REDUCTION OF

GREENHOUSE GAS EMISSIONS REPORT

DECEMBER 2021

Maryland
ENVIRONMENTAL
SERVICE

Message from the Executive Director

The Maryland Environmental Service (MES) is proud to present this report on our efforts to contribute to the reduction of greenhouse gas emissions in the State of Maryland, as required by Section 3-103.4(f) of the Natural Resources Article of the Annotated Code of Maryland.

The mission of MES is to provide operational and technical services that protect and enhance the environment for the benefit of the people of Maryland. We are a quasi-governmental agency, operating on a fee-for-service basis, with no regulatory responsibilities outside of our own governance. MES serves clients and partners, meeting or exceeding the environmental regulations required in our operations.

MES is excited to support our state, county, and municipal partners with projects that mitigate or sequester carbon greenhouse gases, improve the quality of the Chesapeake Bay and its ecosystem, and positively impact the quality of life in Maryland.

The team at MES spent the last six months analyzing carbon emissions and evaluating technologies that have co-benefits, allowing us to meet regulatory permits and mitigate emissions. All four of the operating groups in this organization -- Water and Wastewater, Technical and Environmental Services, Environmental Dredging and Restoration, and Environmental Operations -- have participated in this effort.

One of the most exciting technological innovations is the production of biochar from various forms of organic carbon waste streams. When this technology is fully realized, we will attain a sustainable cycle for biosolids and the organic fraction of solid waste. Biochar is a product of the thermal decomposition of organic matter in an inert atmosphere, devoid of oxygen, produced through pyrolysis or gasification. Pyrolysis is one of the only technologies that destroys Per- and Poly -Fluorinated compounds (so-called “forever chemicals”) found in wastes such as wastewater biosolids and landfill leachate. The process can be optimized to produce a solid, charcoal like material that sequesters organic carbon for more than 1,000 years.

Through this effort and others mentioned in this report, MES seeks opportunities to meet the environmental challenges of our day with innovative solutions for our partners and clients across the state. MES looks forward to the future with hope and all the ancillary benefits that come from lower carbon emissions and carbon sequestration.

Sincerely,

Charles C. Glass, Ph.D., P.E.
Executive Director

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1. Introduction to the Maryland Environmental Service

MES was created by the General Assembly in 1970 to support the maintenance, improvement, and management of the quality of air, land, water, and natural resources and promote the health and welfare of the citizens of the state. Today, MES employs over 800 teammates, and operates more than 1,000 environmental projects across Maryland and the mid-Atlantic region. As a non-budgeted instrumentality of the state, MES provides multidisciplinary environmental services to enhance and protect the environment through innovative solutions to the region's most complex environmental challenges.

MES is a leader in the environmental management service area. Operating in and managing projects, including dredging, shoreline restoration, water, wastewater and stormwater management, and solid waste and recycling programs. MES looks forward to continuing its leadership role in promising areas like renewable energy production, carbon sequestration, and greenhouse gas (GHG) emission control technologies to ensure that communities where we work and live are clean, healthy, and safe.

2. The Status of Climate Change Actions in Maryland

2.1 Maryland's Greenhouse Gas Emissions Reduction Act (GGRA)

In 2009, the state enacted its first comprehensive plan to reduce GHGs, contributing to the global fight against climate change. The Greenhouse Gas Reduction Act (GGRA) formally adopted in statute the GGRA Plan of 2008, which required a reduction of GHG emissions by 25% of 2006 baseline levels by the year 2020. In addition, it also set a long-term goal of reducing GHGs by up to 90% emissions from 2006 levels by 2050. While the GGRA has been amended only once, the GGRA plan was updated in 2013, 2015, 2019, and again in 2021. The current plan developed by the Maryland Department of the Environment (MDE) calls for the state to reduce GHG emissions by 50% of 2006 levels by 2030 and achieve net-zero emissions by 2045.
In 2016, Governor Hogan signed the GGRA – Reauthorization. The most significant enhancement was a new benchmark requiring a 40% reduction from 2006 levels by 2030[1]. This additional benchmark was included to ensure continued progress toward the state's long-term GHG emission reduction goals. According to a World Resources Institute report, published in August 2020, from 2005 to 2017 Maryland lead the nation in emissions reductions (38%) and simultaneous growth of GDP (18%)[2].

The 2030 GGRA Plan (Plan), which MDE submitted to Governor Hogan and the Maryland General Assembly in February 2021, exceeds the goals required under current state law[3]

"This Plan is ambitious and achievable, bold and balanced with over 100 actions that underscore the urgency for real and lasting climate solutions," said MDE Secretary Ben Grumbles. "According to the World Resources Institute, Maryland's long-standing leadership is shown by being ranked the No. 1 State in the nation in reducing greenhouse gas emissions while growing the economy. As the United States rejoins the Paris Agreement, the Hogan Administration intends to keep the momentum going in Maryland with a bipartisan plan that builds upon our success and adds new measures across all sectors of the economy and levels of government."

Major features of the Plan are:

- The Plan recognizes a new, more ambitious goal of 50% reductions over 2006 levels by 2030 recommended by the independent Maryland Commission on Climate Change (MCCC) in their 2020 Annual Report and a long-term goal of net zero GHG emissions by 2045. Technically, while the 2030 GGRA plan recognizes 50% reduction by 2030, it does not state it as a goal, since the current statute calls for a 40% reduction by 2030.
- The Plan incorporates a comprehensive set of over one hundred different programs and measures all aimed at reducing GHG emissions. These include:
    - investments in energy efficiency and clean, renewable energy solutions,
    - clean transportation projects and widespread adoption of electric vehicles,
    - planting more than 7 million trees, and
    - improved management of existing forests and farms to capture and contain more carbon in trees and soils.
- The Plan supports new "green" jobs by encouraging investment in the modernization of electricity, transportation, and the buildings sectors, the largest sources of GHG emissions in Maryland.
- Significant elements of the Plan also include the "implementation of programs and measures that address environmental and climate justice, recognizing that disadvantaged communities can be disproportionately affected by climate change and environmental pollution."
- In addition to reducing GHGs, the Plan will reduce air pollutants attributed to ground-level ozone and fine particulate pollution.
- It also will improve water quality through reductions in nitrogen and phosphorus pollution to the state's waterways, including the Chesapeake Bay.
- In addition to extensive input from the public and stakeholders, MDE developed this Plan in coordination with nine state agencies and the MCCC.

2.2 Greenhouse Gas Emissions Reduction Policies

At least 16 states and Puerto Rico have approved legislation establishing GHG emissions reduction requirements[4].

Several states have also implemented carbon pricing policies either independently or through regional agreements to reduce emissions and drive adoption of renewable energy and clean energy technologies.

For example, California is employing a multi-sector GHG cap-and-trade program. In addition, several Northeast and mid-Atlantic states are participating in the Regional Greenhouse Gas Initiative (RGGI), the first binding cap-and-invest program to reduce GHG emissions from the power sector.

Other states have multiple policies in place, as shown in the map below (Figure 1), including binding statutory requirements that reduce statewide emissions and completion of emissions inventories. Additionally, multiple states have implemented statutory GHG reduction and reporting requirements and carbon pricing policies. Thirty states, including Maryland, have renewable or clean electricity standards, which require a percentage of electricity sold by utilities to come from renewable sources. Several states have recently increased their standards to require 100% renewable or zero-emissions electricity by mid-century.

3. Opportunity to Transition to a Carbon Negative Adaptation

Understanding the real risks that climate change poses to businesses and developing pragmatic programs to manage and mitigate those risks is one of the most complex issues jurisdictions face today.

The world's response to the challenges of climate change is creating a wide range of issues that businesses must understand and manage. Developing and executing a plan that mitigates risk and identifies the new business opportunities created by these challenges requires a unique combination of strategy, business acumen, and profound energy, climate, and environmental policy expertise.

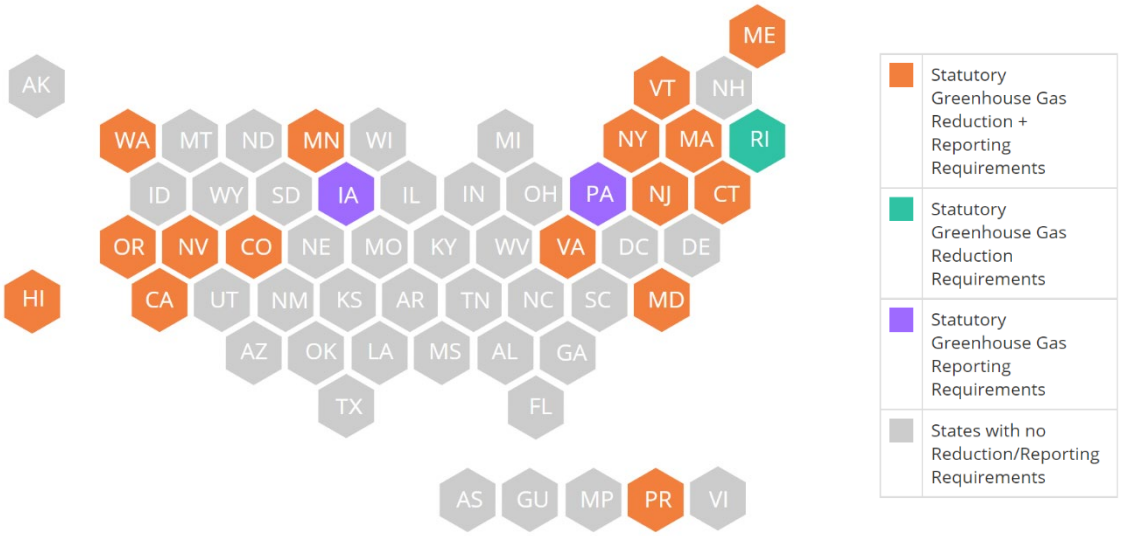

Figure 1: States with Statutory GHG Reduction and Reporting Requirements (source: National Conference of State Legislatures) [4]

The primary sources of GHG emissions in Maryland are electricity consumption, transportation, residential, commercial, and industrial fossil fuel use [5]. MES actively works in all these sectors. To reach the reduction goal of 55 million metric tons (MMT) of carbon dioxide-equivalent (CO_2e) – the weighted representation of global warming potential of different GHG gases relative to CO_2 - annually, enhanced programs throughout all sectors (energy, transportation, agriculture, etc.) were identified by MDE[6].

