Maryland Animal Waste Technology Assessment and Strategy Planning

FINAL REPORT SUMMARY | September 2023

UNIVERSITY OF MARYLAND

Maryland Animal Waste Technology Assessment and Strategy Planning

FINAL REPORT SUMMARY | September 2023

Our website: https://go.umd.edu/AWTF has additional animal waste technology information, including the full report, appendices, Maryland Extension Briefs, and FactSheets.

Final report submitted by the following University of Maryland contributors:

PI: **Stephanie Lansing**, Co-PIs: **Shannon Dill, Kathryne Everts, Amro Hassanein, Marccus Hendricks, James MacDonald, Jonathan Moyle, Nancy Nunn, Sarah Potts, Jennifer Rhodes, David Ruppert, Jeff Semler, and Elizabeth Thilmany**

Post-docs, staff, and students: **Priscila B. R. Alves, Beverly Bolster, Higor Brito, Eric Burnstein, Danielle Delp, Rachele Franceschi, Mimi Sanford, and Derek Wietelman**

EXECUTIVE SUMMARY

The Maryland Animal Waste Assessment and Strategy Plan was created to guide future Animal Waste Technology Fund (AWTF) awards administered by the Maryland Department of Agriculture (MDA). The stated goal of the AWTF is "to encourage the development and implementation of economically feasible technologies that help protect public health and the environment by reducing the amount of nutrients from animal waste to enable farmers to meet nutrient management requirements and provide alternative animal waste management strategies to farmers." This Assessment and Strategy Plan researched and evaluated animal waste and nutrients in animal waste generated in Maryland (by county). The feasibility of animal waste technologies used in Maryland were evaluated, including anaerobic digestion, gasification, pyrolysis, composting, and manure injection. Policy implications, greenhouse gas (GHG) emissions, and economic analyses were documented for animal waste technologies. Interviews, surveys, and focus groups were conducted to gauge understanding and acceptance of the technologies, expected future changes in manure management, and the effect of waste management technologies on surrounding communities through an environmental justice perspective.

The results showed that three animal species (broilers, cattle, and equine) account for 98.7% of the animal population (total animal units) and 91.9% of state animal waste nutrients (N and P) produced in Maryland (in 2022). Broilers alone accounted for 88.3% of total animal units in Maryland in 2022 (one animal unit is defined as 1,000 pounds of live-weight animals of the same species; animal units are used to compare populations across species). However, broilers accounted for a smaller share of animal waste nutrients: 43% of nitrogen and 56% of phosphorus produced in Maryland, indicating the importance of effectively managing manure from broilers and other species (cattle and equine) to protect natural resources.

Looking ahead to 2032, we project only a small decrease (1-3%) in the total annual volume of animal waste nutrients produced in Maryland, indicating that nutrient management will continue to be important for the state. There is a large projected decline (~25% decline from 2022 baseline) in the state's population of dairy cattle, offset by a ~10% increase in liveweight production of broilers (driven by increased broiler weights rather than number of broilers). Our projections for nutrients were based entirely on changes in animal populations without any expectation of reduced waste or nutrient generation per animal.

The data confirm well known trends in concentrations of cattle production in northern Maryland and poultry production in Eastern Shore counties. Specifically, 65.6% of the cattle and cow inventory in Maryland are located four Maryland counties: Washington (23.8%), Frederick (21.4%), Carroll (11.8%), and Garrett (8.7%), while 86.9% of the poultry inventory is located in four Eastern Shore counties: Worcester (23.5%), Caroline (20.9%), Somerset (19.4%), and Wicomico (19.4%), according to the 2017 USDA Agriculture Census. Due to the larger volume of manure produced per

animal, most manure generated in Maryland is from cattle and cow populations. Yet, most nitrogen and phosphorus in manure (51%) comes from poultry litter, as these nutrients are more concentrated in the litter. Nutrient output from poultry is expected to rise through increases in bird weights over the next ten years. The greatest quantity of nitrogen in manure resources was in Frederick (11.9%), Worcester (11.7%), Somerset (11%), Caroline (10.1%), Washington (9.7%), and Wicomico (8.8%) counties, while the greatest quantity of phosphorus in manure resources was in Worcester (14.3%), Somerset (13.2%), Caroline (12.2%), Wicomico (10.9%), Frederick (9.7%), and Washington (9.7%) counties (2019 data). This data indicates the impact of different animal species' manure on the total and type of nutrient resources.

Even with the decreasing dairy cow inventories and farms in Maryland over the past four years, the highest greenhouse gas (GHG) emissions occurred from open lagoon storage of dairy and beef cattle manure. The annual GHG emissions from manure storage from all animal species in Maryland (533,652 $MtCO_{2e}$/year) was highest in Fredrick (111,527 $MtCO_{2e}$/year), Washington (107,336 $MtCO_{2e}$/year), and Carroll (59,032 $MtCO_{2e}$/year) counties due to the higher populations of dairy cattle. In Frederick County, dairy cattle accounted for 43.7% of the total GHG emissions from manure storage, with similar percentages in Washington (45.4%) and Carroll (37.0%) counties. The reductions in GHG emissions from implementing waste technologies were explored. Anaerobic digestion reduced more than 100% of the GHG emissions from manure storage with renewable electricity production, resulting in negative (sequestering) GHG emissions.

Poultry processing creates a liquid 'Dissolved Air Flotation' (DAF) product. Maryland is the largest importer of DAF in the Delmarva region, receiving shipments from poultry processing facilities in Delaware and Virginia. Data from 2021 indicated a steep drop in DAF imports to Maryland relative to 2020, with increased transport to Pennsylvania. Industry interviews indicated that this change may be due to Maryland's PMT (phosphorus management tool) implementation and more rigorous application restrictions in Maryland compared to Pennsylvania. More than 95% of the DAF utilized in Maryland is land applied as soil amendment, providing ~2 million lbs. N per year; for comparison, this is approximately 9.15% of the N derived from land application of poultry litter manure. The remainder is used as input to anaerobic digesters at two locations (approximately 450,000 gallons/year) or composted.

The status of animal waste technologies in Maryland, including anaerobic digestion, thermochemical processing (gasification, pyrolysis, and combustion), composting, and manure/waste injection, was documented. Two of these technologies, anaerobic digestion and thermochemical processing (gasification and pyrolysis), produce renewable energy in the form of heat, electricity, or transportation fuels. Composting, anaerobic digestion, and thermochemical processing also reduce GHG emissions and create beneficial byproducts, such as fertilizers, soil amendments, biochar, compost, or animal bedding. The use of manure injection on-farm is increasing (currently at 2500 acres in Maryland) and is expected to continue to increase, while most other manure management technologies (composting, anaerobic digestion, and thermochemical

processing) are not expected to have large increases in adoption without further economic support. There are currently only four digesters receiving manure or DAF in Maryland, including two digesters receiving poultry litter that are being intermittently operated. There are four more anaerobic digestion systems in the construction or planning processes. There is one poultry litter pyrolysis system under construction and one poultry litter fluidized bed combustion system that was decommissioned. There are five permitted manure composting facilities and an additional 1,085 mortality composting facilities in Maryland.

Surveys were conducted at 17 University of Maryland Extension meetings to gauge the interests of farmers in the adoption of animal waste technologies, with 246 respondents from every county in Maryland (except Baltimore City). The majority of respondents supported implementation of manure technologies (anaerobic digestion, gasification, and manure injection), but most respondents stated that there were barriers to adoption due to high capital costs, long lead times, limited subsidies, complex regulations, lack of technical expertise (to permit, operate, and troubleshoot), and social resistance (often due to lack of education). Our interviews, surveys, and focus groups revealed that more incentives, permit assistance, and education are needed to increase animal waste technology adoption in Maryland.

The market trend analysis projects slow growth (16%) in US electricity consumption over 2020-2050 but with a major shift toward renewable sources, which are projected to account for 60% of US electricity generation in 2050 compared to 22% today. Most of that shift is projected to occur by 2035, with 6-8% annual growth in renewables-based generation.

Our analyses for Maryland found a trend of state renewable energy policies that do not include the terms “biomass” or “waste technologies,” resulting in delays in permitting and hindering the financial success of projects. There is a need to better educate the general public, policy makers, and future animal waste technology adopters of the current permitting process, policies, and the renewable electricity that could be produced from waste technologies in Maryland. For example, if all the manure resources in Frederick County alone were converted to electricity using anaerobic digestion, the annual renewable electricity production would be 34,745 MWh of renewable electricity. The anaerobic digester in Cecil County processing dairy manure and DAF waste produces 2,000 MWh annually, enough electricity to power 190 houses per year and reduces GHG emissions by 20,000 $MtCO_{2e}$/year, offsetting emissions of 4,000 vehicles per year.

Maryland has a GHG emissions reduction goal of 60% (from 2006 levels) by 2031, with net-zero GHG emissions by 2045. The large expansion of renewable electricity generation in the US has been driven by sharply declining prices for wind and solar installations, which presents a significant challenge for manure-based technologies aimed at electricity markets. Biomass technologies, including those based on animal wastes, have not seen similar cost declines and without further innovations may not be cost-competitive with wind and solar in most circumstances. Hence, advocates for biomass-based technologies face an opportunity in the rapid projected growth of

renewables-based electricity generation but also a major challenge in developing technologies that can compete with wind and solar in the near term. Public policies that broadly target the adoption of renewables-based sources for electricity generation and transportation will likely be met from solar and wind-based sources. In contrast, biomass-based sources will likely need policies targeted specifically at them, such as California's programs or the cost share for biomass projects under USDA's Environmental Quality Incentives Program (EQIP) program.

Maryland's net-metering standards were based on solar capabilities, not biomass, leading to a lower payout for animal waste technologies generating electricity compared to technologies such as anaerobic digestion, where the energy outputs can be upgraded to renewable natural gas (RNG) and benefit from federal incentives (e.g., renewable fuel standard). The federal and other US state incentives (e.g., California, Washington, Oregon) make RNG production from anaerobic digestion profitable at large dairies. Still, there are no federal or Maryland policies that incentivize electricity production for the smaller animal production facilities more commonly seen in Maryland. It is expected that additional policies in Maryland that incentivize renewable electricity from animal waste-based biomass would increase the adoption and success of smaller and mid-scale anaerobic digestion and thermochemical processing units while reducing methane emissions from manure storage. Currently, the benefits of baseline methane emission reductions from manure storage and the non-intermittent renewable electricity production that increases grid stability when employing anaerobic digestion and gasification/pyrolysis are not internalized in Maryland's current policies.

