 animal units can receive grants to cover up to 87.5% of the cost to install such conservation measures, with a total cap of $150,000 for non-manure BMPs and up to $450,000 if manure BMPs are included.[5] This could significantly defray installation costs, if the program were to be amended. Another potential source of revenue is the Maryland Nutrient Trading Program and accompanying markets, if more robust trading activity were to occur; composting would need to be designated an eligible generator of nutrient credits, perhaps for its ability to stabilize and reduce nitrogen.

<u>Regulatory drivers</u>: Under Maryland's new Phosphorus Management Tool regulations, farms with high soil phosphorous levels will be more strictly limited in applying manure to their land, and thus will have a stronger impetus to find alternative uses for the manure they produce. Most farms subject to this regulation are poultry producing farms in the Lower Eastern Shore counties of Somerset, Wicomico, and Worcester, where an estimated 28% of the land area is not enriched with phosphorous and unrestricted in manure use, compared 79% for the state as a whole.[6] However, poultry litter is not ideal for composting because of its low moisture content, and further, composting only serves to *stabilize* phosphorus, not reduce its quantity, so it is unlikely that composting would be viable solution for such farms to comply with PMT.

A separate set of regulations affect farms statewide by prohibiting the application of any nutrient-containing material during winter months. MDA anticipates that more than 200 dairy farms statewide need additional manure storage capacity in order to comply with this rule; in total this will require more than $40 million in investments.[7] For farms that need additional storage, finding a way to reduce overall organic material volume – which composting does effectively – could be very helpful.

Private financing outlook: In the absence of public funding, it is unlikely that Days End Farm would make the investment in this composting technology. Assuming the farm had sufficient cash on hand, and it did not need to acquire any debt to complete the project, the internal rate of return on the project (i.e., ~1.04%) suggests the investment is not competitive with alternative investments the farm might make elsewhere in the economy. Moreover, for the farm to be cash positive for the duration of the project while taking on debt, it would need to secure a 15-year loan (assumed life of the system) for the entire cost of the system at an interest rate of less than 1%. Interest rates in the 1 – 1.5% range are currently available via MDA's Low Interest Loans for Agricultural Conservation program. However, even if the farm received *interest-free* financing on a 15-year loan, the net annual savings would be only about $750. Given the information at hand, it appears unlikely that this project would occur at Days End Farm and similar operations in Maryland without public financial support.

Conclusion

The GMT composting system applied on Days End Farm can be considered a cost-effective investment in innovative animal waste technology, as the simple payback on the investment is less than the useful life of the technology. Expanding the scope of analysis to consider broader transferability to other horse farms in the state, it appears the technology would be more feasible (not necessarily feasible) without grant funding if: (1) The farm's default manure management approach is landfilling; (2) The finished compost can be sold as a soil additive or used to offset bedding costs on the farm; or (3) The farm is able to take advantage of subsidized interest rates via the Low Interest Loans for Agricultural Conservation to finance the project. The technology would be even more viable if it were to become eligible for cost share assistance via the Maryland Agricultural Water Quality Cost-Share Program, and if composting were to be designated an eligible generator of credits via the state's Nutrient Trading Program.

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FINANCIAL FEASIBILITY ASSESSMENT:

Composting at Glamour View Farm, Frederick County

Prepared for the Maryland Department of Agriculture by the University of Maryland Environmental Finance Center, December 2017

Background

The Maryland Department of Agriculture's Animal Waste Technology Fund (AWTF) provides grants for on-farm demonstration projects of innovative technologies for managing animal manure. These technologies are expected to better manage on-farm waste, improve water quality, and create new revenue streams for farmers in the form of cost savings and marketable byproducts.

Figure 2. Green Mountain Technology's composting system at Glamour View Farm is housed within a permanent structure. Figure 2. The Earth Flow composting system features automated mixing and aeration equipment. Photo credits: David Kann.

Glamour View Farm, located in Frederick County, Maryland, is a 146-acre dairy operation home to 180 Holstein and Jersey cows. The farm has embraced innovative technology as a core element of its operations, using robots to milk cows and distribute feed, installing solar panels on two barn roofs to provide electricity for farm operations, and re-using purified rain water to bathe and water cows.[8]

In 2015, Green Mountain Technologies (GMT), a firm that designs commercial-scale composting systems, received an AWTF grant to install a site-built composting system at Glamour View. The patent-pending Earth Flow (EF) composting system automates mixing, aeration and moisture addition, making it more efficient and effective than manual composting. The composter at Glamour View Farm is expected to process at least 500 tons of manure per year.

Expected Benefits

Glamour View's new composting system is designed to treat manure (animal waste plus bedding material) from the heifer segment of the dairy operation, which includes about 60 cows. These animals produce approximately 500 tons of manure each year, which will be treated in the composter and then used on the farm as bedding material or fertilizer, or sold as a soil amendment. In the absence of the Earth Flow composter, this manure would either be stored in a farm field (field-stacked) or diverted to a manure lagoon for treatment, when it could then be applied on the farm as a fertilizer or sold to another farm.

The new composter improves on these default management alternatives. Field-stacking raw manure is problematic in that nutrient runoff can impair nearby streams and/or reduce productivity of cropland near the storage site. Further, new Maryland regulations limit field-stack storage of manure during the winter months, allowing it only if the material has a moisture content of 65% or less, which may necessitate the construction of additional covered storage facilities. Composting alleviates this issue by converting the media to a dryer, more stable media and reducing its overall volume, which has the dual benefit of making it eligible for field stacking as well as making it possible to store a greater amount in limited covered facilities.

Glamour View's composter also makes the management of wet manure more efficient by decreasing the volume of material put into the farm's manure lagoon, reducing electricity needs as well as wear-and-tear on lagoon components. In addition, finished compost has a good market value, comparable to or better than what Glamour View would receive for raw manure. Overall, the composter gives the farm more options for managing and storing manure while producing a consistent, easily transportable, marketable, and environmentally benign byproduct.

Results: Financial Feasibility Assessment

The Environmental Finance Center developed a full cost balance assessment for the GMT composter project at Glamour View Farm. This assessment contrasts pre- and post-technology expenses and revenues across various modules including labor, operations and maintenance, materials and services, energy, capital costs, monetized environmental costs, and byproducts. EFC developed this assessment through desktop research and interviews with the vendor and other specialists familiar with the technology and with Glamour View Farm.

Table 1. *Cost assessment results for base scenario (see inputs and assumptions below)*

	Pre-Technology	**Post-Technology**	**Balance *(positive indicates cost savings or revenue)***
Labor costs ($)	2,167	633	1,533
O&M, material, and services costs ($)	2,005	3,511	-1,506
Energy costs ($)	7,216	6,274	941
Byproduct revenue ($)	0	2,000	2,000
Sub-total	*$11,388*	*$8,418*	*$2,970*
Monetized environmental costs*	$6,000	$0	$6,000
			Summary
Capital costs			$219,106
Annual cost savings + revenue			$8,968
Simple payback on investment			24 years

* Monetized environmental costs associated with field stacking or land-applying dairy manure have not been estimated in any scientifically rigorous manner. The analysis above identifies the avoided environmental cost that would be necessary to arrive at a cost-effective project defined as the simple payback equaling the useful life of the technology.