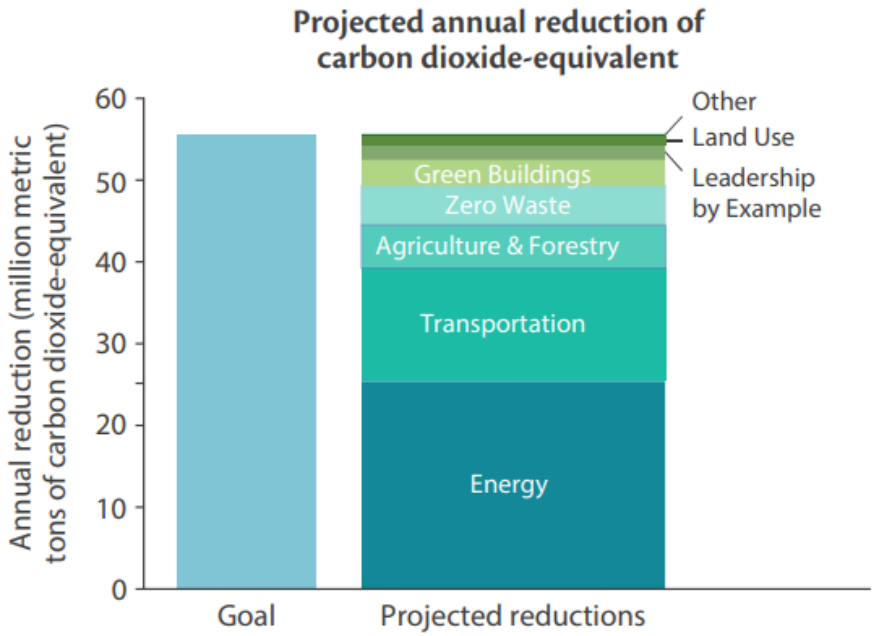

Figure 2:Projection of Annual CO2 Reduction from the Major Sources of Carbon Emissions in Maryland[6]

3.1 Carbon Offset Credit

CO_2 is the most abundant GHG produced by human activities and the essential pollutant to address for curbing climate change. However, human beings create and emit numerous other GHGs, most of which have a far greater heat-trapping effect, pound for pound, than CO_2. The most prevalent of these gases are methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF_6). Fully addressing climate change will require reducing emissions of all GHGs. Therefore, scientists have established global warming potentials (GWPs) to express the heat-trapping effects of each GHG in terms relative to CO_2e. This makes it easier to compare the effects of different GHGs and denominate carbon offset credits in units of CO_2-equivalent emission reductions.

The terms carbon offset, carbon offset credit and "offset credit" are used interchangeably, though they can mean slightly different things. A carbon offset broadly refers to a reduction in GHG emissions – or an increase in carbon storage (e.g., through land restoration or the planting of trees) – that is used to compensate for emissions that occur elsewhere.

A carbon offset credit is a transferable instrument certified by governments or independent certification bodies to represent an emission reduction equivalent to one metric ton (MT) of CO_2. The purchaser of an offset credit can "retire" it to claim the underlying reduction toward their own GHG reduction goals.

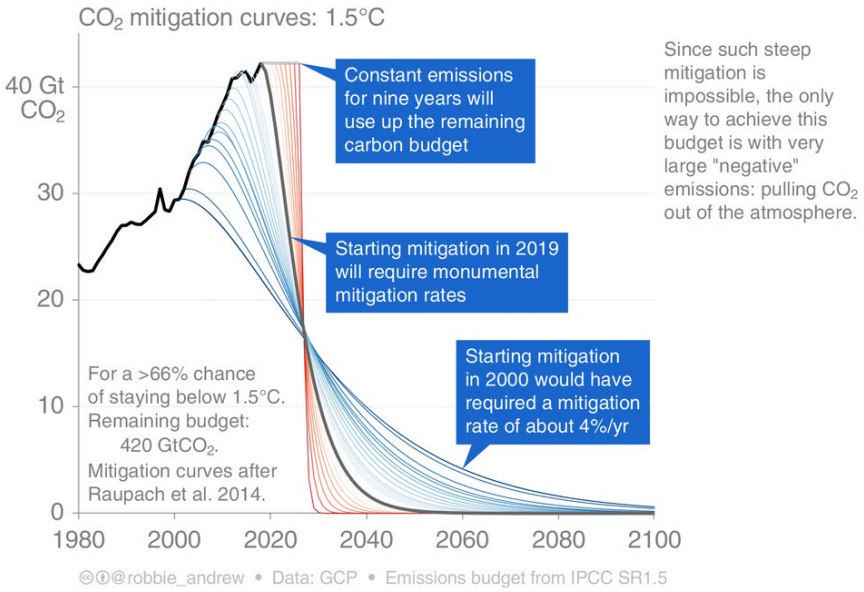

Figure 3:Establishing a Common Denomination for Different GHGes Where Required

a) Wetland Carbon Credits

A basic tenet of the carbon credit market is the requirement to show project additionality – that is, that the project itself will lower carbon emissions from the baseline scenario. Accordingly, any wetland project activity that results in decreased carbon emissions with respect to its baseline scenario could be eligible for credits if in conformance with a given carbon credit methodology.

b) Blue Carbon Credits

According to Sapkota and White (2020)[7], there are four methodologies currently approved for carbon credit generation for coastal wetlands in the U.S. (so-called Blue Carbon Credits).

1. American Carbon Registry
    a. Restoration Degraded Deltaic Wetlands of the Mississippi Delta Methodology, v 2.0
    b. Spatial coverage is limited to the Mississippi Delta
2. Verra Registry
    a. Methodology for Coastal Wetland Creation, v 1.0
    b. Spatial coverage is limited to Louisiana and other coastal regions

3. Verra Registry
    a. Methodology for Tidal Wetland and Seagrass Restoration, v 1.0
    b. Spatial coverage is worldwide
4. Verra Registry
    a. Restoration of Deltaic and Coastal Wetlands Methodology
    b. Spatial coverage is limited to California

In addition, the Verra Registry has a recently released methodology, Estimation of Baseline Carbon Stock Changes and Greenhouse Gas Emissions in Tidal Wetland Restoration and Conservation Project Activities, v 1.0, to establish the baseline scenario under their Wetland Restoration and Creation. This methodology is applicable to mangroves, tidal and coastal wetlands, marshes, seagrasses, floodplains, deltas, and peatlands.

As an additional note, there is the Clean Development Mechanism methodologies for Afforestation and Restoration of Mangrove Habitats, as well as Wetland Activities that have been developed under the Kyoto Protocol. These methodologies, however, are only applicable to participating member countries of the Kyoto Protocol.

c) Carbon Credit Methodologies – Non-Coastal Wetlands

The additional following methodologies are applicable or potentially applicable to non-coastal wetlands:

1. Verra Registry
    a. Methodology for Rewetting Drained Tropical Peatlands, v 1.0
    b. Spatial coverage is limited to Southeast Asia
2. Verra Registry
    a. REDD+ Methodology Framework, v 1.5
    b. Spatial coverage is limited to forested wetlands and peatlands worldwide
3. Verra Registry
    a. Methodology for Rewetting Drained Temperate Peatlands, v 1.0
    b. Spatial coverage is limited to drained temperate peatlands worldwide.
4. American Carbon Registry
    a. Methodology for the Restoration of Pocoson Wetlands
    b. Spatial coverage is limited to drained peatlands of the coastal plains of Southeast Virginia, North Carolina, South Carolina, and Georgia in the US
5. American Carbon Registry
    a. Afforestation and Restoration of Degraded Land, v 1.2
    b. Spatial coverage is forested wetlands and peatlands worldwide.
6. Climate Action Reserve
    a. Forest Project Protocol, v 4.0
    b. Forested Wetlands of the US and US Territories

As illustrated above, there are a variety of methodologies that could be employed to determine the potential for a carbon credit market in Maryland. MES has dedicated staff resources to ensure that we are current with the scientific community and the worldwide response to calculate and assess progress toward mitigation goals. As illustrated above, there are a variety of methodologies that could be employed to determine the potential for a carbon credit market in Maryland.

4. MES' Contribution to Climate Change Mitigation

4.1 Operating Groups

In concert with the GGRA Plan, MES is committed to assisting Maryland achieve carbon neutrality for all scopes of emissions by 2045. MES continues to develop and administer opportunities for reducing climate impacts on the environment. Within its four groups, MES is actively working on carbon emissions reductions.