Maryland's climate change goals are intertwined with environmental justice (EJ) concerns, with new federal initiatives (Justice40 and EPA's EJScreen Mapping & Screening Tool) adding a new conscious layer to project planning. Depending on the site, traffic patterns, and surrounding communities, electricity generation could have less perceived EJ concerns than upgrading to RNG. With any manure technologies employed, better information on GHG emissions from land application and manure transport is needed to accurately calculate reductions in GHG emissions that would occur if more animal waste technologies were employed near concentrated animal feeding operations (CAFOs) sites to reduce the large movement of manure and DAF throughout the state. It would be helpful to use information from manure transportation and nutrient management to identify site priorities based on a manure-shed approach instead of county or state lines.

An EJ framework for animal waste technologies was developed through a thorough literature review, participatory approaches (interviews and focus groups), and geographical information systems (GIS) tools that can be used in other studies. In total, 25 interviews and three in-person focus groups were conducted in different parts of Maryland. Results showed potential exposures, engagement levels, social vulnerability challenges raised by participants, and recommendations for incorporating EJ in AWTF proposals. Evaluation of AWTF proposals should include engagement with residents, communication with communities throughout the project period, and considerations of social vulnerability, exposure, and impact assessments, with monitoring and evaluation of EJ-related communication, engagement, and exposure considerations.

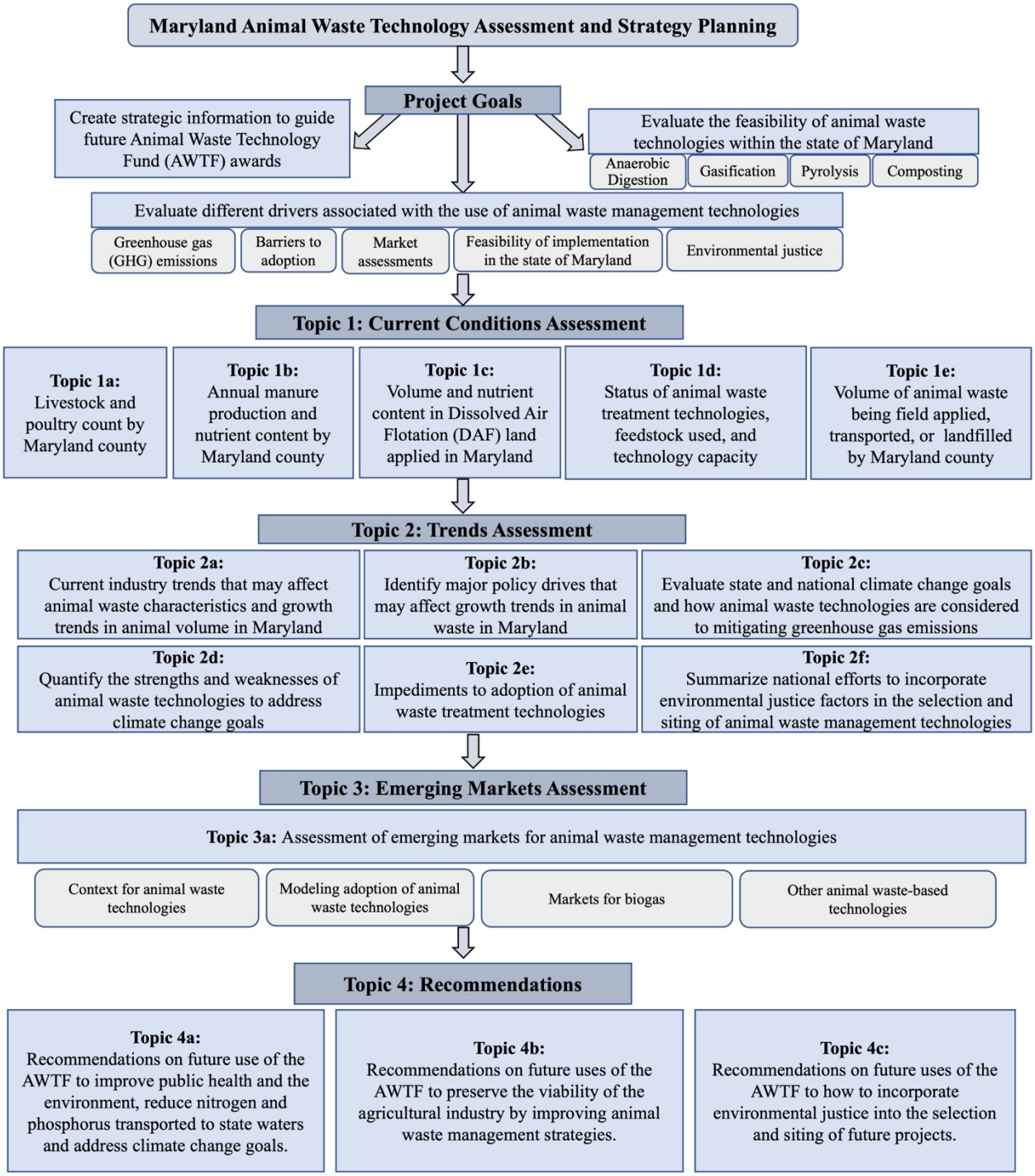
Recommendations for the AWTF include: 1) education, 2) collaboration, 3) data utilization and evaluation tools, and 4) future decision-making based on research and community inclusion. Interviews and EJ focus groups revealed a large need for public education. Education and outreach would increase animal waste technology adoption, project viability, counter misinformation, and engage surrounding communities. Specific outreach to the public and policy makers on animal waste technologies could include FactSheets, websites, and workshops. There is a need for legislation in Maryland to increase in animal waste technology adoption and increased knowledge in how these technologies work towards meeting Maryland's climate change goals. To improve project success, there should also be targeted education to AWTF applicants on permitting, installation, and evaluation of waste technologies as part of the application process, with required attendance for potential applicants at workshops, listening sessions, or outreach events. California's equivalent AWTF has technical support providers that increased both the quality and quantity of applicants.

More collaboration is needed between state agencies, electric companies, farmers, industry, and policy makers to ensure project implementation timelines are not unduly delayed. This needed collaboration should include guidance from government agencies in obtaining required permits and electric interconnection. Enhanced state agency collaboration would help potential adopters understand differing regulations for waste systems, especially for systems that incorporate animal waste and other resources (e.g., food waste). Coordinating climate change, renewable energy, and manure management activities across state agencies would greatly increase impact.

Data mining and analytics of nutrient management plans, CAFO applications, manure transport cost-sharing, Watershed Implementation Plans (WIP) data, and GHG emission reductions are needed to properly determine the effect of nutrient and waste movement throughout the state, farming practices and on-farm technology adoption. Digitization and internal statistical analyses of this data would aid future analyses of the state of Maryland's agriculture. For the AWTF, there should be follow-up data by completed grant awardees to analyze economic and environmental progress, with analyses of GHG emission reduction calculations to aid in understanding MDA's return on investment. Documentation of the role of manure management and waste technologies in meeting legislation for climate change goals is needed. For example, California's Low Carbon Fuel Standard (LCFS) has agriculture-specific methane reduction goals and funds to help farmers meet these goals and could be used as a model for meeting Maryland's climate change goals.

Surveys and interviews indicated that AWTF decisions should be backed by research before implementation, especially regarding GHG emissions and nutrient reductions to meet state compliance and state climate change goals. California has a GHG emission reduction calculator that applicants use for fund submission. Community involvement is needed to incorporate EJ concerns, including letters of support or public hearings. Additionally, having an EJ expert on the AWTF Technical Committee would aid in ensuring community engagement is part of the funding criteria. MDA technical support to applicants using EJ mapping and screening tools would aid in identifying these communities and help guide community engagement.

Graphical Executive Summary



Graphical Abstract: A flow chart of the project goals and four topics explored in Maryland Animal Waste Assessment and Strategy Plan conducted by University of Maryland researchers. The report is organized by the topics requested in the Request for Proposals by the Maryland Department of Agriculture (MDA).

TABLE OF CONTENTS

TOPIC 1: Current Conditions Assessment

Topic 1a. Estimated livestock and poultry count by MD county for 2018, 2019, 2020, & 2021.

Topic 1a Summary

County-level estimates of animal inventories for the years 2018-2021 were created using data from the Maryland Department of Agriculture (MDA), Maryland Department of the Environment (MDE), and the US Department of Agriculture (USDA). Livestock and poultry inventory estimates based on animal units were generated and used to calculate manure estimates. A benchmarking process from the 2017 Census in Agriculture data revealed that these multiple data sources produced comparable animal inventory levels. Inventory estimates by county in 2018-2021 confirm well known trends in concentrations of cattle production in northern Maryland and poultry production in Eastern Shore counties. Specifically, 65.6% of the cattle and cow inventory in Maryland are located four Maryland counties: Washington (23.8%), Frederick (21.4%), Carroll (11.8%), and Garrett (8.7%), while 86.9% of the poultry inventory is located in four Eastern Shore counties: Worcester (23.5%), Caroline (20.9%), Somerset (19.4%), and Wicomico (19.4%), according to the 2017 USDA Agriculture Census. The MDA nutrient management annual implementation reports (AIR) and USDA National Agricultural Statistics Service (NASS) data from more recent years yield similar county-level animal shares. Concentrated animal feeding operations (CAFO) sites in the state are shown in Figure 1a.1, providing point data beyond the county-level aggregates. Additionally, the locations of current animal waste technology sites are shown in relational to CAFOs (shown by animal species).