<u>Key finding</u>: When considering only labor, energy, materials and services, and revenue from the sale of byproducts, the GMT composter as applied on the Glamour View Farm will result in annual cost savings of less than $3,000. This calculation assumes the pre-technology manure management

practice has zero value as a saleable product (because Glamour View produces more than enough manure for its own fertilizer needs, and because the market for raw manure in Frederick County is weak), and it assumes costs associated with field stacking and lagoon wear-and-tear. However, to the extent the market or the State values decreased nutrient runoff from field applied manure (e.g., via nutrient credit trading, public subsidy, etc.), and the farm can generate additional revenue, the project financial balance will improve drastically. Solving for conditions whereby the simple payback of the project is equal to the useful life of the technology (i.e., 25 years), then the project could be considered cost effective if the value of preventing raw manure from being field-applied were $12/ton or greater. Under these conditions, the total annual cost savings (internal and external costs) would be $8,968 (see Table 1).

Table 2. *Critical inputs, value, and corresponding notes for base scenario*

Input Name	Value	Note
Animal waste + bedding input per year (tons)	500	Per the vendor, Earth Flow can process as much as 1,300 tons/year, but Glamour View plans to process only approximately 500.
Pre-technology manure allocation ratio (field apply : sale)	1:0	Pre-technology, 100% of manure is field stacked and 0% of manure is sold.
Compost sale price ($/ton)	10	Conservative estimate per conversation with nutrient management expert (who suggested $12-18/ton).[9]
Post-technology revenue from compost sale ($)	1,000	Based on 200 tons of compost (40 percent efficiency of composter; 500 tons input) sold at $10/ton.
Post-technology labor commitment (hrs/year)	26.6	Accounts for labor required to load system (2 minutes per ton) compared to labor required to field stack (10 minutes per ton).
Post-technology operation and maintenance costs associated with EF system ($)	2,097	Based on 3 percent of Earth Flow equipment cost of $69,900.
Useful life of site-built EF composting system (years)	25	Per vendor.
Value per ton avoided for land-applied manure ($/ton)*	12	Set to simple payback equal to the useful life of system or 25 years based on other given inputs.
Field stacking pre-technology internalized cost per year ($)*	6,000	Based on 500 tons of manure land applied at an internalized cost of $12/ton (minimum value in order for the project's simple payback to equal the useful life of the technology; see discussion above).

* Inputs highlighted in gray are hypothetical (see discussion above).

<u>Critical model inputs and assumptions</u>: The results presented above are sensitive to key inputs and assumptions. In order of relative importance, the most important inputs include: (1) the default costs and benefits of alternative uses for manure – in this case the sale of raw manure or field storage and application – for the farmer and/or the public, (2) the amount of manure loaded in the composter per year (with higher amounts yielding greater cost savings), and (3) the price at which compost is able to be sold, as well the price differential with the sale of raw manure.

Scenario analysis findings: The base scenario outlined employs inputs that represent EFC's best understanding of operations at Glamour View Farm. However, some of the assumptions may not be applicable to other farms, and even within the Glamour View Farm operation, if the farmer elects to change operations in the future. For example, the base scenario assumes that 500 tons of manure are loaded into the composter yearly, but GMT estimates that the system could process significantly more, as much 1,300 tons per year. Likewise, the base scenario assumes that the farmer does not sell the diverted manure or need it as fertilizer, that compost is valued at $10/ton, and that compost *isn't* used for bedding at Glamour View Farm, which it may very well be at some point in the future.

The scenario analysis findings (see Table 3 below) demonstrate the impact on project feasibility associated with the change of a few key inputs. Namely, higher input capacity for the composter (the upper range of GMT's estimate) and higher dollar value for finished compost (upper end of the range estimated by Glamour View's nutrient management consultant) yield a better payback (Scenarios A + B). Additionally, if the farmer were interested in using the compost as a bedding substitute, there is significant savings potential (Scenario C), as the current cost of bedding is around $.9 cubic foot for shaved wood. If the farmer had previously been using raw manure as fertilizer and substituted finished compost for manure, however, annual cost savings decrease and the project's simple payback period may exceed its useful life (Scenario D). Similarly, if the farmer had been extracting value from raw manure via sale to other farmers, financial feasibility of the composting project decreases (Scenario E).

Table 3. *Base scenario financial results plus five alternative scenarios with modified inputs**

	Scenario A 1,300 tons/year input, $10/ton compost sold	**Scenario B** 500 tons/year input, $18/ton compost sold	**Scenario C** 500 tons/year input, compost used to offset bedding*	**Base Scenario** See inputs above**	**Scenario D** 500 tons/year input, compost used on farm as fertilizer***	**Scenario E** 500 tons/year input, pre-technology manure sales****
Annual cost savings + revenue ($)	26,002	10,568	18,903	8,968	6,219	7,219
Simple payback (years)	8.1 < 25 year useful life	20.7 < 25 year useful life	11.8 < 25 year useful life	24.4 < 25 year useful life	35.2 > 25 year useful life	29.3 > 25 year useful life

* Assumes zero sales of compost, which instead goes to offset bedding costs. Assumes composter produces 12,705 cubic feet of compost material per year, which is used to offset fresh shavings valued at .9 $/cubic feet; ** All scenarios assume $12/ton for monetized environmental cost of avoiding land applied manure, the minimum value needed in order for the technology's simple payback to equal its useful life, as discussed above. *** Assumes that finished compost is substituted for raw manure as on-farm fertilizer; due to conversion of manure to compost at 40% efficiency, farmer must purchase 300 tons/year of manure at $2.5/ton. ****Assumes pre-technology sale of raw manure at $2.5/ton, and implies that after conversion to compost, operation takes a loss by selling compost instead of raw manure.

Discussion: Transferability and Policy Considerations

The analysis above pertains specifically to Glamour View Farm. As discussed below, a number of factors affect whether these findings are transferable to other farms in the state, and whether investment in this composting technology will be feasible on a given farm.

Default manure management costs: The greatest determinant of whether composting is a cost-effective alternative is the farm's default manure management options. If a farm is able to regularly sell raw manure at a high price, and the cost of shipping it is not prohibitive, it will be more challenging for composting to demonstrate cost effectiveness. Likewise, if a farm can use manure to fertilize its own cropland (while complying with nutrient management regulations), there is a reduced financial incentive to invest in composting technology. On the other hand, if the farm cannot use or does not need manure to fertilize its own crops, or if there is a weak local market for manure, composting will be a more financially compelling option, especially if there is a strong market for finished compost.