The four major operational groups in MES are:

- Environmental Dredging and Restoration
- Environmental Operations
- Technical and Environmental Services
- Water/Wastewater

4.1.1 Environmental Dredging and Restoration

The Environmental Dredging and Restoration Group (EDR) provides operational and technical services on behalf of our clients in the areas of dredged material management, outreach and engagement related to dredged material management, habitat restoration, hazardous materials management, environmental management systems and compliance, permitting and mitigation services, and wetland delineation and forest conservation services. EDR has assisted our client's efforts to reduce the impacts of climate change and GHG emission through the implementation of multiple projects some of which are highlighted below.

A. Port of Baltimore Clean Diesel Program and Greenhouse Gas Reductions Strategies

MES has supported the Maryland Department of Transportation Maryland Port Administration's (MDOT MPA) air emissions inventories since 2006. These inventories illustrate commitment to reducing air emissions at the Port of Baltimore Public Terminals and other MDOT MPA facilities by generating valuable data used to strengthen their successful programs to improve air quality, including the Port of Baltimore Clean Diesel Program. Following the most recent engine emissions standard implemented by the U.S. Environmental Protection Agency (EPA) signed in 2004, Tier 4 emissions standards were phased-in from 2008 to 2015. The goal in Tier 4 was to significantly reduce nitrogen oxide (NOx) and particulate matter (PM) emissions, while carbon monoxide (CO) emissions limits remained the same from Tier 3.

MES has administered $13 million in grant funding since 2009, providing funds to retrofit, repower, or replace older dray trucks, cargo handling equipment, and marine vessels with cleaner burning diesel engines, equipment, and technologies at the Port. This program has also benefited the Dredged Material Containment Facilities (DMCF) that MES operates on behalf of MDOT MPA. Two of MDOT MPA's DMCF crew vessels received engine upgrades and diesel emissions reduction technologies on numerous pieces of construction equipment.

EDR will continue to support MES clients' efforts to combat climate change and GHG emissions through the implementation of new technologies and assistance with feasibility. EDR assists clients by providing cutting edge technical expertise and grant management experience, specifically focusing on transitioning diesel and gasoline powered vehicles and equipment to electrically powered vehicles and equipment, where viable.

B. The Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island

As climate change increases global temperatures of air and water, polar ice melts and thermal expansion raises sea levels. Combined with land subsidence in the mid-Atlantic rising sea level and wave action cause erosion, resulting in the loss of valuable island habitats throughout the Chesapeake Bay. In the last 150 years, it is estimated that 10,500 acres have been lost in the middle eastern portion of Chesapeake Bay alone. Islands and the surrounding habitat are preferentially selected by many migratory birds, as well as other fish and wildlife species, as nesting/production areas. The Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island (Poplar Island) is an environmental restoration project located in the Chesapeake Bay in Talbot County. The beneficial use project relies on dredged material from the approach channels to the Baltimore Harbor (necessary to keep the Port of Baltimore's commerce flowing) to restore what was once a nearly completely lost remote island habitat within the Chesapeake Bay.

In 2001 Maryland enacted the Dredged Material Management Act of 2001, Maryland Code Annotated, Environment Article §§ 5-1101 through 5-1108. This prioritizes beneficial and innovative reuse of dredge material as the preferred placement options in Maryland.

United States Army Corps of Engineers (USACE) and MDOT MPA began the project to achieve three goals:

- Restore remote island habitat within the mid-Chesapeake Bay
- Optimize the placement capacity for sediment dredged from shipping channels
- Cause no harm to the environment around the restoration site

The Poplar Island project is a cost share between the federal sponsor, the USACE who funds 75%, and the non-federal sponsor, MDOT MPA, who funds the remaining 25%. In addition, MES on behalf of MDOT MPA, manages the daily operations and technical and environmental services on site as well as provides valuable onsite construction services to build portions of the island.

Photo 1:Poplar Island

Listed below are specific projects at Poplar Island that address climate change.

a) Carbon Sequestration Study

The University of Maryland Center for Environmental Science (UMCES), under contract to MES conducted a carbon budget and sediment (total suspended sediment or TSS) budget study on Poplar Island from 2013–2014 in Wetland Cell 1B (see Figure 3). The study focused on carbon sequestration and carbon export from a restored marsh. Carbon sequestration is a goal of restored marshes; additionally, the carbon incorporated into the sediment helps increase vertical accretion and combat sea level rise.

The results from the study show that the input of macrophytic fixation at 73,145 kg/year is very large, whereas the input of benthic algal carbon fixation is only about 23,502 kg/year. The export of carbon via tidal flux is about 4,994 kg/year, and about 15,700 kg/year of carbon is sequestered. The carbon fixed by macrophytes is incorporated into the vegetation that persists through the growing season, and through a large part of the winter, and can be exported into the estuary; the carbon fixed by the benthic algae is largely recycled through the marsh and no large accumulations of algae are usually seen. UMCES did not measure methane emissions, nor did they estimate biota entering or leaving the marsh (fish, birds, etc.).

UMCES generated three main conclusions from this carbon-fixation study:

1. In Poplar Island marshes, the nitrogen supply drives extremely high rates of carbon fixation, and high rates of decomposition and remineralization.

2. Even though the Wetland Cells are open to tidal flow, the perimeter dikes help retain above-ground biomass (wrack) and support accretion.
3. As marshes age, nitrogen supply declines and:
    a. Production shifts to roots/rhizomes
    b. Decomposition slows and carbon burial increases
    c. Dike removal should not occur until this nitrogen decline occurs

b) Methane Study

Methane is a carbon compound that acts as a powerful GHG when released into the atmosphere. Methane's effectiveness in trapping heat in the atmosphere is 25 times that of carbon dioxide when examined over 100 years, making it influential to global warming. Wetland ecosystems have a vital role in the carbon cycle, removing carbon from the atmosphere and sequestering it within the substrate. Wetlands also can emit methane, through the anaerobic decomposition of organic material that occurs within saturated soils.

There is a salinity gradient throughout estuaries that ranges from a tidal freshwater marsh to an oligohaline marsh and then to salt marsh, depending on the proximity to the influx of oceanic salt water. The variability of salinity in wetlands coupled with changing soil temperature, plant diversity and abundance, and saltwater intrusion and precipitation events, can result in different marshes throughout the estuary acting as carbon sinks or sources.

Methane emissions have been quantified in natural marshes varying in salinity but there is a lack of information regarding methane emissions in restored marshes. The goal for the pilot methane study was to examine methane generation in the Poplar Island marshes to determine if there is a trend related to marsh maturation. UMCES examined the oldest marsh, Wetland Cell 3D, a middle-aged marsh, Wetland Cell 1B, and the newest marsh, Wetland Cell 5AB. UMCES concluded that the rates of methane flux within this cell are low, and not considered major in terms of net carbon exchange in Wetland Cell 5AB. The high sulfate concentrations within the soil at the time of planting may inhibit methanogenesis.

In 2021, a separate methane study that examines seasonal methane fluxes in the low and high marsh of Wetland Cell 1A began. Wetland Cell 1A measurements will be compared with measurements taken in a natural marsh, Monie Bay, and will be completed in Spring 2022.

c) Mid-Chesapeake Bay Island Ecosystem Restoration Project

The Mid-Chesapeake Bay Island Ecosystem Restoration Project (Mid-Bay Project) is a beneficial use project using dredged material from local navigation channels and the federal Chesapeake Bay approach channels serving the Port of Baltimore and the Chesapeake and Delaware Canal to restore remote island habitat and wetland habitat near Barren and James islands. The Mid-Bay Project will provide improved health and sustainability to aquatic and wildlife species, benefit navigational safety and passive recreation, while providing additional shoreline protection. Construction for Barren Island (Figure 4) is scheduled to begin in 2022, and for James Island in 2024 (Figure 5).

Located adjacent to Taylors Island, the James Island portion of the project will restore 2,072 acres of lost remote island habitat, with approximately 45% upland habitat and 55% wetland habitat. The restoration of Barren Island, located adjacent to Upper Hooper Island Bay, will utilize dredged material to restore a minimum of 72 acres of remote island habitat. The USACE will fund 65% of the Mid-Bay Project, and MDOT MPA will fund the remaining 35%. MES is providing support to this project on behalf of the MDOT MPA.

In 2021 MDOT MPA convened the Mid-Bay Project Resiliency Workgroup to identify, evaluate, and recommend design and habitat features that enhance climate resiliency, mitigate for climate change, and strengthen carbon sequestration while contributing to ecological improvement around the Mid-Bay Project. The goals of the workgroup are to review the existing Mid-Bay Project information for potential opportunities and constraints, compile a list of effective climate resilient restoration features, and develop a decision-making matrix. On behalf of MDOT MPA, MES is tracking the final document and options that will be identified by the group.