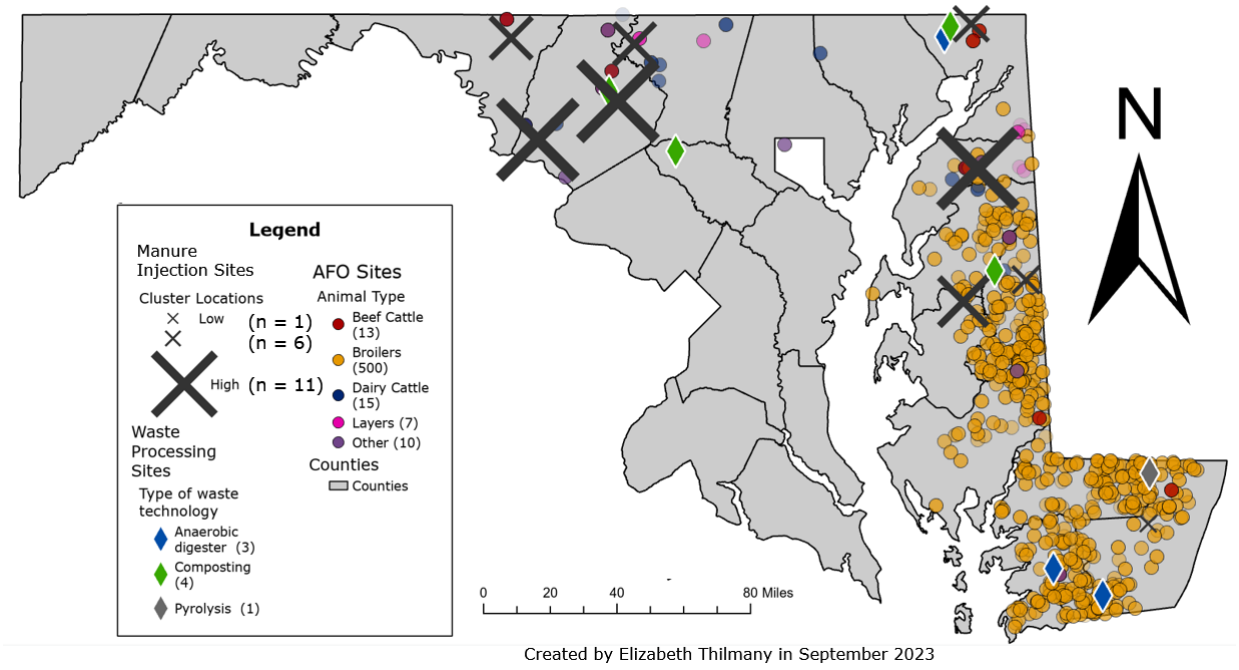


Figure 1a.1: Locations of all active concentrated animal feeding operations (CAFO) sites in Maryland, with the locations of animal waste technology sites shown, including anaerobic digesters, pyrolysis units, animal composting sites, and manure injection locations.

Topic 1a Key Findings and Recommendations

1. Multiple data sources at the federal and state level (Ag Census, MDA AIR data, MDE permitting data) provided helpful information for assessing animal inventories by county in Maryland. Considering all data sources together provides a clearer picture of the current state of animal inventories than any single data source alone.
2. Livestock inventories are concentrated in northern Maryland counties, while poultry inventories are concentrated on the Eastern Shore.
3. Most Maryland CAFOs are poultry operations located in the interior of the Eastern Shore.

Topic 1b. Estimated annual manure and nutrient content generated by livestock and poultry by county for 2018, 2019, 2020, and 2021.

Topic 1b Summary

Coefficients from the UMD Agricultural Nutrient Management Program provided the most accurate snapshot of present-day manure production characteristics to generate county-level manure and nutrient estimates in pounds over the years 2018-2021 for each county-species-year combination, given changing animal sizes and diets over the years in Maryland. The results showed that cattle produce the most overall manure (78% of statewide total in 2019); however, broilers contribute the largest portion of N and P production of any species (51% in 2019). Cattle, however, still produce 36% of statewide nutrients, indicating that effectively managing manure from both broilers and cattle is necessary to protect natural resources. The counties that produce the most nutrients are cattle-heavy counties like Frederick (11% of statewide total in 2019) and Washington (9%), and poultry-heavy Eastern Shore counties like Worcester (12%), Somerset (12%), Caroline (11%), and Wicomico (9%). There are no significant upward or downward trends in overall manure production over the study period of 2018-2021, while nutrient production, driven by broilers, does appear to show a decline in 2021, potentially related to pandemic-era reductions in broiler production.

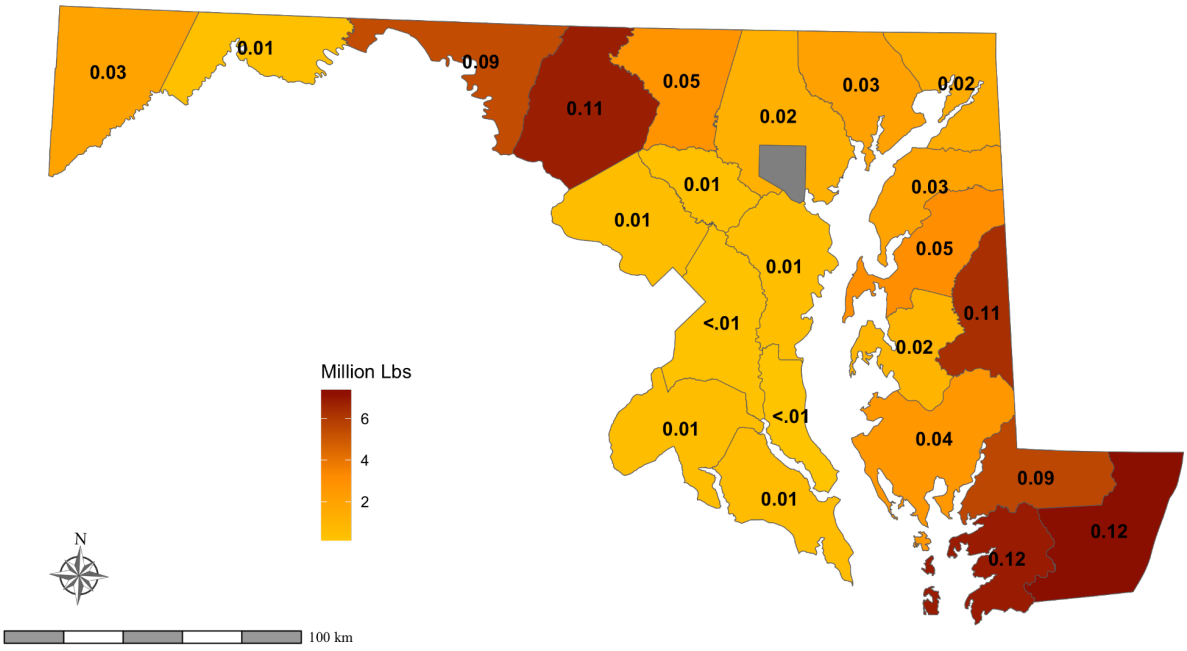


Figure 1b.1: Total nutrient production (N + P) by county, 2019. The shading in each county represents million pounds of nutrients, while the labeled proportions represent the share of the statewide total in 2019.

Topic 1b Key Findings and Recommendations

1. Manure transfer coefficients from the University of Maryland's Agricultural Nutrient Management Program provide the most accurate snapshot of current manure production in Maryland.
2. Cattle produce the largest quantity of total manure followed by broilers. Conversely, broilers contribute the single largest share of nutrient production (N and P) due to higher concentrations of nutrients in their litter.
3. On the Eastern Shore, Caroline, Somerset, Wicomico, and Worcester counties produce the most nutrients.
4. There do not appear to be any notable trends in overall manure production statewide between 2018-2021. There may be some evidence of a pandemic-era decline in nutrient production, specifically in Eastern Shore counties.

Topic 1c. Estimated volume and average nutrient content of nitrogen and phosphorus in Dissolved Air Flotation (DAF)

Topic 1c Summary:

Dissolved air flotation (DAF) sludge is an animal waste byproduct from animal mortality and processing facilities composed of flocculated solids, proteins, and fat that rise to the surface and removed by mechanical scraping. Maryland generates DAF at three poultry processing facilities and receives substantial shipments from Delaware and Virginia. Most of the DAF Maryland receives is field applied as a soil amendment in Dorchester and Wicomico counties (Appendix A, Table 1c.3). The sludge from DAF has potential as a feedstock for anaerobic digesters and composting; two MD digesters are already accepting DAF shipments to co-digest with food and manure wastes. However, poorly executed DAF land application has caused smell and insect nuisances in surrounding communities, which prompted the updating of MDAs 'Nutrient Application Requirements' to include special requirements for land application of 'food processing residuals' in 2022. We analyzed data from MDA and industries that generate and ship DAF to better understand the generation, shipment, and usage of this unique animal waste, and how its management impacts nutrient loading in the state. It is estimated that between 2019 and 2021, 93.9 million gallons of DAF were imported into MD counties, containing 4.78 million lbs of N, 1.75 million lbs of P, and 0.273 million tons of K.

<u>Topic 1c Key Findings and Recommendations</u>:

1. Statistics regarding DAF transport in the region are available only from recent years (2018 and on).
2. There are currently 15 soil amendments derived from DAF registered for land use in Maryland, however, only 4 explicitly use "DAF" in the name to specify its composition.
3. Maryland produces little DAF relative to the larger Delmarva region but it is a major importer with most of it going to land application.
4. DAF production is relatively static regionally, but trends in transport vectors change over time due to differing state laws and regulations; most recently, this has resulted in PA becoming a more preferred location for DAF disposal than MD.
5. Industry perceives state-wide policy as impactful regarding trends in DAF transport and usage.
6. While millions of gallons of DAF are imported to MD annually, the amount of nutrients relative to that in poultry litter is minor.
7. Soil amendments derived from DAF mostly contain organic N rather than PAN, so pre-processing with animal waste technology that mineralizes N (e.g. anaerobic digestion, composting) may be suitable to improve its effectiveness as a fertilizer and reduce runoff.

Topic 1d. Current operational status of animal waste treatment technologies, feedstock, and technology capacity to accept animal waste in Maryland.

Topic 1d Summary:

The operational status of animal waste treatment technologies in Maryland was determined through cost-sharing information provided by MDA, the Natural Resource Conservation Service (NRCS), and interviews. Collected data included the type of animal waste storage, capacity, and site location. Waste technologies evaluated include anaerobic digestion, gasification, pyrolysis, composting, liquid-solids separation, and manure/waste injection. Most manure technologies employed in Maryland are basic waste storage facilities, followed by storage ponds and treatment lagoons. Poultry litter has the highest storage capacity in the state through covered, padded storage facilities and treatment lagoons. Dairy and beef manure has the next highest storage capacity through storage facilities, storage ponds, and treatment lagoons.