For all these reasons, manure composting technology is more likely to be cost effective for dairy and horse farms than for poultry operations. Poultry litter is relatively dry, light and easy to ship, and it has ready buyers. Dairy manure, on the other hand, does not enjoy as strong demand and it is more expensive to transport, even when there is demand. While farms can get cost share assistance via the state's Manure Transport Program, it still is not typically cost-effective to ship dairy manure long distances. Horse manure has low nutritive value and thus isn't in demand as fertilizer. For farms in areas with soils that are over-enriched with phosphorous (and thus subject to new, more rigorous state phosphorous regulations), composting might be especially cost effective, as it reduces manure's volume (meaning more can be stored in limited storage facilities) as well as its moisture content and weight (meaning it can be shipped at lower cost). In these cases, a composting system may prove more profitable than the next-best alternative of building additional manure storage facilities, which can cost $200,000 or more and still present manure management complications.[10]

<u>Value of byproducts:</u> Closely related to the previous factor is the price at which a farm is able to sell raw manure or compost. This varies by location and across nutrient compositions. In general, finished compost is more valuable than manure (selling for $10-18/ton compared to $2.50/ton),[11] because it is stable, pathogen-free, familiar to consumers, and has broader markets than raw manure, including landscaping and plant nursery applications. Further, as discussed above, compost is drier than raw manure and thus easier and cheaper to ship. However, the process of converting organic material into compost results in a 30 to 50 percent reduction in volume, so even though compost commands more per-pound, farmers would have a greater quantity to sell if the product was raw manure versus finished compost.

<u>Capital costs and other sources of revenue</u>: The capital cost of Glamour View's composting system was $69,900. Design, permitting, site prep and installation were an additional $134,099. As they are location-dependent, site prep costs may vary greatly depending on the available space and necessary infrastructure installation. Design and permit costs may vary as well, meaning that total capital expenditures to begin operations may be higher or lower. Further, a farmer's share of capital costs for a similar composting system could be reduced if this technology were to become eligible for financial assistance through the Maryland Agricultural Water Quality Cost Share Program, which subsidizes best management practices for water quality management on farms. There are currently about 30 approved BMPs through this program, including practices such as planting streamside buffers and installing waste treatment lagoons. Eligible farms can receive grants to cover up to 87.5% of the cost to install such conservation measures, with a total cap of $150,000 for non-manure BMPs and up to $450,000 if manure management BMPs are included.[12] Adding composting as an approved BMP under this program could defray installation costs and incentivize farmers to pursue this technology.

Regulatory drivers: Under Maryland's new Phosphorus Management Tool (PMT) regulations, farms with high soil phosphorous levels may be more strictly limited in applying manure to their land, and thus may have a stronger impetus to find alternative uses for the manure they produce. Most farms subject to this regulation are poultry producers in the Lower Eastern Shore counties of Somerset, Wicomico, and Worcester, where an estimated 30% of the land area is not required to use the PMT to manage phosphorous use, compared 79% for the state as a whole.[13] However, poultry litter is not ideal for composting because of its low moisture content, and further, composting only serves to *stabilize* phosphorus, not reduce its quantity, so it is unlikely that composting would be viable solution for such farms to comply with PMT (and, as mentioned above, strong demand for raw poultry litter means that poultry operations don't have a great incentive to pursue composting in the first place).

PMT might make a bigger difference for dairy farms that are subject to the regulations, or in regions where the new regulations apply to many farms because of widespread phosphorous over-enrichment. Restricted in how much manure can be field applied or sold to nearby farms (if they are also subject to PMT), these operations have two main alternatives: build more manure storage facilities and ship manure out of the region, or invest in alternative manure management systems such as composting system that changes the material's physical characteristics and may broaden available market uses.

Beyond PMT, farms statewide are subject to regulations that prohibit the application of any nutrient-containing material during winter months. MDA anticipates that more than 200 dairy farms across the state need additional manure storage capacity in order to comply with this rule; in total this will require more than $40 million in investments.[14] For farms that need additional storage, finding a way to reduce overall organic material volume – which composting does effectively – could be tremendously helpful.

A final policy driver affecting financial feasibility of composting projects on other Maryland farms is Maryland's Nutrient Trading Program and accompanying markets. If composting were to be designated an eligible generator of nutrient credits – and if the market were to start to see stepped-up trading activity – composting would represent a potential source of revenue for farmers.

Private financing outlook: Grant funding via the Animal Waste Technology Fund makes the Glamour View project financially feasible. If the farm had to take on a 25-year term private loan to finance the project with an interest rate above 1 percent, base scenario assumptions would not support the investment. Assuming the farm had sufficient cash on hand, and it did not need to acquire any debt to complete the project, the internal rate of return on the project (i.e., ~.012%) suggests the investment is not competitive with alternative investments the farm might make elsewhere in the economy. Moreover, for the farm to be cash positive for the duration of the project while taking on debt, it would need to secure a 25-year loan (assumed life of the system) for the entire cost of the system at an interest rate close to zero. Interest rates in the 1 – 1.5% range are currently available via MDA's Low Interest Loans for Agricultural Conservation program.

Yet it is important to note that even relatively small changes in assumptions – higher input to the composter, greater sale value for finished product, using compost to offset bedding – would make this project more realistic as a privately financed endeavor (see Scenarios A, B, and C, above).

Similarly, lower capital costs – which could be achieved by constructing a simpler hoop house to contain the composter, for example – could improve the cost effectiveness of a similar project.

Conclusions

On-site manure composting reduces the volume of raw manure and stabilizes its nutrient content, producing a material that is easier and more cost effective to store, sell, and transport, and that typically commands a higher price than raw manure. For medium to large dairy operations facing significant manure management costs, and/or those subject to regulations limiting the application of raw manure, composting represents a potentially profitable alternative.

As applied on Glamour View Farm, however, the GMT compost project cannot be considered a cost-effective investment unless external costs are included. Namely, without the value-added to the farmer or to the public through the avoidance of field applying manure (the predominant alternative to composting), the simple payback on the investment is greater than the useful life of the technology.

Expanding the scope of analysis to consider broader transferability to other farms in the state, it appears the technology would be more feasible (not necessarily feasible) if: (1) The farm's default manure management strategy yields little revenue and/or incurs significant costs, as is likely to be the case for farms in areas with a weak or unstable manure market, such as horse farms statewide and dairy farms in areas subject to PMT regulations; (2) The finished compost can be sold as a soil amendment or used to offset bedding costs on the farm; (3) The farm is able to take advantage of subsidized interest rates via the Low Interest Loan for Agricultural Conservation to finance the project; or (4) The technology were to become eligible for cost share assistance via the Maryland Agricultural Water Quality Cost Share Program, or if it were to be designated an eligible generator of credits via the state's Nutrient Trading Program, which would compensate farmers for preventing raw manure from field application.