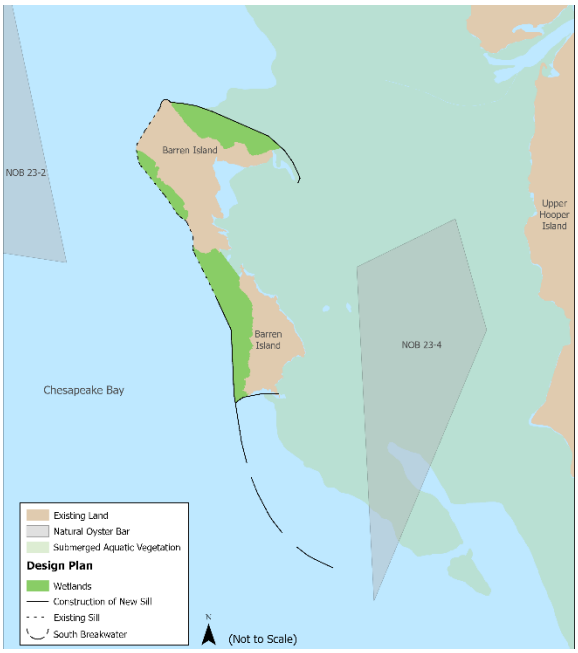

Figure 4:Barren Island

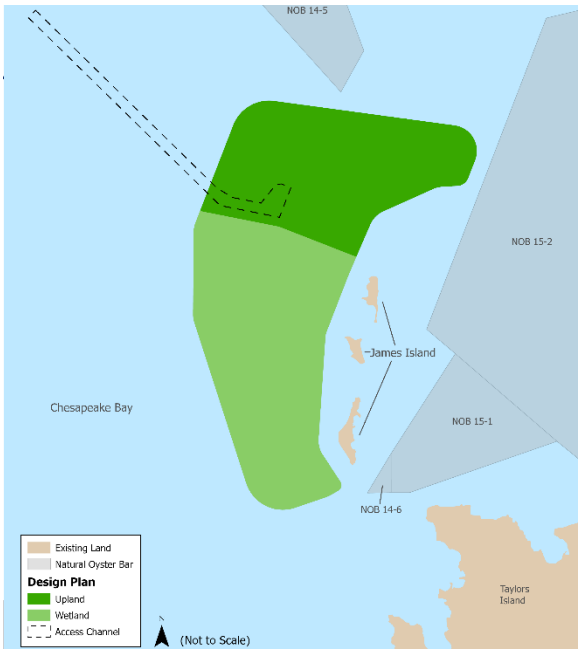

Figure 5:James Island

d) Environmental Justice and Climate Change

The EPA defines Environmental Justice (EJ) as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." The EPA describes achievement of this goal "when everyone enjoys: the same degree of protection from environmental and health hazards, and equal access to the decision-making process to have a healthy environment in which to live, learn, and work."[8] Unfortunately environmental inequalities disproportionately impact the nation's overburdened and underserved communities. MES has worked together with its clients over the years to provide outreach, engagement, and planning support to strategically provide project details and execute

technical projects throughout Maryland in equitable and inclusive ways. MES has also subcontracted with Minority Business Enterprises and Small Business Reserve firms to aid state clients in finding experts that specialize in addressing EJ concerns using collaborative approaches with target communities.

MES continues to provide technical, planning, and outreach services in support of the Dredged Material Management Program (DMMP), which recently reached a hallmark of 20 years of community engagement and programming. In 2001, Maryland passed the Dredged Material Management Act signaling the start of the DMMP; the act mandated that MDOT MPA develop a 20-year plan for managing dredged material. MES assists MDOT MPA in managing the committee structure to establish education on dredged material management issues and address concerns around development of dredging and restoration projects that involve state and federal partnerships. As part of MDOT MPA's 20-year planning process to find placement locations for dredged material, MES has assisted MDOT MPA in various projects that identify EJ concerns and assist in implementing technical studies, and outreach.

e) Seagirt Loop Channel Feasibility Study

The Baltimore Harbor Anchorages and Channels Modification of Seagirt Loop Channel Feasibility Study was initiated in 2020. The purpose of this project is to provide an analysis of the proposed deepening of the Seagirt Loop Channel to accommodate the new large Class IV Post Panamax ships calling on the Port of Baltimore. MES is providing various technical services associated with the required studies in the Environmental Assessment and Feasibility sections of this report.

More specifically related to EJ, MES provided the necessary information to identify any impacts to neighborhoods surrounding the project area and placement of dredged material. MES provided an analysis of the proposed dredging and placement project by providing information:

- on the neighborhoods most impacted by the proposed project using Census data,
- a report on air quality/conformity and identified impacts to the neighboring community,
- a GHG accounting analysis following USACE regulatory standards,
- an assessment on noise impacts,
- for a community informational meeting (planned for 2022), and
- a traffic analysis to determine if there is an increase in over the road traffic in the area based on cumulative effects of the project and the impacts on the surrounding neighborhoods.

f) Masonville Dredged Material Containment Facility

The Masonville DMCF, located in Baltimore City, was identified as a viable placement site to help meet the DMMP 20-year placement capacity requirement and was completed in 2010. MES worked diligently with MDOT MPA to identify stakeholders (neighboring communities, non-governmental organizations (NGOs), businesses, resource management agencies), to educate neighboring communities about the importance of constructing DMCFs, dredging's economic

benefit to the State of Maryland, and the science related to dredged sediment from Baltimore Harbor channels.

The larger successes of the collaboration with neighboring communities were the Masonville Cove Environmental Education Center, which is a green education center that MDOT MPA constructed for community use and community access to waterfront. Living Classrooms, a local NGO, runs several science-based activities for the public, including local school systems around Baltimore City. Masonville Cove was restored as a nature area; that and the nation's first Urban Wildlife Refuge Partnership not only provides a haven in the city for wildlife, but the surrounding community can now come and engage with nature and the waterfront through this access, including walking trails and a pier.

4.1.2 Environmental Operations Group

a) Landfills and GHG Reduction Activities

Methane gas is the byproduct of decomposing organic materials. In a landfill, food and yard wastes can make up a significant portion of solid waste, producing large quantities of methane emissions. GHG that emits through landfills is of significant concern for Maryland. MES owns and operates the Midshore I, and Midshore II landfills located on the Eastern Shore. MES also operates the Harford Waste Disposal Center (HWDC) in Harford County, and the W.R. Grace Landfill in Baltimore.

i. Old Easton Landfill – Easton, Talbot County

The Old Easton Landfill is located adjacent to the Midshore I Landfill. Waste acceptance occurred from the 1960s through 1991, with an estimated 548,000 short tons landfilled. The title to the Old Easton Landfill was transferred from the Town of Easton to MES as part of the original Midshore Agreement. The relatively minor amount of landfill gas that is generated at the landfill is passively vented. In 2020, the amount of landfill gas released from the closed landfill was modeled to be 4,587,437 standard cubic feet (scf), resulting in estimated emissions of 433 mtCH_4 (metric tons of methane) and 1,189 mtCO_2e.

MES is currently accepting proposals to lease solar energy installation/generation rights at the closed Old Easton Landfill and/or areas atop or adjacent to the interim-closed fill area of the Midshore I Landfill. A Request for Proposal (RFP) is being developed during the 2nd quarter of FY22 to advertise this potential opportunity for renewable energy generation at an MES-owned property.

ii. *Midshore I Landfill – Easton, Talbot County*

The Midshore I Landfill ceased accepting waste in 2010 with a total waste-in-place of 2,032,481 tons. It subsequently expanded its central landfill gas collection and control system and was covered with an Exposed Geomembrane Cap in 2016. The landfill was issued interim closure approval by MDE in 2017.

Landfill gas is collected via a network of approximately 67 wells. The landfill was issued interim closure approval by MDE in 2017. Gas is conveyed to the central flare station consisting of three candlestick flares and, between 2017 and 2020, was also delivered to a nearby gas-to-energy facility operated by Easton Utilities Commission for beneficial reuse. Landfill gas collected and combusted by the flares to produce electricity is quantified for net GHG reductions/removals under the Verified Carbon Standard (VCS) by a contracted third-party, Blue Source Canada ULC. During the 2020 reporting period, which included a portion of 2019, the gas captured and combusted at the Midshore I Landfill resulted in net GHG reduction/removals totaling 20,936 $mtCO_2e$. An additional 140,389 $mtCO_2e$ of GHG reductions/removals are estimated for the remainder of the project's crediting period under VCS (through October 2029).

iii. *Midshore II Landfill – Ridgely, Caroline County*

The Midshore II Landfill began accepting waste in 2010 and will continue to do so through 2030. At the end of 2020, the landfill had a total waste-in-place of 1,262,396 tons. Landfill gas is collected via a series of horizontal wells that have been constructed in two of the three constructed cells at the facility and passively vented via five candlestick flares. MES has retained an Architect/Engineering firm to design a central gas collection and control system for the facility. It is anticipated that the 90% design for this facility will be completed by the end of 2021. The system is being designed to accommodate beneficial reuse technologies, such as landfill gas-to-energy or renewable natural gas (RNG). An RFP will be issued for carbon offset marketing and sale coupled with a beneficial reuse feasibility analysis following the completion of the construction-ready gas system design. Construction of the gas collection and control system is expected to occur in 2022. According to the design engineering firm, once operational, this system will reduce at least 41,360 $mtCO_2e$ GHG per year through 2030.