It is estimated that there are 2500 acres in Maryland utilizing manure injection (see Figure 1a.1). While there are anaerobic digesters, composting, and gasification/pyrolysis facilities in Maryland, the overall number of sites is small and not necessarily co-located with concentrations of nutrients in manure (Figure 1d.1). There is one operating manure and food waste digestion facility in Maryland, one food waste only digester, and two poultry litter digestion systems being intermittently operated. There are four more digestion systems in various states of construction and planning (two dairy and food waste systems, one poultry litter and food waste system, and one poultry litter and cover crop system). One poultry litter pyrolysis system is under construction and one fluidized bed combustion system was decommissioned. There is no central database of composting that encompasses both on-farm and registered commercial composting, with data provided showing only six permitted composting facilities accepting manure out of 22 total facilities. An additional 1,085 on-farm mortality composting structures were also accounted for. A similar lack of data prevented the estimation of solids/liquids separation technology used in Maryland. It is recommended that future reporting, possibly in the AIRs, allow farmers to report on-farm technologies used to manage their animal waste.

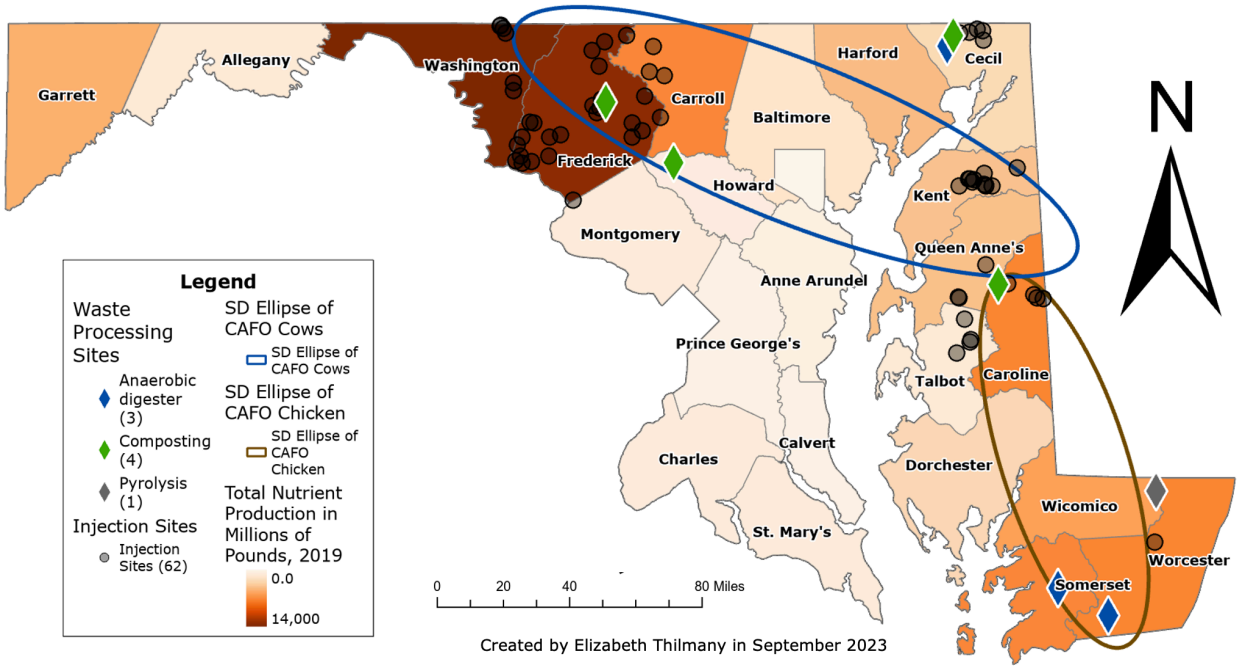


Figure 1d.1: Map of current animal waste technology sites in Maryland, including anaerobic digesters, composting sites, pyrolysis, and manure injection sites. Also included in the map is the standard deviation (SD) ellipse showing 66.2% of the concentrated animal feeding operations (CAFO) for cattle and cows (in blue) and poultry (in brown), with total produced manure in 2019 in each county from all livestock and poultry operations shown in gradient shade of orange that correspond with previous figures.

Topic 1d Key Findings and Recommendations:

1. Animal waste technologies (anaerobic digestion, gasification/pyrolysis, manure injection, and composting) are being implemented in Maryland on a limited scale. Land application, manure injection, and animal waste composting remain the most established waste/nutrient management processes.
2. There are limited reporting requirements or databases for many animal waste technologies, such as on-farm composting, solids-liquids separation, and pyrolysis/gasification facilities. There is a need for state-level reporting and data collection on the use of these technologies.
3. Most commercial composting facilities in Maryland do not accept manure waste.
4. Manure injection and anaerobic digestion facilities are slowly increasing, with a much greater increase in the use of manure injection due to lower capital costs and no interconnection, construction, or permits needed, which causes delays in planning new digesters.

Topic 1e. Estimated the volume of animal waste being field applied, transported to waste treatment technology, or land-filled by county for 2018, 2019, 2020, and 2021.

Topic 1e Summary:

The results from Topics 1a, 1b, 1c, and 1d were used to estimate the volume of animal manure transported for field application (acres), transported to waste treatment technologies, land-filled, or otherwise disposed of in Maryland (by county, calendar year, and farm type) from 2018-2021. Land application of manure was quantified using data from the WIP, AIR, and NASS data, as well as the 2012 and 2017 Census of Agriculture, which asked respondents to report the acres of cropland and pastureland to which manure was applied. Data from MD's cost-shared manure transport program was used to estimate the amount of manure being shipped with assistance from the program.

The findings indicate that Maryland is a net importer of animal waste for land application purposes. Dairy manure was initially the type of animal waste with the highest volume shipped by the transport program (502,000 wet US tons imported or exported to MD counties in 2018). However, shipments have declined over time; in 2021, only 11,600 wet US tons of dairy manure were shipped from Baltimore to Harford County. Waste from the poultry industry (broilers, layers, and poultry waste) has become the most transported waste as of 2021, with a total of 110,400 wet US tons imported or exported from MD counties that year. Waste from beef transported for land application remained within the county where it was generated, and cost-shared shipments ceased entirely in 2021. An estimate of animal waste transport for use in animal waste technologies was not possible since the available data only specified whether the land application was to be used. Additionally, accurate estimates of emissions from transport could not be made due to transport data only being available up to county-level specificity. To improve future analyses, it is recommended that regional animal waste transport and use reporting contain more specifcity about the origin and destination of waste shipments, waste handling, storage, and disposal.

Topic 1e Key Findings and Recommendations:

1. Maryland is a net importer of waste, primarily derived from dairy, broilers, and layers being the most common types of waste shipped in Maryland between 2018-2021.
2. The state's cost share data only designates waste as "land applied" or "other animal waste management," with no additional details about the fate of the transported waste.
3. County-level transport data may not be suited for assessments of animal waste technology, as more specific site-to-site data on transport to assess sustainability is required.
4. Higher specificity for the fate of transported waste is advised, as current county-level summary data only distinguishes between land application and all other technologies. It is recommended that MDA make more specific specifications of the fate of agricultural waste in the future.

TOPIC 2: Trends Assessment

Topic 2a: Current Industry Trends that May Affect Animal Waste Characteristics and Growth Trends in Animal Waste Volume in Maryland.

Topic 2a Summary

In this section, we sought to understand how industry trends over the next decade are expected to shape the growth of animal waste production in Maryland. The team compiled information from USDA baseline projections for each relevant animal species in Maryland and used that data to calculate contemporaneous inventories, manure, and nutrient concentration in 2022, as well as projections for such numbers in 2032. We supplemented these projections with information gathered from surveys with relevant Maryland agricultural stakeholders. Several strong trends emerged from the analysis.

In 2022, the results showed that three animal species (broilers, cattle, and equine) that account for 98.7% of animal population (total animal units) also account for 91.9% of state animal waste nutrients (N and P) produced in Maryland. Broilers alone accounted for 88.3% of total animal units in Maryland in 2022. Results from calculated manure and nutrient estimates revealed that broilers contribute 43% of nitrogen and 56% of phosphorus produced in Maryland, indicating the importance of effectively managing broiler manure from the Eastern Shore.

Looking forward, Maryland broiler production is projected to increase by 13% over the decade, with the increase coming largely from increased bird weights rather than number of heads. Maryland has experienced a steady decline in dairy cow inventories since the late 1980s, which is expected to continue. Beef cow inventories have remained constant, which is also expected to continue. In total, these trends are offsetting. Increased production of nutrients from increased broiler production offsets declines in nutrient production from decreased cattle production. In total, we project a small decline in N and P production over the next decade.

Table 2a.1: Maryland nutrient production, by species, in 2022 and projected for 2032.