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FINANCIAL FEASIBILITY ASSESSMENT:

Fluidized Bed Combustion at Double Trouble Farm, Dorchester County

Prepared for the Maryland Department of Agriculture by the University of Maryland Environmental Finance Center, January 2018

Background

The Maryland Department of Agriculture's Animal Waste Technology Fund (AWTF) provides grants for on-farm demonstration projects of innovative technologies for managing animal manure. These technologies are expected to better manage on-farm waste, improve water quality, and create new revenue streams for farmers in the form of cost savings and marketable byproducts.

Figure 3. Fluidized bed combustion system at Double Trouble Farm. Credit: BHSL. Figure 2. Chicks raised in poultry houses heated by the new FBC system. Credit: Edwin Remsburg.

Double Trouble Farm, located in Dorchester County, Maryland, is a poultry operation that raises chickens for the integrator Mountaire. Double Trouble has partnered with Biomass Heating Solutions Inc., a corporation that specializes in manure-to-energy technologies, to install a fluidized bed combustion system (FBC) at the farm.

The technology converts poultry litter into heat and electricity, by suspending litter above upward-blowing streams of air during a combustion process. This creates a turbulent mixing of gas and solids and improves the efficiency of chemical reactions and heat transfer.[15] The technology has been used in power plants for decades, and BHSL's Irish arm has successfully used FBC in poultry operations in Europe. However, the system at Double Trouble Farm is the first such application in the United States.

Expected Benefits

The FBC system at Double Trouble Farm processes about 1,000 tons of poultry litter per year (with capacity for up to 3,300 tons/year), generating energy to heat four poultry houses and offsetting the need for purchased propane. The system also produces a high-phosphorous and high-potassium ash byproduct. While the market for this product is still being developed, initial sales indicate a market value of $65/ton and this value is expected to rise. In addition to introducing a new revenue stream for the farmer, production of this byproduct benefits regional water quality by enabling the majority of the phosphorous found in poultry litter to be captured and either sent out of the Chesapeake Bay region or recycled on farmland where the nutrient management plan calls for additional phosphorous inputs.

Another expected benefit of the FBC system is the production of additional energy (beyond what is needed for poultry house heating) that can be converted to electricity and sent to the grid to offset the farm's electricity costs. The output of Double Trouble's system has proven insufficient to capture this benefit, but future systems may be sized to take advantage of net metering. Another initial expected benefit of the technology was improved growth rates and improved feed conversion efficiencies for poultry raised in houses heated by the FBC system (which produces a dryer, healthier heat compared to propane and allows for increased ventilation which reduces ammonia levels in the houses). This benefit has been achieved in European applications of the technology, but flocks raised via Double Trouble's system to date have not demonstrated statistically significant altered growth rates or feed conversion rates.

Results: Financial Feasibility Assessment

The Environmental Finance Center developed a full cost balance model for the FBC system at Double Trouble Farm. This assessment contrasts pre- and post-technology expenses and revenue across various modules including labor, operations and maintenance, materials and services, energy, capital costs, and byproducts. EFC developed this assessment through desktop research and interviews with the vendor and other specialists familiar with the technology.

Table 1. *Cost assessment results for base scenario (see inputs and assumptions below)*

	Pre-Technology	**Post-Technology**	**Balance *(positive indicates cost savings or revenue)***
Labor costs ($)	2,773	3,057	-284
O&M, materials, and services costs ($)	2,000	24,343	-22,343
Energy costs ($)	30,727	1,703*	29,024
Byproduct revenue ($)	18,000**	9,100	-8,900
Sub-total	*$17,500*	*$20,003*	*-$2,503*
			Summary
Capital costs			$2.73 M
Annual cost savings + revenue			-$2,503
Simple payback on investment			Infinite
Return on investment			N/A

* Includes revenue from the sale of renewable energy credits. ** Includes revenue from the sale of unprocessed poultry litter.

<u>Key finding</u>: Based on available information, the fluidized bed combustion system at Double Trouble Farm appears to result in approximately $2,503 in annual losses for the farmer and/or vendor (see Table 1). The project benefits from a $29,024 net decrease in the energy line, due to avoided energy expenses and the sale of renewable energy credits. Also beneficial to the project's bottom line is the sale of the ash byproduct at a value of $65/ton. However, these benefits are offset by an $22,343 increase in operations and maintenance, materials, and services costs, as well as by substantial lost income from the sale of unprocessed litter (estimated to be worth a total of $18,000 at the price of $18/ton).

This result does not account for any environmental impacts from operating the system, such as reduced water quality degradation from land application of untreated poultry litter. Further, it does not include revenue from net metering or accelerated poultry growth rates, since initial performance has not borne out these anticipated benefits as discussed above. For the project to be considered cost effective, defined here as having a simple payback less than the useful life of the technology, or 25 years, the system would need to yield cost savings and/or revenue totaling approximately $110,000 per year through enhanced bird production, byproduct sales, net metering, nutrient trading credit sales, and/or monetized environmental benefits.

Table 2. *Critical inputs, value, and corresponding notes for* ***non-energy factors***

Input Name	Value	Note
Poultry litter input (tons/year)	1,000	Average of 1.88 tons per day for 275 days per year (average number of days poultry is on farm), doubled to reflect heating all four houses instead of two.
Additional labor post-technology (hours/year)	284	22 hours to move/raise fans to facilitate cleaning; 61 hours to clean ash bag every 1.5 days at 15 minutes per cleaning; 70 hours to market and package ash or .5 hours per ton produced. Labor cost set at $20/hour.
Pre-technology revenue from sale of litter ($/year)	18,000	1,000 tons sold at a rate of $18/ton. Subsidized via the Maryland Manure Transport Program.
Post-technology operations and maintenance costs ($/year)	21,943	Based on $25K median from $20K-$30K BHSL estimate, less labor costs explained above.
Total capital costs ($)	2.73 million	Sum of $960,000 from MDA AWTF state award and $1,768,000 remaining capital investment from BHSL.
Quantity of ash produced (tons/year)	140	Based on 14 percent conversion rate from input litter to output ash, as provided by BHSL.
Post-technology revenue from the sale of ash ($/year)	9,100	Based on initial market value of $65/ton (BHSL anticipates higher values, up to $150/ton once market is developed).
Useful life of the technology (years)	25	Mid-range estimate; vendor anticipates 20-30 years.

Table 3. *Critical inputs, value, and corresponding notes for* ***energy factors***

Input Name	Value	Note
Pre-technology purchased electricity costs ($/year)	17,879	248,172 kWh combined usage at 4 houses
Pre-technology purchased propane costs ($/year)	12,848	Total of 21,414 gallons of propane consumed per year to heat four poultry houses.
Post-technology electricity output (kWh)	99,645	Based on 65 kW x 8,400 hours/year x 25% efficiency* minus 2,200 hours/year when heating/steam delivery takes priority over electricity output. *Monitored efficiency during first year was closer to 10% due to mechanical issues but 25% is used as a reasonable expectation w/ continual operation.
Post-technology electricity usage (kWh/year)	273,172	25,000 kWh annual usage from heater-fans plus baseline 248,172 kWh (see above).
Post-technology net electricity export per year (kWh)	0	The FBC system is currently using more electricity than it is producing.