Photo 2: Midshore II Truck Scales

MES also recently completed the construction and planting of a 7.9-acre wetland, along with an additional buffer area, to mitigate wetlands impacted during the construction of Midshore II. This wetland could sequester approximately 16.8 $mtCO_2e$ per year.

iv. Harford Waste Disposal Center – Street, Harford County, MD

The HWDC began accepting waste circa 1957 and, through 2020, has a total waste-in-place of 1,894,976 short tons. Landfill gas at the facility is collected via a vertical gas collection well network and controlled by a central, enclosed flare. In 2020, the gas collection and control system had a calculated capture efficiency of 36% and collected 64,312,556 scf of landfill gas. The methane destruction efficiency of the system was calculated to be 99%. Using the 2020 annual quantity of methane recovered, 669 metric tons, a methane combustion efficiency of 99%, and a methane GWP of 25 the flaring of landfill gas at the facility in 2020 resulted in roughly 16,550 mtCO2e reduction. Increasing the landfill gas system's capture efficiency could yield higher net GHG reductions in the years to come.

v. W.R. Grace Landfill – Baltimore City, MD

MES operates the industrial waste landfill at this location on behalf of W.R. Grace. Approximately 17,000–25,000 short tons of industrial waste comprised of silica filter cake material are landfilled per year. This material has a high inorganic content and, therefore, generates comparatively little gas compared to a sanitary landfill. Landfill gas is not collected at this facility.

b) Composting and Recycling Activities

MES operates a variety of recycling programs that positively impact GHG emissions compared to other disposal methods. In FY21, our recycling programs processed 140,470 tons of curbside recycling material (aluminum, plastics, paper, etc.). MES also composted 186,794 tons of organic materials, including 18,243 tons of food scraps. Based on CY18 waste diversion data from all Maryland counties, MDE estimates a reduction of 7,194,137 $mtCO_2e$ achieved through recycling when compared to traditional waste disposal.[9]

MES operates two of the largest Material Recovery/Recycling Facilities (MRFs) in the state. In Prince George's County, we operate a single stream facility that processes approximately 70,000 tons of material per year. In addition, we operate a dual-stream recycling facility in Montgomery County, which processes 40,000 tons of paper and 12,000 tons of commingled material (aluminum, plastic, and glass) per year. MES also operates the Midshore Recycling Program, which collects 3,500 tons of recyclables annually.

When compared to virgin resin production, plastics recycling represents a significant reduction in CO_2. In 2018, The Association of Plastics Recyclers evaluated the impacts of both virgin and

recycled resin production[10]. Compared to the generation of virgin material, recycled resin shows an average reduction of 683 kgCO_2 eq per 1000 lbs. of resin. This amounts to a 70% reduction in CO_2 e per 1000 lbs or a reduction of 14,455 tons of CO_2e for resin recycled through the Prince George's County and Montgomery County MRFs.

In addition to plastics, MES recycles paper, cardboard, steel, and aluminum at the MRFs. Using the EPA's WARM model[11] differential between virgin and recycled production, these items represent an additional reduction of 30,776 mtCO_2e/ton.

MES also operates various statewide recycling programs, for which GHG emissions can be estimated. The Maryland Used Oil Recovery Program collected 415,177 gallons of used motor oil in FY21. Based on industry estimates, utilizing recycled oil instead of virgin oil saves 3,662 mtCO_2e/ton.[12]

In addition, MES operates three composting facilities throughout Maryland.

- The Prince George's County Organics Composting Facility processes roughly 20,000 tons of food scraps and 40,000 tons of yard trim annually.
- The Montgomery County Organics Composting Facility processes 60,000 tons of yard trim per year.
- Harford Compost and Mulch Facility processes 13,000 tons of material into compost every year.
- The finished compost product is sold to consumers, sequestering carbon, and reducing the use of synthetic fertilizer.

Photo 3: Composting Equipment

c) Combined Heat and Power and Steam Plant Operations - Natural Gas Conversion

MES operates boiler plants at the Maryland State Correctional Institution at Hagerstown (Washington County), the Central Maryland Correctional Facility in Eldersburg (Carroll County),

and the Jessup Correctional Institution in Jessup (Anne Arundel County). Steam produced by those boilers provides heat for cooking, laundry operations, and heat for the prison complex.

In addition to the boiler plant operations, MES operates a biomass-fueled combined heat and power system at the Eastern Correctional Institution (ECI) in Westover (Somerset County).

ECI is a medium-security Maryland State correctional facility for men. It has a dedicated cogeneration power plant. The four-megawatt (MW) capacity plant utilizes debarked wood chips, which are transported over the road by diesel-fueled trucks, as its primary fuel source for two high-pressure boilers, consuming approximately 50,000 tons per year of wood with a calorific value of 5,000 British thermal unit per pound. The plant generates approximately 85% of the electricity and 100% of thermal needs for ECI on an annual basis.

In August 2019, MES entered a 10-year Gas Service Agreement with Chesapeake Utilities to utilize natural gas as a bridge fuel. To make the cogeneration power plant ready for natural gas consumption, MES started the design-bid-build process to install a natural gas distribution pipeline and convert the two high-pressure boilers with the goal of emissions reduction. In addition, MES collected five years of actual emissions data for a Baseline Actual Emissions (BAE) analysis. The BAE numbers were used for quantifying expected net changes in emissions, as seen below

	Pollutants (tons/yr)				
	NO_X	**VOC**	**CO**	**SO_2**	**PM_{10} / $PM_{2.5}$**
Baseline Actual Emissions	35.77	6.09	235.40	0.81	45.79
Projected Future Emissions	11.99	1.81	24.34	0.56	2.5
Net Emissions Change	- 23.78	- 4.28	- 211.06	- 0.25	- 43.29
Reduction (%)	66.5	70.3	89.7	30.8	94.5

Table 1: ECI Cogeneration Facility

In partnership with the Maryland Energy Administration (MEA), MES conducted a competitive procurement process that will bring critical natural gas energy infrastructure to ECI and the University of Maryland Eastern Shore in Somerset County. Once complete, the project will provide the two institutions with a reliable, affordable energy source, advance a critical economic development initiative for the region, and significantly reduce GHG emissions.

4.1.3 Technical and Environmental Services

The Technical and Environmental Services (TES) group is responsible for a variety of projects and services that support a diverse group of state agencies, counties, municipalities, private industries, and universities in managing a range of environmental challenges. Service areas include environmental monitoring, reporting, laboratory services, National Environmental Policy Act review support, geospatial and engineering services, as well as digital mapping.

The TES group is actively working on a variety of projects aimed to assist in floodplain preservation, conservation, and restoration. Flood protection of wetland areas is an important component of carbon sequestration because dense vegetation in wetland and coastal areas can absorb CO_2 from the atmosphere. Healthy vegetated coastal areas and wetlands need to keep up with sea level rise resiliency to continue providing a renewable carbon sink; when the plants die, the carbon remains stored in the decomposed plant matter in the wetlands.

a) Watershed Resources Registry

The WRR is a multi-agency, multi-state geographic information system (GIS) mapping initiative that identifies opportunities for restoration and preservation across the state. MES developed the GIS mapping with models that use marsh migration data and sea level rise data along with various other GIS data layers to determine ideal locations for coastal restoration and preservation efforts, and then provide the reports and data for governmental and resource agencies to use in decision making.

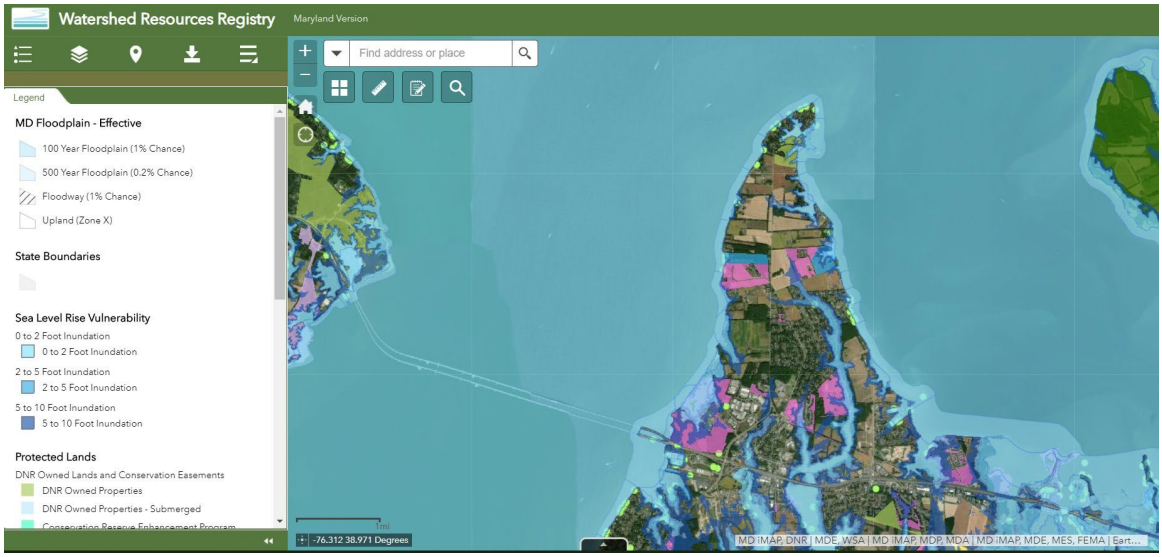

Figure 6: Watershed Resources Registry

b) Floodplain and Coastal Resilience Technical Support

To build capacity to address challenges, MES partnered with the Maryland Department of Natural Resources (DNR) and MDE to support efforts to better understand local needs related to the connections between floodplain management and coastal resilience. This partnership supports outreach and engagement with the community and compliance with the National Flood Insurance Program and assists communities with applications to the Community Rating System.

c) Climate Action Plan Support

Through use of innovative GIS mapping and database tools, MES assisted Baltimore County in development of their Climate Action Plan (CAP), which identifies strategies and actions to improve the sustainability of community facilities and infrastructure against climate change,

develop enhanced land use and management processes, expand the efficiency of the county's transportation infrastructure, and reduce county government energy consumption.