	2022 (million pounds)		**2032** (million pounds)		**Percent of Total (2032)**	**Percent of Total (2032)**
	N	P	N	P	N	P
Broilers	20.9	8.5	23.0	9.3	48.9%	61.6%
Layers	2.9	1.1	3.1	1.1	6.6%	7.3%
Turkeys	0.1	0.1	0.03	0.03	0.1%	0.2%
Milk cows	8.1	2.0	6.2	1.4	13.2%	9.3%
Beef cows	3.8	0.9	3.7	0.9	7.9%	6.0%
Other cattle	6.4	1.5	5.2	1.3	11.1%	8.6%
Hogs	0.2	0.02	0.1	0.02	0.2%	0.1%
Horses	5.7	0.9	5.0	0.8	10.6%	5.3%
Sheep	0.4	0.1	0.4	0.1	0.9%	0.7%
Goats	0.2	0.1	0.3	0.1	0.6%	0.7%
Totals	**48.7**	**15.2**	**47.0**	**15.1**		

Topic 2a Key Findings and Recommendations

1. We expect Maryland broiler production to grow by 13% between 2022 and 2032, with the increase coming almost entirely from increased bird weights.
    a. Growth in live-weight broiler production will fuel modest growth in aggregate N and P production, assuming no change in N and P concentrations per pound of manure.
    b. Egg layers make a small but noticeable contribution to aggregate N and P production (6-7% of total) with no substantial increases expected in layer numbers over 2022-2032.
2. Maryland has experienced a persistent and steady decline in milk cow inventories since 1988. This trend is projected to continue given macro-level factors, such as geographic shifts in the location of dairy farms and continued consolidation in the dairy industry.
    a. If past trends continue, the number of milk cows in the state will decline by 27% by 2032, with concomitant declines in dairy calves and replacement heifers.
    b. Beef cattle inventories are expected to remain largely constant over the next 10 years.
    c. The net effect of the dairy contraction will be a noticeable decline in aggregate N & P production associated with cattle by 2032.
3. Horse numbers are difficult to count. We believe that the Maryland horse inventory is much larger than that reported in the Census of Agriculture or in MDA's AIR data.
    a. We relied on survey estimates of horse inventories from the Maryland Equine Council.
    b. Consequently, we estimate much larger production of N and P than would be implied by the USDA and MDA inventory estimates.
    c. Because of limited historic data, projections of horse populations are quite uncertain.
4. We do not project substantial increases in hog, sheep, goat, or turkey populations over the next decade, and their current populations are small enough as to account for very small shares of state-wide N and P estimates.
5. Future AWTF decisions should incorporate technologies that address the manure coming from the highest projected N and P generation for 2032, which is broilers (48.9 and 61.6%, respectively) followed by milk cows (13.2 and 9.3%, respectively), other cattle (11.1 and 8.6%, respectively), and horses (10.6 and 5.3%, respectively).

Topic 2b. Identification of major policy drivers that may affect growth trends in animal waste within Maryland.

Topic 2b Summary:

Maryland's agricultural landscape reflects national trends and related policy, including:

- *Clean Energy Goals:* Many states and municipalities have GHG emission reduction plans around electrifying and upgrading heating and cooling, with "clean energy" often associated with electric-based energy. This has led to a boom in solar energy, but less forethought and emphasis on animal waste technologies for renewable electricity.
- *Circular Economics:* With minimizing land mass and farm concentration, farms have begun using animal waste technologies to close their economic loops and gain revenue.
- *Global Trade Impacts:* Fertilizer prices have risen in the 2020s, aided by the ongoing war in Ukraine, resulting in increased interest in using animal waste as an organic fertilizer. Poultry litter in Maryland is a widely accepted and desired commodity.
- *Agricultural Sector GHG Contribution:* Different sectors have been identified to meet climate change goals, with agriculture often lumped as one sector and only a few states showing the possibility for certain animal waste technologies to be used to meet goals.
- *Strict Nutrient Management:* Due to specific Chesapeake Bay restoration and protection programs, Maryland is one of the few states that require intense vigor and regulation of nutrient management plans, which has affected DAF application and animal production.

*The national Justice40 initiative to support underserved and disadvantaged communities is a driver across all aspects of policy and not specific to animal waste growth trends (see Topic 2f).

Topic 2b Key Findings and Recommendations:

1. Stakeholders agree there is no 'silver bullet'/specific alternative waste technology solution.
2. 2% of the 2023 MD legislative session was related to animal waste technologies, with MDE and MDA responsible for implementing 35% and 15%, respectively, of the passed laws.
3. Maryland legislation is heavy on food waste diversion and electrification, both of which can aid animal waste technologies' adoption but neither explicitly mentions animal waste.
4. There are concerns from stakeholders about an increase in regulation, while noting there is still a lack of education for the multiple parties involved.
5. The California program has technical experts to help applicants in their application process.
6. Michigan has a "Right to Farm" law that supports farmers over third-party vendors when it comes to animal waste technology investment and ownership.
7. North Carolina has specific electricity goals from manure sources, with an alternative technology program funded from a settlement due to Hurricane Floyd manure overflows.
8. Pennsylvania situates their WIP goals using a manure shed nutrient management approach that drives site selection based on reducing transportation and soil nutrient overloads.
9. Vermont's has had digesters close prematurely due to the delay of hauler rollout for the Universal Recycling Law and food waste diversion efforts.
10. The lack of widespread adoption and maintenance of animal waste technologies in Maryland is likely due to lack of specific regulation and governmental support directed towards animal waste and a lack of educational guides geared to the agricultural community to aid applicants in determining the best technology for their operations.
11. MDA should work closely with other state agencies to create unity in the process of permitting, energy rebates, and tax credits, and a regional approach, including out-of-state impacts.

Topic 2c. An evaluation of state and national climate change goals and how animal waste technologies are considered in mitigating greenhouse gas emissions.

Topic 2c Summary:

Maryland's climate change goals are aligned with federal goals and goals in many other US states. Animal waste technology implementation aligns with efforts to mitigate GHG emissions (Topic 2d), but widespread adoption has been minimal in MD and in most parts of the US due to the following trends/drivers:

- *Animal Populations:* Regional concentrations of specific species have resulted in higher concentrations of animals on farms. Larger farms have the capital and large feedstocks to use these technologies for renewable energy generation and mitigating GHG emissions, but the time to deployment and lack of incentives in Maryland have limited implementation.
- *'Clean' Energy Goals:* Maryland's emission reduction plan is 60% below 2006 levels by 2031, which is more ambitious than the federal goal of 50-52% reduction to 2005 levels by 2030. In Maryland, 'clean' has become synonymous with electric-based energy, leading to a boom in solar energy but less emphasis on waste technologies for renewable electricity.
- *Circular Economics:* Farmers have begun using animal waste technologies to close their economic loops and gain revenue. Federal credits for RNG have the largest return on investment, which reduces electric production investment, which is a state-specific policy.
- *Justice40 Efforts:* Federal IRA funds prioritized the efforts of the national Justice40 initiative, including disadvantaged and underserved communities and indigenous populations, who may need additional capital to incentive animal waste technologies.
- *Strict Nutrient Management:* Maryland is one of the few states that require rigorous nutrient management with the PMT, which has resulted in increased transportation of animal waste. With an increased move to electrify vehicles, there is also a GHG emissions impact from the movement of nutrients across 'sources' and 'sinks' across the state.

Topic 2c Key Findings and Recommendations:

1. Electrifying infrastructure and transportation is a large climate change goal, yet there is minimal language in the specification in these goals for agriculture.
2. Upgrading biogas to RNG is eligible for RIN credits due to the 60% reduction in GHG emissions and listing as a renewable fuel. Thus, there has been a large push to larger systems that upgrade to RNG due to these financial benefits; less financial benefits are given to electricity production from digestion and gasification and the eligible RECs.
3. Net-metering has a heavy focus on solar projects rather than animal waste technologies.
4. Zero emission vehicles (ZEV) are on the rise in state mandates of adoption, which could impact animal waste hauling of animal waste and farm operations in Maryland.
5. MDA through the AWTF should collaborate with MEA, MDE, or UMD Extension to create educational pathways to aid applicants in understanding electric net-metering or RNG potentials, including regulatory and environmental justice implications, grid connections, and/or pipeline infrastructure.
6. MDA through the AWTF should consider how proposed animal waste technologies will reduce transport-based GHG emissions due to the current use of large trucks to transport liter long distances.

Topic 2d. Quantify the strengths and weaknesses of animal waste technologies to address climate change goals.

Topic 2d Summary:

Anaerobic digestion consistently reduced GHG emissions compared to baseline manure lagoon storage. Composting of wet manure (dairy and swine) resulted in net GHG emissions due to only the solid fraction of the manure being compostable, while the liquid fraction was assumed to remain in storage untreated. The total GHG emissions between each type of facility analyzed varied according to the waste being treated (Figure 2d.1), with annual GHG emissions from all manure in MD (533,652 $MtCO_{2e}$) concentrated in Fredrick and Washington counties. These GHG emissions could be eliminated through use of anaerobic digestion (Figure 2d.2). Frederick County had 111,527 $MtCO_{2e}$ annual GHG emissions from animal manure, followed by Washington (107,336 $MtCO_{2e}$) and Carroll (59,032 $MtCO_{2e}$) counties.

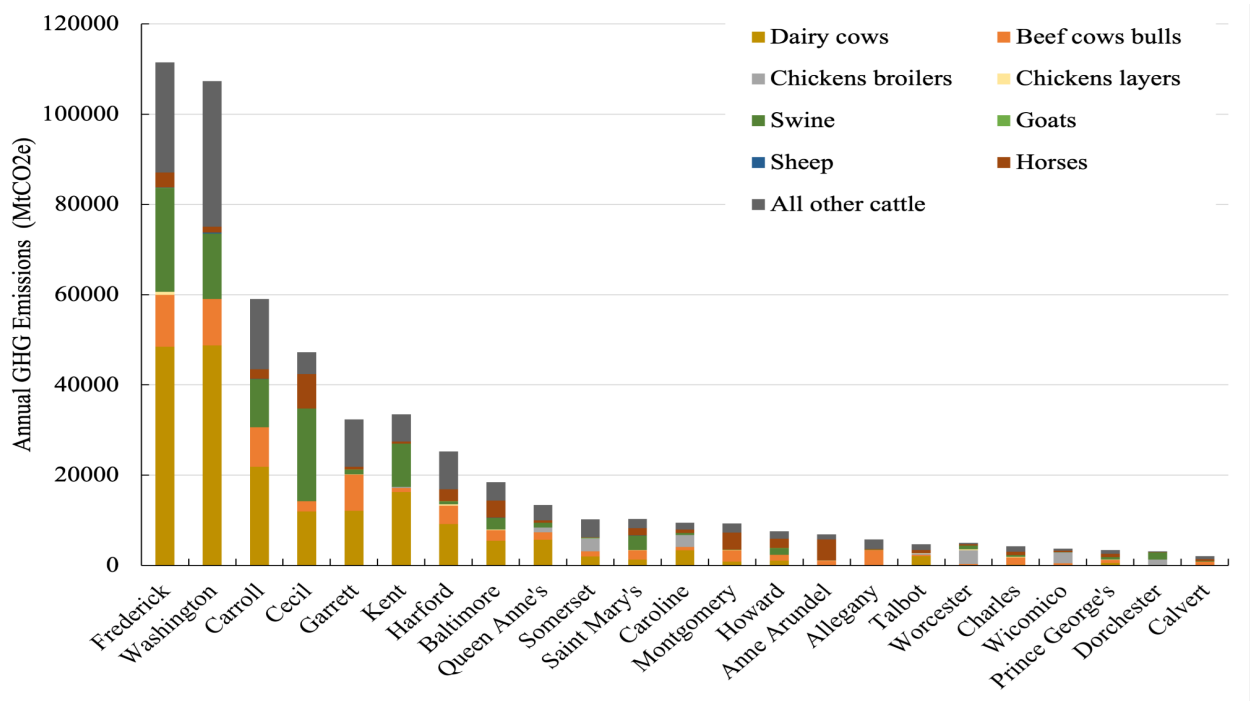


Figure 2d.1: Annual greenhouse gas emissions from different types of manure sources in MD. Dairy cattle were the primary contributors to the high GHG emissions in MD. In Frederick County,

GHG emissions from dairy cattle were 48,488 $MtCO_{2e}$ annually, followed by Washington (48,733 $MtCO_{2e}$) and Carroll (21,844 $MtCO_{2e}$) counties. By covering open manure lagoons, these GHG emissions could be eliminated. Additionally, sealed lagoons help in conserving water, reducing odors, and preventing the contamination of surrounding ecosystems.