Revenue from the sale of Tier 1 renewable energy credits ($/year)	2,048	Based on 137 MWh/year production and an annual Tier 1 REC price of $15/MWh, or the average price in Maryland in 2016 for a Tier 1 REC plus another 115 MWh of equivalent thermal RECs sold at the same price.
Post-technology diesel costs ($/year)	1,000	Based on back-up/auxiliary power for combined heat and power generator at the assumption of 667 gallons per year at $1.5/gallon.
Post-technology net energy costs ($/year)	1,703	Based on renewable energy credit revenue less diesel and other energy costs.

Critical model inputs and assumptions: The results for the base scenario are sensitive to inputs. In order of relative importance, the most important inputs include: (1) sale of raw poultry litter at a rate of $18/ton (the market value for litter may reasonably be expected to decrease as Phosphorous Management Tool regulations come into full effect, as is discussed in the Transferability and Policy Considerations section below); (2) Double Trouble Farm's lower-than-anticipated electricity output and inability to realize revenue from net metering; and (3) the market value for system's high-phosphorous ash byproduct at $65/ton (value is expected to rise).

Scenario analysis findings: Table 4, below, depicts four alternatives to the base scenario described above. These demonstrate the impact that changes to key inputs can have on the project's payback period and overall financial feasibility. Altered inputs represent reasonable but theoretical assumptions, not necessarily realistic expectations based on the pilot project's initial performance.

Scenario A assumes greater energy output of the FBC system's generator, with an efficiency rate of 77.5% (as originally modeled) compared to the lower rate based on the system's initial performance. With the generator operating more continually and efficiently, Double Trouble could see a net electricity export of ~36,000 kWh/year, which at the retail electric rate of $.12/kWh would produce $4,287 in revenue from net metering per year. The resulting overall annual net revenue of $6,085 would put Double Trouble's FBC system in the black, but it would not be sufficient to produce a positive payback period for the project.

Profitability would improve slightly if the farmer were able to earn revenue from the sale of nutrient trading credits, as shown in **Scenario B**. Because a nutrient credit market has not emerged in Maryland, this scenario uses Virginia credit values as proxies and is fairly theoretical. It yields $10,137 in annual revenue from credit sales, for a total net annual revenue for the project of $7,634. The payback period on the $2.73 million investment is still significantly higher than the technology's useful life.

Scenario C depicts a situation that is somewhat likely over the long-term (i.e. within the coming fifteen years), in which the market value for poultry litter is reduced. This scenario assumes a sale value of $5/ton, compared to $18/ton in the base scenario. By dampening the farmer's pre-technology revenue potential, this scenario improves the FBC system's financial picture, with annual net cost savings plus revenue rising to $10,498. While an improvement over the base scenario, this result is not enough to demonstrate financial feasibility when considering the payback period.

A situation much closer to achieving feasibility is modeled in **Scenario D**, which accounts for improved health of chickens raised in houses heated by the FBC system. As discussed above, improved bird health was an expected benefit of the system, as European applications of the technology have shown that poultry raised on the FBC system's relatively dry heat experience accelerated growth compared to birds raised in control houses. This scenario assumes an additional half pound per bird by production time, for four poultry houses and four flocks per year. At an average price per pound of $2.8,[16] this scenario generates $89,600 per year in additional revenue, and $87,098 in total annual net revenue. The simple payback period is 31.3 years – just above the vendor's upper-range estimate of the technology's useful life.

Incorporating the revised inputs from *all* the above scenarios portrays a best-case scenario in terms of project feasibility. This would yield $118,821 annual net revenue and a simple payback period of 22.9 years relative to the initial investment.

Table 4. *Base scenario financial results plus four alternative scenarios with modified inputs*

	Scenario A 36K kWh/year export	**Scenario B** Sale of nutrient credits	**Base Scenario** See inputs above	**Scenario C** Pre-technology litter sales at $5/ton	**Scenario D** Accelerated poultry growth rate
Annual cost savings + revenue ($)	6,085	7,634	-2,503	10,498	87,098
Simple payback (years)	448 > 25 year useful life	357 > 25 year useful life	Infinite > 25 year useful life	260 > 25 year useful life	31.3 > 25 year useful life

Discussion: Transferability and Policy Considerations

The analysis above pertains specifically to Double Trouble Farm. As discussed below, a number of factors affect whether investment in this technology will be feasible on other farms in the state.

<u>Capital costs and additional sources of revenue</u>: The total cost for engineering, permitting, and constructing Double Trouble Farm's FBC system was $2.73 million. These capital costs can be expected to vary in future installations due to differing siting conditions, infrastructure needs, local sourcing of materials, and other factors. Further, as the FBC technology is tested and refined over time, capital expenditures for future systems may reasonably be expected to decrease.

The profitability of future applications of this technology would also improve if the project could take advantage of revenue opportunities such as nutrient credit trading and/or augmented revenue from net metering. Appropriate sizing of the generator to farm size and output potential are important for future systems to benefit from connection to the regional electricity grid.

The profitability of future FBC systems will also be affected by their ability to tap into existing or new sources of state or federal support via subsidy or incentive programs. For example, access to cost-share assistance offered through the Maryland Agricultural Water Quality Cost Share Program would reduce farmers' out-of-pocked expenses for installing the system.[17] Such assistance may be necessary to help bridge the gap until the technology is able to become financially self-sustaining.

Byproduct value: The high-phosphorous ash produced via the FBC process is a fertilizer source with various potential applications and markets. From a regional water quality perspective, a major benefit of this product is that it captures the majority of phosphorous found in poultry litter into a form that can be marketed and sold outside the Chesapeake Bay region, where phosphorous input is in demand. However, the ash is a novel product and its market is still being explored and developed. BHSL estimates a market value ranging from $65 (actual price for initial sales) to $150 per ton. To the degree that robust demand and a good market price for this product develop, revenue opportunities for future FBC implementers will increase.

Regulatory drivers: As with other advanced manure management practices, multiple state and federal regulatory drivers have the potential to affect the profitability of poultry litter FBC systems. Chief among these is Maryland's **Phosphorus Management Tool** (PMT) requirements, which begin to go into effect in 2018 and will more strictly limit phosphorous application on Maryland farms with high soil phosphorous levels. PMT is likely to have the greatest impact on Maryland's Eastern Shore (Somerset, Wicomico, and Worcester counties), where only an estimated 28% of the land area is not required to use the PMT to manage phosphorous, compared to 79% for the state as a whole.[18] Poultry farmers on the Eastern Shore have historically applied poultry litter as fertilizer on their own grain fields, or they have sold litter to other grain farmers in the region. By making these manure management practices less feasible, PMT is likely to have the effect of encouraging alternative uses for poultry litter.