The CAP and its resource tools aim to guide the county's efforts to reduce emissions and fossil fuel consumption across three broad categories of county operations: buildings and energy, transportation, and waste management.

d) Maryland Resiliency Partnership Website

In support of DNR, MDE, and the Maryland Association of Floodplain and Stormwater Managers, MES developed a website to improve the content and usability of the Maryland Resiliency Partnership website. The website is a public engagement tool making the information accessible to all Marylanders. The website contains resources for local governments and nonprofits about flood preparedness and mitigation, a searchable database of grant opportunities, and a new landing page for Maryland Flood Awareness Month.

e) Carbon Pricing Review Support

MES is providing technical support and expertise to MEA to evaluate carbon pricing approaches. MEA seeks to explore viable approaches to reducing carbon emissions at the lowest cost to residents while continuing to meet needs. Carbon pricing seeks to directly set a price on carbon by defining a cost of carbon on GHG emissions, most commonly fossil fuel carbon content. Evaluating carbon pricing may serve, in coordination with the goals of the GGRA Plan, to provide an additional financial incentive for curbing emissions.

4.1.4 Water/Wastewater Program

MES operates and maintains 144 water and 89 wastewater facilities for the State of Maryland and municipal clients, also providing services in areas that do not have access to public water and sewer. During FY21, MES treated 1.8 billion gallons of drinking water and 6.7 billion gallons of wastewater. Our primary goal for our clients is compliance with the applicable standards. To meet that goal, MES tracked 83,230 permit parameters with a compliance rate of 99.7%.

The MES Water/Wastewater Group provides water and wastewater utility support services to the Departments of Natural Resources, Public Safety and Correctional Services, Juvenile Services, Health, Veterans Affairs, and Maryland Military. The group is responsible for coordination with the agencies to ensure their water and wastewater systems meet agency needs and are compliant with health and environmental regulations.

MES maintains the State Water and Wastewater Utility Master Plan, which is updated every 2-3 years to reflect changes in regulations, population, or use changes at state facilities. The Water and Wastewater Engineering Division visits facilities throughout the state to talk to utility operations staff about their treatment systems performance issues, or difficulties they may be having with equipment, and possibilities to accommodate expansion or discharge permit

changes. The staff reviews the laboratory data and notes any trends that might predict future permit violations. The entire staff then develops a multi-year Capital Improvements Plan and shares it with the capital budget analysts from DBM, as well as each agency.

The biosolids staff works to ensure environmentally acceptable, reliable, and cost-effective methods are used to manage the solid material generated by MES' numerous wastewater treatment plants (WWTPs). Water and wastewater facilities operated or supervised by MES generated approximately 27,000 wet tons (3,124 dry tons) of biosolids in CY20. Approximately 55% of the material generated in 2020 was beneficially reused, primarily as recycled tonnage that was land applied to farmland in Virginia. This mirrors the beneficial reuse rate on a national basis, which is approximately 55%. Trucked sludge and other wastes from smaller, satellite facilities are transported to MES operated regional sludge treatment facilities located throughout the State at three larger WWTPs. MES accepted approximately 7 million gallons of liquid sludge, landfill leachate, and holding tank wastes at our regional facilities in CY20.

Photo 4: Dorsey Run Advanced WWTP

a) Nutrient Removal from Wastewater

The 89 MES-operated WWTPs treat wastewater by removing nutrients like nitrogen, and phosphorus, and other pollutants such as total suspended solids and biochemical oxygen demand. Many of the MES operated plants have been upgraded with enhanced nutrient removal (ENR) systems that discharge treated wastewater with nitrogen concentrations of less than 3.0 mg/l and total phosphorus concentrations of less than 0.3 mg/l. MES is continuously working on upgrading the additional wastewater treatment systems to provide best services to our clients and protect Maryland's environment.

- MES also explores the use of innovative treatment systems, such as those that have the added benefit of sequestering carbon or reducing the treatment plants' carbon footprint in addition to reducing nutrient discharges. One of these technologies is the algal treatment of wastewater. In 2021 we investigated a new treatment system developed by Gross-Wen Technologies that uses revolving algal biofilm equipment. In this system algae growing on rotating belts uptakes nutrients present in the wastewater. There are several benefits to employing algal treatment of wastewater: Algae has the potential to remove nitrogen and phosphorus from the wastewater stream.
- Less energy is used during algal treatment. The energy savings results in a reduced carbon footprint for the treatment process.
- Conventional ENR treatment typically uses chemicals such as methanol to reduce nitrogen or alum (aluminum sulfate) for phosphorus treatment. Chemical manufacturing often uses fossil fuels for feedstocks and energy requirements, exerting a large carbon footprint for the purchased chemicals at the treatment plant. Algal treatment reduces chemical consumption. Thus, a consequence of reducing chemical usage is that the carbon footprint of the treatment plant is also reduced.
- Algae absorbs CO_2 from the atmosphere and uses sunlight to grow. Gross-Wen Technologies claims that 2 mt of CO_2 eq are removed for every ton of algae grown in their process during the treatment of wastewater[13]. Thus, carbon is sequestered naturally during algal treatment of wastewater.
- The algae grown can be used as a fertilizer substitute. The use of biological based fertilizers such as algae replaces conventional fertilizers. These conventional fertilizers use fossil fuels during their manufacture. Again, the use of fossil fuels increases carbon emissions, which are avoided when using algal systems.

b) Biosolids Management

MES Water and Wastewater staff also provide technical assistance and expertise in biosolids management for several municipalities in the state, the D.C. Water Blue Plains Advanced Wastewater Treatment Facility, and the Washington Suburban Sanitary System Water. These services include planning, developing nutrient management plans, inspections, regulatory permitting, and reporting functions on a customized basis for individual wastewater facilities.

MES currently employs a regional approach to managing solids generated by our treatment plants. Liquid sludge from smaller, "package" WWTPs is transported to one of three treatment plants for further treatment and end use. MES utilizes dewatering and lime stabilization to treat these sludges for pathogen reduction. The resulting biosolids (treated sludge) from these regional facilities is then transported to Virginia and land applied by a contractor to farmland. The treated biosolids are used by the farmers as a fertilizer and soil conditioner.

A master planning effort was completed in 2020 for MES' biosolids management. The resulting Master Plan focused on generating a more treated biosolids product with respect to pathogens, termed Class A material. This material can be marketed to the public. One of the Class A treatment options selected in that Master Plan was pyrolysis and biochar production. MES has been actively engaged in planning for producing a biochar from biosolids. Biochar is a charcoal-like, stable carbon rich material. It is created using a process called pyrolysis.

Applying biochar as a soil conditioner can sequester that stable carbon for long periods of time (i.e., on the order of hundreds of years). Using pyrolysis, organic wastes such as residual wood wastes, agricultural byproducts, or solid wastes such as municipal WWTP sludge is burned in the presence of little or no oxygen, yielding an oil, synthetic gas (which has a heating value) and the solid biochar material. It has been conservatively estimated that the global potential for biochar carbon sequestration is in the range of 0.3-2 Gt CO_2 eq per year[14].

Another benefit of the pyrolysis process is that it can thermally destroy chemical pollutants of concern, especially Per- and Polyfluorinated Substances (PFAS). PFAS chemicals is a class of compounds that were developed for consumer applications such as non-stick cookware, stain resistant fabrics, and firefighting foam. PFAS compounds are often called "forever chemicals" because they persist in the environment for long periods. PFAS has received considerable media attention lately due to its persistence and likely health effects at very low concentrations ranging from cancers to endocrine disruption. Due to their multiple uses, these compounds are ubiquitous in our society and can be found in drinking water supplies, landfill leachate, air emissions, and biosolids.

In FY21, MES issued a Request for Information (RFI) to solicit interest from pyrolysis technology providers to design, build, and operate a biochar production facility using sludge (or treated biosolids) as a feedstock. Four companies responded to the RFI. Using the RFI submittals, MES developed a capital improvement program for one of our regional wastewater treatment sludge facilities at the Dorsey Run Advanced Wastewater Treatment (AWWTP) plant located in Anne Arundel County. Funding has been requested from DBM to design and construct a pyrolysis facility at Dorsey.

The pyrolysis and biochar production process can be considered a "carbon negative" technology when the syngas and heat produced is used to dry the biosolids feedstock prior to thermal treatment and the biochar is used as a soil conditioner. In 2009 the Canadian Council of Ministers of the Environment developed a model to estimate GHG emissions for typical biosolids management practices, the Biosolids Emission Assessment Model (BEAM)[15]. MES used the BEAM model to estimate the carbon footprint of the current sludge processing treatment process, and for another scenario using pyrolysis and biochar for one of our facilities, the Dorsey Run AWWTP. Using the BEAM model, the total carbon footprint for the Dorsey Run AWWTP's current sludge management scenario was estimated to be 1,681 mt CO_2e/yr. Applying the pyrolysis and biochar setting resulted in an order of magnitude reduction of emissions to approximately 145 mt CO_2e/yr. This is equivalent to removing 333 cars per year from the roads due to the reduction in GHG emissions[16]. This example shows the promise of

pyrolysis and biochar production as a climate change mitigation strategy.

c) Future Sustainability Projects: Water and Wastewater Program

A large amount of the footprint area of a WWTP is dedicated to process tanks at these sites. The area over these large open tanks provides an excellent opportunity for the placement of solar panels. An example of a WWTP that is utilizing this concept is the Camden County Municipal Utilities Authority (CCMUA) in New Jersey. As part of CCMUA's "Green Initiatives" program, they have installed 1.8 MW of solar panels above most of their treatment process tanks. CCMUA has entered into a power purchase agreement (PPA) with the developer of this project that is estimated to save the Authority $300,000 per year in energy costs[16]. MES is currently exploring the option of installing solar panels toward meeting its sustainability goals.