All MD counties would achieve significant reductions in GHG emissions by implementing composting or anaerobic digestion (Table 2d.1). In Frederick County, composting all manure resources would reduce emissions by 75,421 $MtCO_{2e}$, which is a 67.6% decrease, while anaerobic digestion would decrease GHG emissions from all manure resources by 118,367 $MtCO_{2e}$, which

is a 106% reduction (Figure 2b.2). Both composting and anaerobic digestion present substantial opportunities for GHG emission reductions. However, the ability of anaerobic digestion to achieve reductions exceeds 100% due to reductions of GHG emissions naturally occurring in open air lagoons combined with the ability to turn this captured biogas into renewable energy. Frederick County could provide 34,745 MWh of renewable electricity from anaerobic digestion of all manure resources in the county.

Table 2d.1: Expected annual GHG emissions and annual GHG emissions reduction from different feedstock with loading rate of one ton manure per day using EPA AD screening tool.

	Annual GHG Emissions production $MtCO_{2e}$			
	Without compost or AD or Thermal conversion (baseline)	**Compost only**	**Thermal conversion**	**AD only**
Dairy manure	70.4	23.5	-	-3.9
Other cattle	66	20	-	-3.62
Broiler litter	13.8	1.7	0.1	-14.6
Layer litter	12.6	1.6	0.1	-13.3
Swine manure	154	51.2	-	-8.58
Horses	85	31.8	-	-4.71

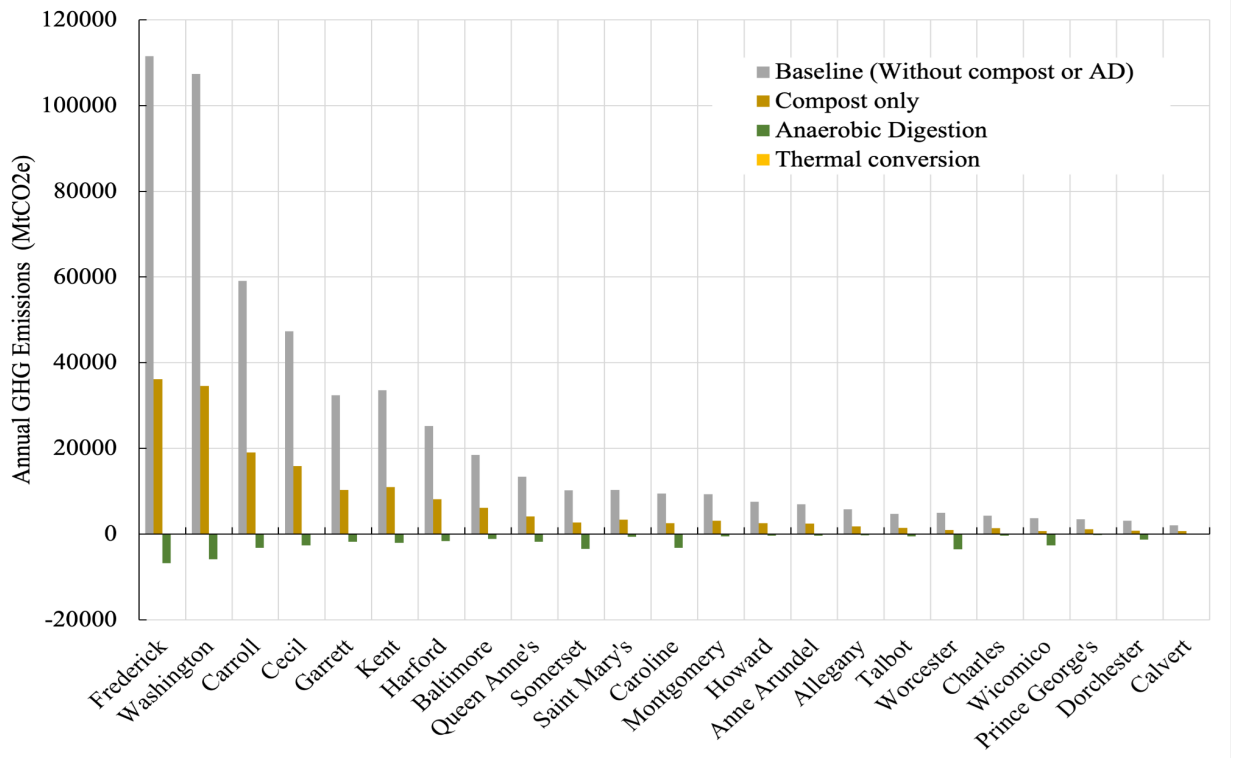


Figure 2d.2: Annual greenhouse gas emissions ($MtCO_{2e}$) from all manure types, calculated using daily manure generation data from Topic 1b. Scenarios tested included no animal waste technology utilized (baseline), composting, thermal conversion, and anaerobic digestion (AD) using all the manure resources available in that county for each animal waste technology adopted.

Topic 2d Key Findings and Recommendations:

1. Anaerobic digestion of dairy manure reduced GHG emissions by 106%, while composting had 66.7% reductions in GHG emissions compared to open lagoon storage (baseline)..
2. Digestion of poultry litter resulted in greater GHG emissions reductions (206% reduction) compared to composting (102%), yet the baseline value for GHG emissions for poultry litter (12.6 $MtCO_2e$) was much lower than dairy manure (70.4 $MtCO_2e$).
3. When normalized by animal units (AU), the largest reductions in GHG emissions resulted from digestion of swine manure from 100 AUs of swine (-59.4 $MtCO_2e$), compared to digesting dairy manure from 100 AUs of dairy (-12.8 $MtCO_2e$), and digesting poultry litter from 100 AUs of poultry (-8.99 $MtCO_2e$).
4. The dairy manure, DAF, and food waste digester operating in Maryland reduced GHG emissions by 81% compared to the baseline (23,751 $MtCO_2e$ emitted annually from the uncovered lagoon to 4,495 $MtCO_2e$), with a 448% reduction in eutrophication potential and produced 2000 MWh of electricity annually, enough to power 190 houses.
5. Uncovered lagoons or manure stored on-site emit high volumes of total GHG emissions in each MD county (Figures 2d.1; and 2d.2), which could be completely mitigated through use of animal waste technologies. This should be better factored into the MD's climate change goals.

Topic 2e. Impediments to adoption of animal waste treatment technologies.

Topic 2e Summary

There are a number of obstacles to animal waste technology adoption, including technical, economic, regulatory, and social factors, as summarized below.

- *Upfront Economics:* Many animal waste technologies require a substantial initial investment, which could include erecting buildings, a generator, and interconnection lines.
- *Limited Subsidies:* There is limited funding in MD to support the adoption of animal waste technologies, with the AWTF often funding one project annually, resulting in less adoption.
- *Complex Regulatory Environment:* The permits and regulations required at the state, county, and with private energy companies are difficult to navigate and delay progress.
- *Technical Expertise:* There is a lack of technical expertise available to support writing grants, navigating permits, and troubleshooting adoption of animal waste technologies.
- *Social and Cultural Resistance*: Concerns about the impact on the local environment and communities, combined with a lack of understanding of the benefits of these technologies, can cause social and cultural resistance to the adoption of animal waste technologies.

To fully assess the impediments to adoption of animal waste treatment technologies, interviews and surveys were conducted along with an intensive literature review on previous survey work that evaluated the barriers to adoption, the value to adopters of treatment technologies, costs associated with adoption, and the impact of public initiatives on adoption rates as well as perceived and real barriers to adoption.

Topic 2e Key Findings:

1. Economic barriers include high upfront cost and limited subsidies, with federal incentives favoring larger digester systems that produce RNG and have higher capital costs.
2. Technical barriers range from inexperience navigating complex funding application processes to safety concerns and technical long-term operation of the equipment.
3. Social and cultural resistance is based on environmental justice and public health concerns from nutrients and pollutants. Education, in multiple parties, is lacking and causing stagnant growth and adoption and misconceptions amongst the public.
4. The surveys showed widespread support for anaerobic digestion, gasification/pyrolysis, and manure injection, with more uncertainty associated with gasification/pyrolysis due to lack of knowledge, with cost being the highest barrier to adoption for all three technologies.
5. There is a need for more funding of smaller, electricity-based systems to increase adoption, but there also needs to be more engagement with power companies to navigate this process. It seems that electricity generation has less perceived environmental justice concerns.

Topic 2f. Summarize national efforts to incorporate environmental justice factors in the selection and siting of animal waste management technologies.

Topic 2f Summary

In both the past and present, waste management facilities and other polluting land uses have been disproportionately placed in areas home to vulnerable communities such as racial and ethnic minorities, immigrants, and areas with high concentrations of low-income and low-education residents. In addition to bearing the brunt of exposure, these groups often have the fewest options for mitigating the negative effects of such conditions. Animal waste management sites are overwhelmingly concentrated in low-income, rural communities, although no consensus emerged on whether race is significantly correlated. Historically, waste facilities were disproportionately located near minority communities, especially black and indigenous communities. Communities exposed to waste management sites can be more vulnerable to air pollutants due to pre-existing diseases, other exposures/stressors, and poor access to medical services.