Maryland's **Renewable Energy Portfolio Standard** provides further impetus for future FBC applications, by specifying poultry waste-to-energy technologies as eligible generators of renewable energy credits and thereby introducing a valuable revenue stream for project operators.[19] Additional revenue for systems like this one could also come in the form of nutrient credit sales, if Maryland's dormant **Nutrient Trading Program** were to see trading activity. This technology would need to be designated an eligible generator of nutrient credits under Maryland's program, as recommended by a Manure Treatment Technologies Expert Panel convened by the US EPA Chesapeake Bay Program.[20]

Some federal regulations may increase the operational cost of FBC systems, namely, Clean Air Act rules (administered by the state) that limit emissions from incineration facilities in nonattainment areas according to National Ambient Air Quality Standards. However, another federal regulatory driver may have the opposite – positive – effect on FBC and other advanced manure management technologies. The US EPA's **Chesapeake Bay Total Maximum Daily Load** (TMDL) mandates pollution reductions for all Bay states, incentivizing them to find cost-effective means of reducing agricultural and other nonpoint sources of pollution.[21] Because technologies like FBC have innate profit-generating potential and thereby the potential to engage private sector capacity (financial and otherwise), they represent a worthwhile target for investment of state funds for water quality restoration.

Conclusions

Based on available information from the initial performance period, the pilot fluidized bed combustion system at Double Trouble Farm does not appear to generate sufficient cost savings and revenue to overcome project costs, which suggests that this technology may not be a viable investment for other farmers in similar situations. However, these results are highly sensitive to inputs that could reasonably be expected to change as the project's performance period lengthens. While initial flocks have not demonstrated expected accelerated growth rates, it is possible that this benefit may be realized as the system's operations become more streamlined and efficient over time. Additionally, the farm-scale financial scenario for this and future installations of the FBC technology is likely to change in light of PMT requirements, which have long-term potential to depress the market value of raw poultry litter, as discussed above.

Considering the transferability of this technology to other farms in Maryland, it appears that it will be more feasible if (1) PMT regulations have the expected effect on the market value of poultry litter and consequently on the demand for alternative uses; (2) the system is sized appropriately to realize revenue from net metering when connected to the regional electricity grid; and (3) the project is able to capture most or all of the technology's revenue-generating opportunities, including robust byproduct sales, REC sales, and increased value from higher-weight birds.

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FINANCIAL FEASIBILITY ASSESSMENT:

Poultry Litter Anaerobic Digestion and Nutrient Capture at Millennium Farm, Worcester County

Prepared for the Maryland Department of Agriculture by the University of Maryland Environmental Finance Center, January 2018

Background

The Maryland Department of Agriculture's Animal Waste Technology Fund (AWTF) provides grants for on-farm demonstration projects of innovative technologies for managing animal manure. These technologies are expected to manage on-farm waste, improve water quality, and create new revenue streams for farmers in the form of cost savings and marketable byproducts.

Figure 5. Planet Found Energy Development's anaerobic digestion and nutrient capture system at Millennium Farm. Credit: PFED.

Millennium Farm is a four-house poultry operation and grain producer located on Maryland's Eastern Shore in Worcester County. In 2014, Millennium Farm partnered with Planet Found Energy Development (PFED), a startup manure management technology company, to install a pilot-scale anaerobic digestion and nutrient capture system (AD + NCS) at the farm. Funded in part by an AWTF grant, this system uses a combined heat and power generator to convert poultry litter into methane gas that can generate heat and/or electricity. The system is designed to process 1,200 tons of poultry litter per year, and it became operational in spring 2017.

Expected Benefits

The AD + NCS system at Millennium Farm is a pilot facility, with primary purposes of testing and refining the technology, building the market for nutrient-adjusted byproducts, and exploring future models for scaling-up the system. Other expected benefits of the pilot and/or future facilities include the production of heat and electricity to accommodate system parasitic demand, the generation of excess electricity that can be net metered back to the farm to offset costs, and the production of excess heat to offset propane costs for poultry house heating.

Additionally, the nutrient capture portion of the system separates out the major nutrients found in poultry litter (nitrogen, phosphorous, and potassium) after the litter has been processed by anaerobic digestion and partitions these nutrients into three by-products: a soil amendment, a potting soil, and a high-phosphorous fertilizer that can be sold out of the region. All of these byproducts represent either a revenue stream or source of value for their on-farm use. Other potential benefits for the farmer or vendor include revenue from the sale of renewable energy credits and/or nutrient trading credits.

In addition, poultry litter AD + NCS systems like the one installed at Millennium Farm are expected to have broader regional benefits on Maryland's Eastern Shore. Chief among these is reduced agricultural pollution to local streams and the Chesapeake Bay, due to avoidance of direct land application of unprocessed poultry litter as well as the stabilization and partitioning for formulation of nutrients in the finished byproducts. With the high-phosphorous byproduct able to be sold out of the region and the remaining soil amendment lower in phosphorous, the technology enables the region's farmers to continue deriving value from poultry litter despite new Maryland state regulations that limit the application of phosphorous on certain cropland with high risk of phosphorus movement, as discussed in greater detail in the Transferability and Policy Considerations section, below.

Results: Financial Feasibility Assessment

The Environmental Finance Center developed a full cost balance model for the pilot scale anaerobic digestion and nutrient capture system at Millennium Farm. This assessment contrasts pre- and post-technology expenses and revenues across various modules including labor, operations and maintenance, materials and services, energy, capital costs, and byproducts. EFC developed this assessment through desktop research and interviews with the vendor and other specialists familiar with the technology and with Millennium Farm.

Table 1. *Cost assessment results for base scenario (see inputs and assumptions below)*

	Pre-Technology	**Post-Technology**	**Balance *(positive indicates cost savings or revenue)***
Labor costs ($)	5,648	48,000	-42,352
O&M, materials, and services costs ($)	-1,825*	96,000	-97,825
Energy costs ($)	58,000	58,000	0
Byproduct revenue ($)	0	16,800	16,800
Sub-total	*$61,823*	*$185,200*	*-$123,377*
			Summary
Capital costs			$1,832,137
Annual cost savings + revenue			-$123,377
Simple payback on investment			Infinite
Return on investment			N/A

* Includes value of poultry litter as on-farm fertilizer ($9,125) minus O$M, materials and services costs.

<u>Key finding</u>: Based on available information, the pilot scale AD + NCS system as applied on Millennium Farm will result in approximately $123,377 annual losses for the farm and/or Planet Found Energy Development (see Table 1). O&M, materials and services is the most significant line item, with a post-technology increase of $97,825. Labor costs are also significantly higher post-technology ($42,352). Favorable to the project's bottom line is the value from use or sale of three byproducts, estimated to be worth a total of $16,800. Not included in this result is any benefit from the use or sale of excess energy, as discussed below, or environmental impacts associated with the technology (monetized or otherwise).

An important note is that due to mechanical delays, the facility is not yet operating at full capacity, processing only about 1 ton per day, compared to the 3.3 tons it is designed to process. The vendor anticipates that at full capacity, the system will generate energy in excess of its own operational needs.[22] However, even if operating at full capacity, the pilot AD + NCS system at Millennium Farm is not expected to be financially viable at a farm scale, nor was it intended to be. Rather, the system was designed and installed with the purpose of testing and refining the technology in order to support future installations. The real anticipated value of this technology – both to operators and to the region more broadly – will be in its scale-up to a significantly larger system that is designed to process poultry litter on a regional basis.