Wastewater treatment in particular exerts significant carbon emissions. Treatment plants accounted for 2.2% of methane emissions in the U.S. in 2017. Other opportunities exist to decrease our treatment plants' carbon footprints and generate offsets by executing operational changes. An example of this is reducing chemical usage. Most WWTPs use chemicals, especially for nitrogen and phosphorus removal. Chemicals such as methanol, which are manufactured using fossil fuels as a raw material feedstock are used by some of MES' facilities for denitrification. Methanol use can increase a plant's carbon footprint. There are usually other chemicals that can be substituted that have less of an impact. Other changes such as reducing energy usage can be practiced by cutting carbon emissions. Aeration is usually used at almost all WWTPs by using energy intensive blowers. Installing energy saving aeration devices such as fine bubble diffusers during plant upgrades is an option.

MES anticipates conducting baseline GHG inventories at some of our larger facilities in 2022 as a start to identify specific practices that decrease our carbon footprint.

5. Assessing Risks, Identifying Opportunities

MES can comprehensively assess climate change's impact on Maryland and develop an integrated program that effectively mitigates risks, captures opportunities, and tracks progress.

Our deep understanding of climate policy, transportation, carbon markets, economics, and risk management provides the broad range of insights required to build these plans. In addition, MES has experience assessing and delivering comprehensive environmental services. Our energy and climate change abilities could include:

- Comprehensive GHG inventory and management, from advice on policy and regulatory change to strategy and project planning, permitting, and implementation.
- Life cycle assessment, which helps manage environmental factors and emissions more effectively.
- Knowledge of emerging vehicle, fuel technologies, and tools to assess and develop opportunities to reduce fleet-related emission.

- Expertise in national and regional climate and clean energy regulations, which helps develop strategies to comply with and anticipate future requirements and understand the potential operational implications.
- Local knowledge of regulatory requirements combined with subject matter experts and multidisciplinary teams.
- Information systems experience that helps clients make fact-based decisions, track progress, measure risks, and report performance as required.
- Economic and financial insights to help develop risk-based strategies for compliance and mitigation, and development of quantitative risk assessments and response plans designed to protect the population from the physical risks of climate change.

5.1 Algal Treatment Wastewater/Algal Flow-Way Technology

Algal flow-way technology (AFT) has been actively applied in nutrient and sediment removal from flowing ambient waters in Chesapeake Bay watershed. This technology can make a significant contribution to the reduction of CO_2. Nutrients (total nitrogen and total phosphorus) and sediments are captured through this practice. Nutrient reductions could be made in one of two ways; planning scenarios and operations that do not have access to frequently sampled algal production weights and nutrient concentration assessments of algae produced. The reductions are based on conservative algal production and nutrient concentration estimates of systems in operation around the Chesapeake Bay watershed. These procedures are considered sufficiently general enough to apply to multiple variants of the AFTs. Like nutrients, sediment reductions also occur.

5.2 Anaerobic Digestion

MES has established a contractual relationship with Bioenergy Development Company (BDC) to help the firm launch renewable energy-generating AD technology in Maryland. BDC is constructing an AD facility on the Maryland Food Center campus in Jessup. This will be the largest anaerobic digester in the state and will divert approximately 125,000 tons of food wastes generated per year from landfill disposal. This project will also reduce GHG emissions from landfills. The produced biogas will be used as an energy source. AD technology is commonly used throughout the U.S. to treat municipal sewage sludge at wastewater treatment facilities, by-products at food and beverage processing facilities, and animal waste (mainly manure) at farms.

The AD method occurs in three steps. First, plant or animal matter is hydrolyzed by bacteria into less complex molecules. This hydrolyzed matter is converted to organic volatile fatty acids by a second group of bacteria called acidogens. Finally, these organic acids are converted to biogas, which is a mixture of CO_2 and methane, by a group of bacteria called methanogens.

The by-products of the process consist of biogas, and a semi-solid liquid slurry called digestate. The biogas contains small quantities of H_2S.

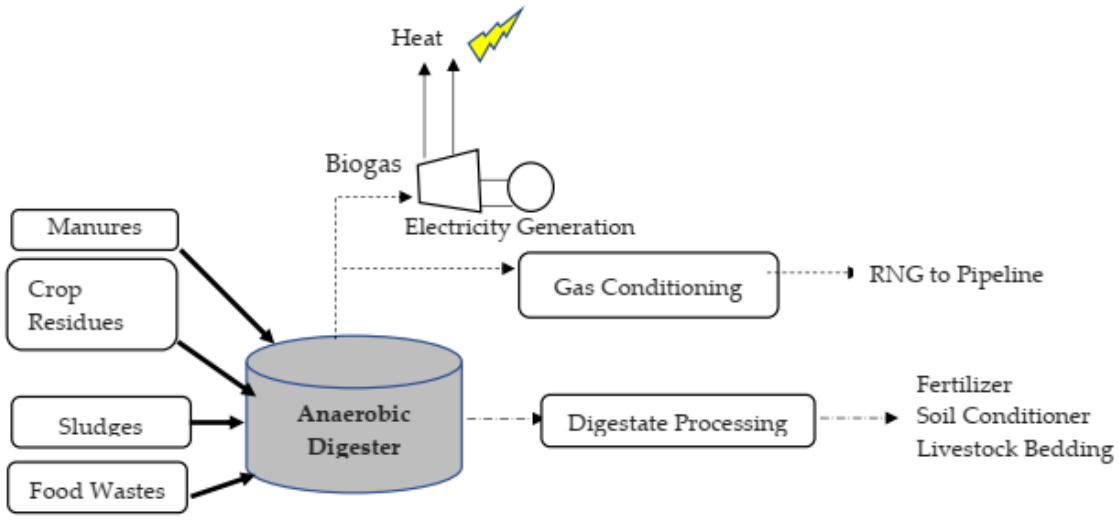

Figure 7: Process Diagram

a) Economic Benefits of Anaerobic Digestion

Apart from numerous environmental benefits, there are several economic benefits associated with utilizing AD technologies. AD converts the solid material in the sludge, or other feedstock wastes, into biogas, thereby reducing the amount of solids that require disposal. This reduces hauling costs, as well as landfill tipping fees. Also, a recent trend that is occurring at WWTPs across the U.S. is the use of excess digester capacity to accept other materials, such as food wastes. Wastewater treatment facilities that incorporate food waste as an anaerobic digesters feedstock experience greater biogas production. The increased biogas translates into more energy to offset on-site power consumption costs. Also, the treatment facilities receive tipping fees for accepting the food waste from food processing companies. Food and beverage processing facilities can leverage the same benefits onsite, but the introduction of food waste into wastewater treatment services has become progressively more popular.

The construction and operation of digesters creates local job opportunities and increases local tax revenues. For example, the BDC digester in Jessup is expected to create 20 new jobs after it has been completed.

An additional revenue stream can be realized when the digestate is composted and the resulting compost is marketed as a soil conditioner. Potential markets include the agriculture sector, horticulture, nurseries, and landscapers.

For all industries employing AD technologies, the prospect to reduce energy costs is present due to biogas to generate electricity or provide fuel for fleet vehicles, thereby reducing dependence on fossil fuel-based energy. However, AD also provides an extra revenue stream with the opportunity to upgrade excess biogas to pipeline quality gas (RNG), or export the

electricity produced to the grid. The biogas provides a locally generated renewable energy source to the community and tax credits, renewable identification numbers and low carbon fuel standard can be obtained by the producer of the biogas.

b) Environmental Benefits of Anaerobic Digestion

Lowering carbon emissions is one of the most evident environmental advantages of AD. By trapping the methane gas that may have been lost to the atmosphere, biogas generation displaces fossil fuels. This promotes climate change mitigation and is especially beneficial in all AD technology use scenarios.

The use of AD technology on farms provides many examples of how AD benefits the environment. As farmers work conscientiously to meet the increasing demand for food and remain viable and profitable in the current global marketplace, the efficient use of water and nutrients for crop and livestock needs can decrease costs and environmental impacts while providing environmentally friendly and productive farms.

Digesters on farms can:

- Protect animal and human health by reducing pathogens.
- Transform nutrients in waste into more accessible forms for plants than raw manure, increasing crop productivity and yields.
- Recycle nutrients on the farm, producing an economically and environmentally sustainable crop production system.
- Produce heat, electricity, or fuel from biogas which can be used onsite, lessening the agriculture sector's dependence on fossil fuel energy.
- Accept food waste from external sources, thereby reducing food waste that is sent to landfills.
- Food waste has the added benefit of increasing the efficiency of farm digesters. Excess digester capacity is used to create more biogas that can be used on-farm to generate electricity or heat barns and chicken houses.

5.3 Benefits of Landfill Gas Energy Projects

Using landfill gas (LFG) to generate energy and reduce methane emissions produces positive outcomes for local communities and the environment. In addition, LFG utilization projects create partnerships among citizens, nonprofit organizations, local governments, and industry in sustainable community planning.

a) Reduce Air Pollution by Offsetting the Use of Non-Renewable Resources

Producing energy from LFG offsets the use of non-renewable resources, such as coal and oil, to produce the same amount of energy. This can reduce emissions of CO_2, criteria pollutants such as sulfur dioxide (a major contributor to acid rain), particulate matter (a respiratory health

concern), nitrogen oxides (NO_x), and trace hazardous air pollutants from power plants and other fossil fuel users.