This context also has a pervasive belief that the general public does not understand new animal waste management technologies including anaerobic digestion and fast pyrolysis, leading to recommendations that further education is needed. However, public engagement by institutional stakeholders has been minimal, and representatives of vulnerable communities, such as minority advocates, have highlighted this lack of communication or engagement. The core refrain of environmental justice, "Nothing about us without us," remains valid for these stakeholders. Regardless of the specific risks and benefits for these communities associated with new waste management technologies, the absence of procedural justice - the substantive engagement of marginalized communities in policy decisions - is notable.

To understand the context of communities near to waste management facilities, we developed the 'Environmental Justice Framework' with an aim to assess Environmental Justice (EJ) factors in the selection and siting of animal waste facilities and/or animal waste treatment technologies in the current and future context. The specific EJ Framework developed for this study was divided into six phases (Figure 2f.1). This section outlines the development and implementation of the EJ framework in Maryland, including the recommendation of next steps for the future.

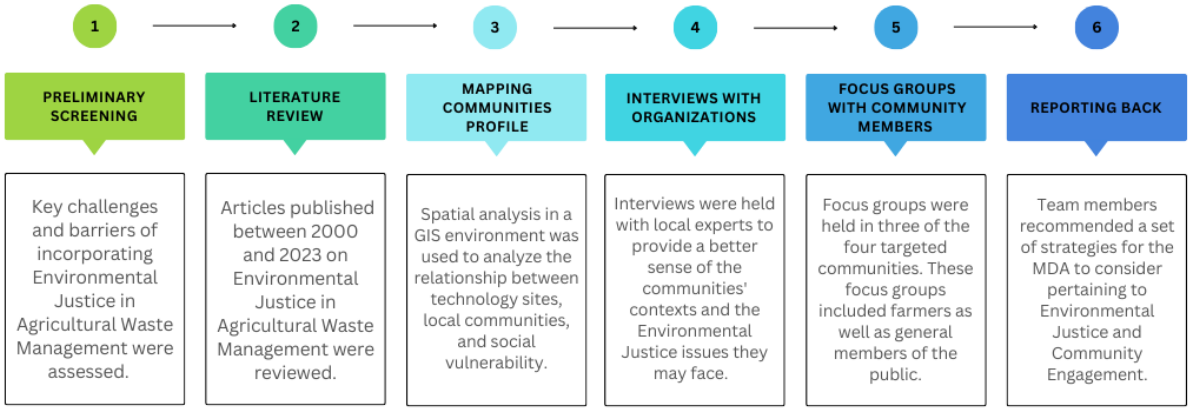


Figure 2f.1: The Environmental Justice Framework for the selection and siting of waste animal technology or waste treatment facilities combines the review of literature, spatial analysis, and participatory approaches with organizations and community members.

Topic 2f Key Findings and Recommendations

1. Fund awardees should have an environmental exposure plan for employees and neighbors. This could include reliable PPE access, local interpreters for visits, affordable health insurance, and plans to reduce odor, traffic, and emissions.
2. MDA should encourage farmers to consider all potential environmental justice issues before a project begins. This is beneficial to developers, governmental agencies, and community members. Support for farmers could be done through conducting analysis of exposure using tools such as EJSCREEN, MD EJSCREEN, or a health impact assessment tool (see more in the topic 4). While conducting this analysis, it should be noted that vulnerable communities near waste management sites may not appear in official data sources due to the presence of migrant and seasonal workers. Spatial analysis should be conducted to help locate and profile the communities most vulnerable to the impacts of animal waste technologies and develop mitigation measures tailored to their specific needs based on surrounding social, economic, and environmental data.
3. In order to ensure that the public is well-informed of the benefits and risks of new waste management technologies being used in their communities, AWTF awardees should have a public engagement plan included in their application. Such a plan could include strategy to publicize the project locally using sources relevant to the local population (e.g., Facebook groups, local print media, etc.), proactively provide information and opportunities for questions before and during facility construction and operation, and engaging with local community organizations.
4. In order to ensure that minority and vulnerable populations are not excluded from the decision making process, boards advising, reviewing, and apportioning funds for AWTs should maintain seats for community representatives from varied vulnerable populations.
5. In addition to providing funds to install and use new waste management technologies, MDA should consider setting aside funds for vulnerable and historically marginalized populations to engage in empowerment activities on local land use and agricultural decisions, such as the formation of local advisory committees. This would provide a permanent and reliable avenue for local communities to provide feedback, express local priorities, and address concerns.
6. MDA should consider establishing a monitoring and evaluation component of the AWTF program to include regular evaluations of awardees' efforts at public engagement and reducing environmental exposure.

TOPIC 3: Emerging Market Assessment

Topic 3a. Assessment of Emerging Markets for Animal Waste Management Technologies

Topic 3 Summary

Markets for technologies to both convert manure for alternative uses and improve manure's value as fertilizer are continuously evolving. Farmers can be expected to adopt these technologies if the present value of expected revenues outweighs the project's expected costs. Currently, Europe produces half of global biogas, with US production lagging behind and mostly coming from landfills as opposed to agricultural sources. Future development of markets for biogas-producing technologies will be shaped by several factors. While the U.S. is committed to decarbonization efforts, the costs of other renewable energy technologies, like wind and solar, have fallen below that of biopower in recent years, making them a more attractive option. Adoption of some technologies, like on-farm anaerobic digesters, have thus far been limited by basic economic constraints, as economies of scale make render on-farm adoption profitable at only the largest dairy operations.

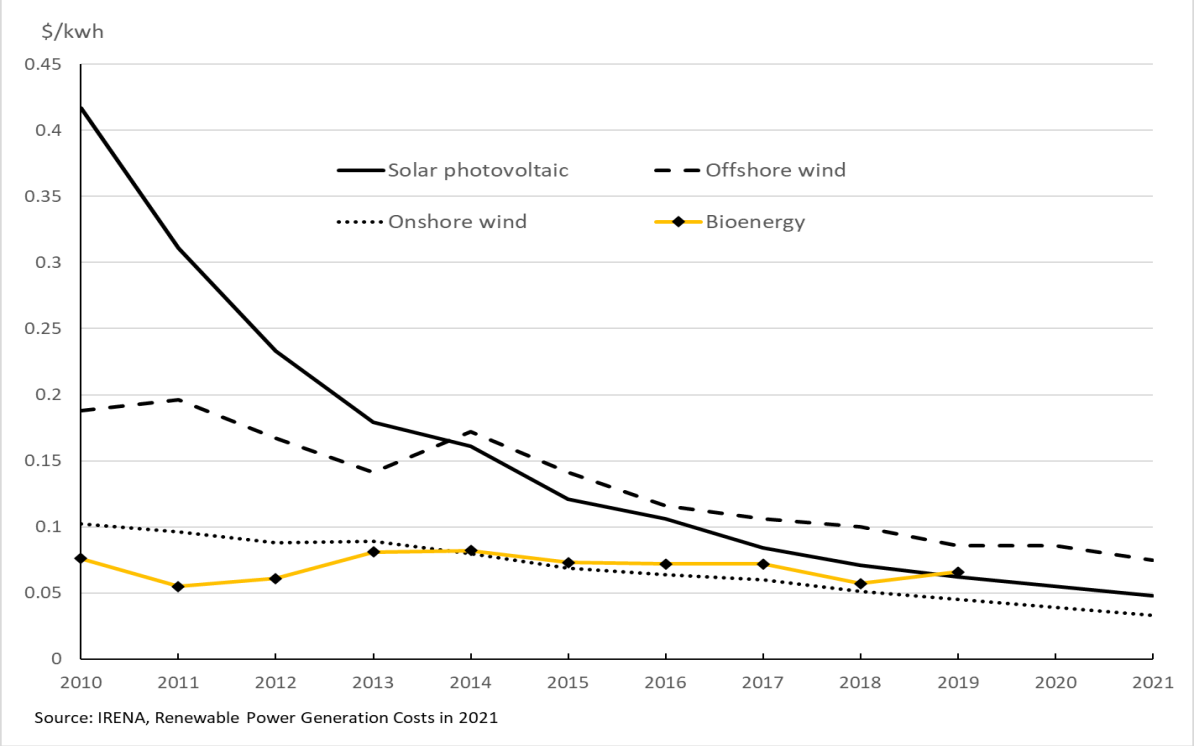


Figure 3.1: Levelized Cost of Solar, Wind, and Bioenergy Power, 2010-2021 (IRENA, 2022).

Topic 3 Key Findings and Recommendations

1. There is growing policy interest in renewable energy. Solar and wind-based energy are expected to account for almost all the growth in renewable energy use for electricity. Without state or federal policy support improvements, we may not see substantial growth in animal waste-based electricity generation due to this steep competitive landscape.
2. Anaerobic digesters, and other technologies for converting animal waste to energy, do not eliminate the need for a land base for nutrient application, as those technologies leave nutrient-dense residuals. Total cropland and available cropland receiving manure is declining in Maryland over time.
3. Animal wastes provide a substantial share of the nutrients applied to farmland in Maryland. In many locations, manure application meets all of a crop's need for phosphorus, even as it meets a much smaller share of nitrogen requirement. In that sense, the phosphorus content of manure constrains the amount that can be applied.
4. Maryland counties vary widely in their use of manure for nutrient applications, suggesting opportunities for expanded applications in some areas, especially if transportation costs and phosphorus content can be reduced.
5. Federal and some state policies (California, for one) make renewable natural gas (RNG) facilities more profitable, resulting in a sharper rise in upgrading biogas to RNG for use as a transportation fuel on larger dairy farms due to the higher capital investment needed.
6. Digesters are far more economic on very large dairy farms, with adopter herd size averaging 4,000-7,000 milk cows in recent years due to substantial scale economies in both digester operations and the dairy industry. Maryland has few large dairy farms, which limits the likelihood of on-farm adoption in the state, without subsidies.
7. There are far fewer thermochemical processing units, making it difficult to conduct full analysis, but the few existing plants produce electricity and must compete with wind and solar, which is challenging due to lower costs of these technologies compared to biomass.
8. The main drivers for digestion and thermochemical adoption are scale for on-farm systems and transportation distances for community systems.

TOPIC 4: RECOMMENDATIONS

Topic 4a. Detailed recommendations on future use of the Animal Waste Technology Fund to improve public health and the environment, reduce nitrogen and phosphorus transported to the waters of the State, and address climate change goals.