Table 2. *Critical inputs, value, and corresponding notes*

Input Name	Value	Note
Poultry litter input (tons/year)	365	System is designed to process 1,200 tons/year but is not operating at full capacity.
Pre-technology litter allocation ration (stored / field applied : sale)	1:0	Pre-technology, 100% of litter was applied as crop fertilizer and/or stored in a standard poultry litter manure shed and 0% was sold to other farmers. Per farmer/vendor.
Pre-technology labor costs ($/year)	5,648	Labor to clean poultry houses and to load and transport litter from houses to field for application.
Post-technology labor costs ($/year)	48,000	Salary for one full-time skilled facility operator employed to run the pilot AD + NCS facility.
Pre-technology revenue from sale of litter ($/year)	0	Pre-technology, Millennium Farm did not sell litter but rather used it on-farm to fertilize its grain crops.
Pre-technology value of litter as on-farm fertilizer ($/year)	9,125	365 tons/year at an average market price of $25/ton, the amount Millennium would have to pay if purchasing litter as fertilizer.
Post-technology operations and maintenance costs ($/year)	22,054	Maintenance costs estimated at 2.5% of capital costs annually (construction, engineering, site prep, equipment), plus $29,000 operations costs, which include chemicals and product transport.
Total capital costs ($)	1.83 million	Represents direct costs for surveying, site prep, engineering, equipment and construction but excludes some early project costs (such as R&D, staff time to seek funding, etc). Accounts for $1,221,470 from MDA, MEA and other grants, with remaining capital investment from PFED.
Purchased electricity costs pre-and post-technology ($/year)	20,000	Per vendor/farmer. Equates to 152,672 kWh total usage at 4 houses at .131 $/kWh average commercial electricity rate on Maryland's Lower Eastern Shore. System is not producing excess energy.
Purchased propane costs pre- and post-technology ($/year)	28,500	Per vendor/farmer. Equates to 47,500 gallons of propane use per year at EIA estimated wholesale prices of $0.6/gallon. No change post-technology.
Net electricity export per year (kWh)	0	Pilot system is currently not meeting its own energy demands.
Soil amendment byproduct produced per year (tons)	161	Based on 50 percent conversion rate from dry litter input to soil amendment output. Conversion rates per vendor.

Post-technology revenue from sale or on-farm use of soil amendment ($/year)	8,050	Based on mid-range estimated market value of $50/ton. Per vendor. May be either sold or used on-farm as fertilizer to offset poultry litter
Potting soil produced (tons/year)	193	Based on 40 percent conversion rate from dry litter input to potting soil output. Conversion rates per vendor.
Post-technology revenue from sale of potting soil ($/year)	6,755	Based on minimum estimated market value of $35/ton. Per vendor.
High-phosphorous fertilizer produced (tons/year)	57	Based on 10 percent conversion rate from dry litter input to fertilizer output. Conversion rates per vendor.
Post-technology revenue from sale of fertilizer ($/year)	1,995	Based on minimum estimated market value of $35/ton. Per vendor.
Useful life of the technology (years)	20	Per vendor.

Critical model inputs and assumptions: The results for the base (pilot-scale) scenario are sensitive to inputs. In order of relative importance, the most important inputs include: (1) the capacity of the system, with higher amounts of litter loaded per year yielding greater cost savings and revenue, (2) the cost of labor, operations, maintenance and service, relative to pre-technology conditions, and how costs are shared between the vendor and host farmer, and (3) the amount of revenue generated from the sale of byproducts, renewable energy credits and nutrient trading credits.

Scenario analysis findings: The base scenario outlined above employs inputs for the Millennium Farm pilot scale system that would not apply to future applications of this technology, as PFED does not anticipate offering the system at the individual farm scale but rather at a significantly larger community or regional scale. However, the pilot scale financial model can be used to demonstrate that changes to a few key inputs and assumptions can impact project feasibility, as illustrated in the scenario analysis findings (see Table 3, below).

For example, higher input of poultry litter to pilot system, so that it is processing its full capacity of 1,200 tons/year (**Scenario A**) yields roughly $54,000 in annual byproduct revenue, as well as annual energy savings of $46,190 above the base scenario, due to the ability to realize revenue from net metering and REC sales. However, this scenario still results in annual losses ($19,655). Financial feasibility improves slightly if the farm or vendor is able to tap into the nutrient credit trading market, which in effect monetizes avoided environmental costs (**Scenario B**). This scenario – which also assumes the system operates at its full 1,200 ton/year input capacity – yields a theoretical revenue of about $12,000/year from the sale of nutrient credits. However, the project would still result in net annual losses, as additional revenue is not enough to outweigh project costs. Greater improvements in farm-scale financial feasibility are realized if labor costs for operating the system are externalized to the project (e.g. borne by the vendor rather than the farmer), as shown in **Scenario C**. This scenario yields annual cost *savings* of $88,509. However, the simple payback on the initial $1.8 million investment would be 32 years, longer than the technology's anticipated useful life.

The system's real potential for profitability, however, depends on system being sized significantly larger than the pilot farm-scale model. PFED has completed projections for various iterations of this larger system, including a public-private partnership model that is portrayed in **Scenario D**. In this scenario, PFED contracts with a public entity such as a college or university to construct and operate a

1.5 MWh facility capable of processing 50,000 tons of poultry litter per year. Capital costs are $8.58 million, and annual costs for materials, services and operations are $4.5 million. In this scenario, PFED does not pays poultry farmers for litter but does assume the cost of cleaning out poultry houses and transporting litter to the facility. The model generates $5.4 million in annual revenue, including not only proceeds from the sale of byproducts and nutrient trading credits but also as much as $220,000 in state subsidies including incentives eligible from the Manure Transport Program. Additionally, the model incorporates revenue from the host entity via an operations contract. With annual profits of $427,323, this scenario yields a simple payback period of 20 years.[23]

In addition to demonstrating financial feasibility, this public-private model offers benefits for both parties: PFED would receive stability and risk reduction, which is important given the evolving political and financial landscape in which the technology is being deployed. The public entity would realize revenue from REC sales, as well as potentially significant cost savings due to net metering; government-owned facilities are good candidates for such a partnership as they are among the largest electricity consumers on Maryland's Eastern Shore. Additionally, this system has the potential to benefit the State and the public, by removing an estimated 305,262 pounds of phosphorous from previously-land applied poultry litter and generating a marketable byproduct.

Table 3. *Base scenario financial results plus four alternative scenarios with modified inputs*

	Scenario A Revised litter input rate of 1,200 tons/yr	**Scenario B** 1,200 tons/yr; sale of nutrient credits	**Base Scenario** See inputs above	**Scenario C** 1,200 tons/yr input; $0 labor*	**Scenario D** Community-scale system ($8.6M, 50,000 tons/yr facility)
Annual cost savings + revenue ($)	-19,655	-7,491	-123,377	40,509	427,323
Simple payback (years)	Infinite	Infinite	Infinite	45 > 20 year useful life	20 = 20 year useful life

* Assumes externalization to the project of labor costs to operate the system.

Discussion: Transferability and Policy Considerations

A number of factors affect whether poultry litter anaerobic digestion and nutrient capture systems have the potential to be profitable in Maryland.

<u>Scale of the system:</u> The greatest determinant of whether an AD + NCS system is financially feasible is the scale at which it is employed. As discussed above, PFED has several models for replicating this system throughout Maryland's Eastern Shore, all of which include sizing the facility significantly larger than the pilot (in the case presented above, the system would receive more than forty times the poultry litter input as does the pilot). In these scaled-up models, litter is received from multiple poultry farmers (various models for compensating contributing farmers are still being explored), and finished byproducts are sold to regional grain farmers and to other buyers outside the Chesapeake region. While these larger systems require greater levels of capital investment, they would also achieve efficiencies in labor and operations and generate greater amounts of electricity and revenue from the sale of byproducts, excess electricity, RECs and potentially nutrient trading credits.

The value of such a community-scale system to individual poultry and grain farmers depends on how costs and revenue are shared between the vendor, the host entity, and other contributing farmers – e.g. who bears capital and operations costs; how revenue from the sale of byproducts and RECs is shared; who benefits from net metering, etc. However, at a minimum, poultry and grain farmers would benefit from the ability to continue to sell or use poultry litter after Maryland's new Phosphorous Management Tool (PMT) regulations come into effect, which as discussed in greater detail below, will limit the amount of phosphorous that can be applied to land with high environmental risk posed by soil phosphorous levels. The technology separates out phosphorous into a byproduct that can be sold outside the region, while also producing a low-phosphorous soil amendment that can be used within the region including as a cropland nutrient source. Because of this product's improved nitrogen to phosphorous ratios, the vendor anticipates that farms will be able to apply more finished byproduct per acre (to supply nitrogen demand) than they could previously apply raw litter in the absence of PMT regulations.[24]

<u>Capital costs and other sources of revenue</u>: Construction costs for Millennium Farm's pilot scale system was $987,081. Engineering, permitting, site prep and equipment were an additional $845,056. These costs can be expected to vary in future installations, depending on siting conditions, infrastructure needs, and the size of the facility. Design, engineering, and programming costs are also likely to vary, and could reasonably be expected to be decline in future applications, as some of these costs relate to technology start-up and would not need to be replicated. Capital costs may not increase linearly as the system is scaled up, because the pilot system needed to incorporate some major components that are oversized for its needs (but were the smallest units available that would still enable the system to function). Over time, as additional systems are installed and the technology is refined, capital expenditures may be expected to gradually decrease. Further, the profitability of future facilities would improve based on their ability to take advantage of any existing or future state subsidies or incentive programs (such as the Manure Transport Program, which provides cost share assistance to eligible entities to ship excess manure).[25]

<u>Value of byproducts</u>: The AD + NCS system at Millennium Farm is producing three novel byproducts, the markets for which are still being developed. To the degree that strong markets emerge for these products – and that values increase – financial feasibility will improve. The technology also enables the distinct byproducts to be blended into custom nutrient mixes, tailored to the needs of individual markets or buyers (horticulture, specialized agriculture, etc.) These possibilities are still being explored and could bring added value.

<u>Regulatory drivers:</u> As discussed above, under Maryland's nutrient management regulations, farms with high soil phosphorous levels may be more strictly limited in applying manure to their land after using the new **Phosphorus Management Tool** (PMT), and thus will have a stronger impetus to find alternative uses for the manure they produce. Farms most impacted by this regulation are located in the Lower Eastern Shore counties of Somerset, Wicomico, and Worcester, where only an estimated 28% of the land area is not required to use the PMT to manage phosphorous, compared to 79% for the state as a whole.[26] Poultry farmers on the Eastern Shore have historically applied poultry litter as fertilizer on their own grain fields, or they have sold litter to other grain farmers in the region. Because PMT may make these manure management practices less feasible, it has potential to encourage alternative uses for poultry litter.

Another policy driver affecting the financial feasibility of AD + NCS systems is Maryland's **Nutrient Trading Program** and accompanying markets. If this technology were to be designated an eligible generator of nutrient credits – and if the market were to start to see stepped-up trading activity – nutrient credit trading would represent a potential source of revenue for the system's host farmer and/or vendor. According to analysis by Planet Found Energy Development, the nutrient capture system installed at Millennium Farm removes approximately 80% of phosphorous from the original poultry litter waste stream, converting it into a product that can be sold outside the Chesapeake Bay region. This suggests that the technology would be a strong candidate to generate nutrient trading credits. A Manure Treatment Technologies Expert Panel convened by the US EPA Chesapeake Bay Program recommends that nutrient reductions from compost systems, thermochemical systems, and other technologies with verifiable nutrient reductions be approved for trading within the watershed.[27] However, each state must determine eligibility requirements for its own trading program, and Maryland has not yet specified eligibility for this technology.

While the sale of nutrient credits is still only a theoretical revenue source, the technology *is* able to benefit from the sale of renewable energy credits. Maryland's **Renewable Energy Portfolio Standard** specifies that methane generation from anaerobic digestion and poultry waste-to-energy renewable energy technologies qualify as eligible fuel sources under the standard,[28] meaning that AD + NCS systems like the one installed at Millennium Farm are eligible to generate RECs.

A final significant regulatory driver is US EPA's 2010 **Chesapeake Bay Total Maximum Daily Load** (TMDL), which mandates levels of nutrient and sediment pollution reductions that must be achieved in each Bay state by 2025 in order to meet water quality standards.[29] The TMDL provides strong impetus for the State of Maryland to invest in cost-effective pollution reduction measures in order to meet targets.

Conclusions

The pilot scale anaerobic digestion and nutrient capture system as applied at Millennium Farm is not financially feasible as a farm scale project – nor was it intended to be. Rather, it enabled the testing and refinement of a novel technology that has strong potential to benefit poultry and grain farmers in Maryland as well as cost-effectively reduce nutrient pollution to the Chesapeake Bay. Based on available data from the pilot as well as financial modeling by Planet Found Energy Development, it appears the AD + NCS technology would be more feasible in other applications throughout Maryland if: (1) the system is sized to process poultry litter from multiple farms and thus realize efficiencies and economies of scale including production of excess heat and/or electricity; (2) the system is used in areas with a high percentage of farms subject to PMT requirements, which can be expected to be a significant driver for the pursuit of alternative uses for poultry litter; and (3) additional revenue can be realized via state incentives or subsidies, a well-developed byproduct market, proceeds from net metering, and the sale of nutrient credits and/or renewable energy credits.

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