- Animal waste technology funding should take into account the manure distribution sources in the state and target locations that would have the largest reductions in GHG emissions and eutrophication. There should be targeting of specific areas in the state and matching of the best technological option and/or mitigation practice with the nutrient and GHG reduction needs in that location. CAFO mapping should be used in decision making. A manure-shed concept mapping effort could be utilized in Maryland, similar to Pennsylvania's effort, where nutrient "sinks" and "sources" are identified for targeted future mitigation efforts.
- The fund should consider assisting in locations to store, compost, digest, or otherwise process DAF in Maryland. There is a large quantity of DAF moving through the state of Maryland to be processed, stored, field applied, or transported to Pennsylvania. There is a need for safer DAF holding units that can process DAF year-round while not causing concerns to the locals in the communities, such as composting or anaerobic digestion to remove odor concerns and aid with application of DAF-based soil amendments.
- The fund should link with state-wide efforts to reduce GHG emissions. As dairy farms are decreasing in Maryland, manure sources are being concentrated on fewer farms and stored uncovered in anaerobic lagoons. Covering these lagoons would reduce GHG emissions and bring alternative income to dairies during the current time of instability in milk prices.
- There should be more direct linkage between efforts at MDE to reduce food waste and MDA's efforts in assisting on-farm manure technologies. Procedural alignment of food waste diversion efforts would ensure consistent feedstocks are brought to a composting or digestion facility and help in securing long-term contracts and reducing economic instability.
- Interviews revealed there is an interest for waste technologies and manure storage systems for large crop farms, which could incorporate manure and/or food waste but permitting these facilities is not allowed under current code. Many farmers and agencies have noted the inability to get certain waste (i.e. poultry litter from the Eastern Shore) to Central and Western Maryland, especially during off-peak seasons. If poultry houses had more local technology options and/or storage capacity to hold litter during the off-peak months, this could reduce long-haul transportation during peak-litter demand season, which would improve local traffic patterns and reduce GHG emissions associated with this transportation.
- There needs to be more education and technical support/tools. There is a lack of education on waste technology systems in the state, both among the public and within state agencies and utility companies (who do not have incentives to engage). Current policy does not recognize the multiple benefits of digesters beyond energy production. Educating applicants in the technologies could lead to designs more tailored to the needs of the agriculturalists as well as meeting climate change mitigation efforts of the state. Additionally, more education could create more robust applicants with varied projects and ideas and help applicants with other federal and state co-funding. Educating the public could lead to more internal expertise and policy changes that incentive animal waste technologies and reduce misinformation.
- There should be specific educational outreach to the public and interested parties prior to applications being submitted. Limited funding has discouraged many from applying or

unsuccessful applicants from reapplying. One option might be moving the AWTF applications to two-year basis, with Year 1 being an educational/instructional year devoted to public and industry education, developing timelines for permits and planning, and technical assistance on the application (ideally in conjunction with UMD Extension, county Soil Conservation Districts, and current farms using these technologies). For example, the California's fund sets aside funds for a dedicated technical board staff to work year-round solely on application support. The following year (Year 2), applicants would submit project proposals, with criteria that applicants participate in a certain amount of provided educational and outreach programs in Year 1 to qualify for the fund. Past projects from the previous years of the fund should be initially contacted and analyzed to see if this type of education and technical support would address some of the past project failures.

RECOMMENDATIONS

Topic 4b. Detailed recommendations on future uses of the Animal Waste Technology Fund to preserve the viability of the agricultural industry by improving animal waste management strategies.

- The fund should consider devoting funds to aid local communities, like county Extension offices or county Soil Conservation Districts, to provide technical support and purchase and maintain equipment for manure injection, composting, or biogas upgrading equipment. A equipment loan program would allow more farms the opportunity to use animal waste technologies and strengthen the relationship and trust between the community and MDA.
- The members of the AWTF boards and committees should consider using portions of the fund for developing or enhancing current state databases, with digitizing information on manure, AIRs, and various manure-based technologies to better understand the current state and the effect of technology implementation on nutrient and GHG emissions reductions.
- The fund could designate portions of the fund to pay for technical service providers to aid applicants in their applications and possibly increase both quantity and quality of applicants.
- The fund should encourage farmers and potential applicants in locations that would be positively impacted from the byproducts and benefits of animal waste technologies. This effort could include cross-referencing with food waste diversion efforts, areas in need of renewable energy, and potential for community-based technological sites. This can be done by highlighting targeted locations and marketing in this area for specific application years.
- Policymaker should be provided with educational and technical knowledge of animal waste technology efforts and the effect of technology adoption incentive programs. For example, increasing electric net-metering for biomass projects to match the resiliency and capabilities of these technologies, or ensuring "biomass" is included in "renewable energy" policies.
- The fund should consider supporting projects that would help reach the state reach mandated climate change goals for 2031 and 2045. This effort could include creating more inclusive language that acknowledges the role that animal waste technologies have in climate change mitigation, GHG reduction calculators for these technologies (similar to California), or other aids to help biomass projects in competitive market for renewable energy production.
- The fund could have a required follow-up, lessons learned to ensure success and longevity of awarded projects. Anonymized follow-up materials could be posted to the AWTF's website to aid future applicants and allow them to hear directly from successful applicants.
- The fund should provide ways to determine return on investment for GHG mitigation and reduction. The California Department of Food and Agriculture's "Dairy Digester Research and Development Program" puts a dollar value on the GHG emissions reduction of each project as part of the application process. It is important to estimate expected GHG emissions before starting a project. Additionally, the fund has evaluation criteria that includes technical feasibility, GHG emissions reductions and co-benefits, NOx reduction, cost-effectiveness, project readiness, community engagement and outreach (i.e. environmental justice), and impact on the California dairy industry (Appendix E). This model could be replicated in Maryland to provide a more inclusive criteria for funding projects based on state goals.

RECOMMENDATIONS

Topic 4c. Detailed recommendations on future uses of the Animal Waste Technology Fund to incorporate environmental justice into the selection and siting of future projects.

In general, recommendations are derived from analysis of information shared in interviews and focus groups by community members and stakeholders that participated in the Environmental Justice Framework (see more details in Topic 2f).

- **Environmental Exposure Plan and Community Impacts Assessment:** Applicants could conduct community impact assessments focusing on exposure and social vulnerability as part of the application process using a tool such as EJScreen, MD EJScreen, Affirmatively Furthering Fair Housing (AFFH) mapping, or a rapid Health Impact Assessment (HIA) (Baskin-Graves et al., 2019) to identify populations and critical services (e.g. schools, healthcare facilities) located in proximity to the proposed site. Specific attention should be paid to vulnerable populations including:
    - Groups with limited mobility and higher risk of illness, including children and seniors.
    - Groups that have historically been disproportionately burdened by the siting of environmental impacts, including BIPOC, low-income, and low-education populations.
    - Groups with limited access to system resources, including limited-English proficiency.
    - If possible, the presence of migrant and undocumented labor populations.
- **Communication:** Community members have highlighted the need for improving the communication and dialogue between funders, farmers, and residents about environmental issues before the project begins. This can be done by using tools, such as EJSCREEN or health impact assessments and starting communication early in the planning process.
- **Social Vulnerability**: When discussing what makes communities more vulnerable in the context of animal waste management, participants shared their experiences, which included the distribution of harms in the community, diseases or odors concentration, the resources to mitigate impacts, health insurances, and nationalities of residents. While conducting EJ analysis, it should be noted that vulnerable communities near waste management sites may not appear in official data sources due to the presence of migrant and seasonal workers. Spatial analyses are suggested to help locate and profile the communities most vulnerable to the impacts of animal waste technologies and develop mitigation measures tailored to their specific needs based on surrounding social, economic, and environmental data.
- **Education:** Recipients should engage in community education on the immediate and longer-term risks and benefits of the specific technologies the grantee is using or plans to use. Application could include a space for an education plan with the following features:
    - Available in appropriate local languages and in terms understandable to the local public and media.
    - Education could include flyers, events, town meetings, and public announcements.
    - Applicant could provide evidence that the methods chosen for education were selected to reach the appropriate audiences identified in the community impacts assessment.

- **Engagement:** AWTF may consider evidence of engagement with community members prior to application and/or during implementation. Engagement should incorporate groups identified in community impacts assessment.
    - Engagement could include in-person or virtual options in appropriate languages.
    - Time of day for engagement should be based on local needs.
    - Evidence of engagement could include attendance sheets, notes showing collection, and consideration of feedback.
    - Engagement could be combined with education efforts if substantial time is given to ensure comprehension and feedback.
    - Minority and vulnerable populations should be included in the decision-making process, advising boards, and apportioning funds for AWTF, with seats maintained for community representatives from vulnerable populations or EJ experts who engage with these groups.
- **Monitoring and Evaluation:** The AWTF could request an EJ evaluation plan, which could include continued contact with diverse community members, updates on areas of concern identified in Engagement, and revision (as appropriate) of the community impacts assessment.
- **Funding:** Engagement with vulnerable and historically marginalized populations can include funds for empowering communities on local land use and agricultural decisions, such as the formation of local advisory committees.
- **Representation:** The fund should have community members and under-represented demographics accounted for in the decision-making process of the AWTF, such as having an EJ expert reside on the Technical Advisory Committee to guide and educate decisions for the application review and ensure community engagement is met.
- **Understanding the "California" model:** The Dairy Digester Research and Development Program funded by the California Department of Food and Agriculture emphasizes public acceptance and environmental justice, with grant applications required to provide detailed plans for mitigating negative environmental impacts and evidence of community outreach efforts. In-person community meetings are mandatory, with supplementary materials, such as at least three letters of support and/or documentation of outreach efforts, required at the time of application (see Appendix E). The evaluation criteria for the California Dairy Digester Research and Development Program includes sections on community impacts and mitigation, localized economic benefits, and benefits to priority populations. The program does not restrict project location but requires individual digester projects at unique sites to address community impact guidelines. Applicants are required to complete the CARB Community Engagement Questionnaire and provide supporting documentation, including letters of support and information on outreach efforts. The program provides guidance and clarification through a Frequently Asked Questions section (see Appendix E). AWTF can also reference EJ factors by using procedural processes from other states which considers EJ efforts and concerns in their regulations.