Like all combustion devices, LFG electricity generation devices emit some NO_x, contributing to local ozone and smog formation. Depending on the fuels and technologies used to produce electrical power, the NO_x emitted from an LFG project may exceed the avoided NO_x emissions from a conventional power plant. Overall, however, LFG electricity generation projects significantly improve the environment because of the methane emission reductions from landfills, hazardous air pollutant reductions, and avoidance of the use of non-renewable fossil fuel resources.

b) Reduce Greenhouse Gas Emissions

Municipal solid waste (MSW) landfills are the third-largest human-generated source of methane emissions in the U.S., releasing an estimated 99.4 million metric tons of CO_2e to the atmosphere in 2019 alone[17]. With a global warming potential more than 25 times greater than CO_2 and a short (12-year) atmospheric life, methane is a potent GHG that contributes to global climate change. As a result, reducing methane emissions from MSW landfills is one of the best ways to achieve a near-term beneficial impact in mitigating global climate change. Many technologies and practices that reduce methane emissions also reduce associated emissions of volatile organic compounds (VOCs), odors, and other local air pollutants.

Given that all MSW landfills generate methane, it makes sense to beneficially use the gas for energy generation rather than emitting it into the atmosphere. It is estimated that an LFG energy project will capture roughly 60 to 90% of the LFG emitted from the landfill, depending on system design and effectiveness. The captured methane in the LFG is destroyed (converted to water and the much less potent CO_2) when the gas is combusted to produce electricity.

c) Other Benefits

Electricity generation from LFG is usually performed using reciprocating engine generator sets, or "gen-sets".

Combustion in gen-sets to produce electricity destroys most non-methane organic compounds (NMOCs), including hazardous air pollutants and VOCs that are present at low concentrations in uncontrolled LFG emissions, thus reducing possible public health risks.

There is a safety component to mitigating LFG emissions as well. The EPA's Resource and Recovery Act Subtitle D regulations codified at 40.CFR 258.23 requires that methane concentrations be controlled in on-site landfill structures and at the site's property line. LFG collection systems are needed to ensure that landfill operators are meeting the regulations. Generating electricity from existing MSW landfills is also a relatively cost-effective way to

provide an alternative to fossil fuel-derived natural gas energy generation capacity to supply community power needs. LFG can serve as a "baseload renewable," providing online availability exceeding 90%.

LFG energy projects generate revenue from selling the LFG, electricity, or rRNG created from LFG. The gas use can also create jobs associated with energy recovery systems design, construction, and operation. LFG energy projects involve engineers, construction firms, equipment vendors, and utilities or end-users of the power produced. Much of the project costs are spent locally for drilling, piping, construction, and operational personnel, helping communities to realize economic benefits from increased employment and local sales. In addition, local businesses can realize cost savings associated with using LFG to replace more expensive fossil fuels. Some companies could save millions of dollars over the life of their LFG energy projects.

5.4 Charles County Resilience Authority

The Resilience Authority of Charles County (Authority) will undertake and support infrastructure projects that mitigate and adapt to the effects induced by climate change by offering a range of financing structures, forms, and techniques that leverage public and private investment. The Authority will also encourage demand for resilience infrastructure projects throughout Charles County. Nuisance and urban flooding are one of the major problems in Charles County with frequent road closures, overwhelmed storm drains, and deterioration of infrastructure such as roads and rail. The MES Executive Director is honored to serve on the Authority in support of this first of its kind efforts.

MES offers lifecycle stormwater expertise for counties and municipalities facing the demands of new stormwater regulations. Services includes best management practices (BMPs) assessments and planning, stormwater inspection, wet-weather compliance sampling, laboratory analysis and compliance reporting, BMP installation, sediment removal and erosion control preventative maintenance, customized compliance and inspection tracking, stormwater pollution prevention plans, spill prevention, control, countermeasures plans, and quarterly and annual stormwater inspections.

5.5 Flood Protection

Urban and nuisance (due to high tide) flooding is a growing concern due to various issues related to development, undersized and dated stormwater infrastructure, and fragmented watersheds. The Nuisance and Urban Flood Plan (Plan) established by MES seeks to find the sources of nuisance and urban flooding in Charles County. The Plan evaluates hazards and recommends actions to reduce flooding. This plan also increases community resiliency. The Plan recommends mitigation actions based on that analysis and will likely include a variety of actions, including stormwater infrastructure upgrades, stormwater best management practices,

community education and outreach, green infrastructure solutions, and combination of analysis and mitigation actions into local plans.

5.6 Living Shoreline

The Living Shoreline Act, a suite of techniques (fiber coir logs, sills, groins, breakwaters, or other natural components with sand, perennials, and grasses plant, expand the buffer zone, underwater grasses in shallow water) are used to protect, restore, enhance, or create natural shoreline habitats. Several living shoreline projects are going on in Windy Hill Farm, Spaniard Point, and Ferry Point habitat, which are directly maintained through DNR. MES can carry out this kind of project to control sea level rise and protect the shoreline from potential erosion and runoff pollution. Sea level rise and coastal erosion are also impactful factors of climate change.

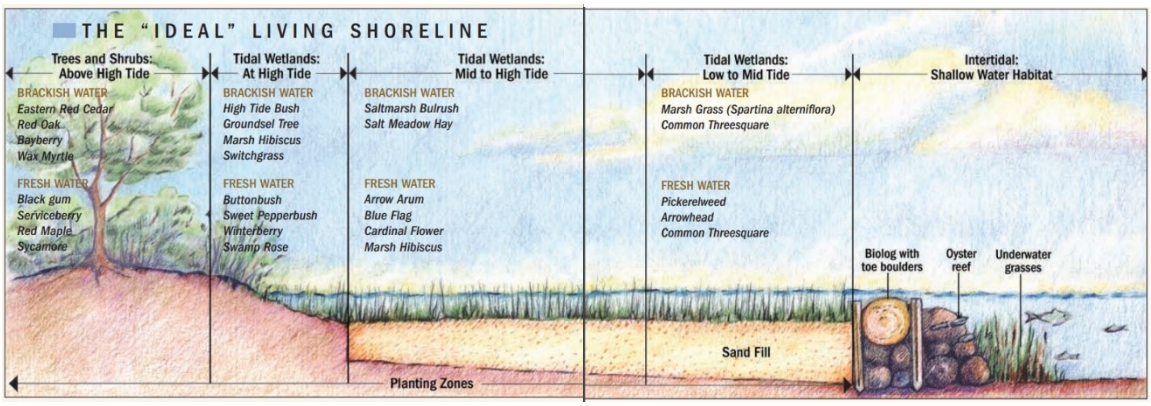

Figure 8: An Ideal Living Shoreline

5.7 Low Carbon Transition and Climate Change

MES works with clients to comprehensively assess their operations and strategically evaluate options for achieving net-zero GHG emissions by a specific date. MES also assists clients in obtaining input from communities, investors, environmental organizations, and other stakeholders. MES provides strategic advice on emerging technologies and strategies for transitioning to lower-carbon systems, including electrification, RNG energy storage, and hydrogen. MES works with clients to consider the municipality and consumer costs, feasibility, technological maturity, and other critical factors.

5.8 MPA Dray Truck Replacement Program

As part of the MPA "Green Port of Baltimore" initiative, MPA is working to reduce emissions from diesel engines in rolling stock serving the Port of Baltimore. The goal of the Dray Truck Replacement Program is to reduce air pollutants and GHGs by replacing older vehicles used by companies working at the Port of Baltimore. The dray trucks are used to transport goods to and from the Port. Older trucks from model years 1993 through 2006 are eligible for replacement. An EPA grant of $870,000 was awarded to MPA with funding up to $30,000 per vehicle. MES administers the program on MPA's behalf. The companies owning the vehicles match the EPA

grant funds. EPA Tier standards are met through diesel engine design and added components to the engines that reduce or eliminate pollutants from the engine exhaust. The EPA Tier Standards for diesel engines were phased in as follows: Tier 1 standards: These were the first federal standards (Tier 1) for new non-road (or off-road) diesel engines adopted in 1994 for engines over 37 kW (50hp), to be phased-in from 1996 to 2000.

- Tier 2 standards: Phased-in from 2003-2005.
- Tier 3 standards: Phased-in from 2006-2010. Tier 3 has been reducing NOx emissions by about 1 million tons per year.
- Tier 4 standards: This was introduced in two stages. To comply with Tier 4, engine manufacturers have employed these additional technologies:
    - DPF (Diesel Particulate Filters) which reduces particulate matter (PM 2.5).
    - CCV (Closed Crankcase Ventilation)

Most of the non-road vehicles in the program were upgraded by replacing the higher-powered engines by replacing Tier 1 engines with mostly either Tier 3 or Tier 4 compliant engines. Both Tiers 3 and 4 significantly reduce carbon emissions as well.

In order to document the estimated reduction in air pollutants and carbon emissions achieved as a result of replacements, MES acquired usage data for those vehicles that were replaced from 2008 through 2020. That MES data was used as inputs into EPA's Diesel Emissions Quantifier (DEQ) tool.[18] The DEQ emissions from diesel engines can be modeled with the use of this web-based, user friendly tool. The output from the DEQ Tool is given in Table 2. It shows that after replacing the dray vehicle equipment the carbon output (measured as CO_2 emissions) was reduced in the range of 97.16 % to 99.23 %. Most pollutant emissions modeled using the DEQ Tool achieved emissions reductions of 93% or more. From 2008 to 2020, every year an average of 380.06 tons CO_2 emissions was reduced through upgrading the dray trucks. The total estimated reduction of CO_2 over the 12-year effort was estimated to be 2,980 short tons.

Photo 5: Dray Truck

		EPA DEQ Tool Output (Short Tons/year or % Reduction)				
		Parameter				
Program Year		**NO_X**	**$PM_{2.5}$**	**HC**	**CO**	**CO_2**
	Baseline for vehicles/engines (T/yr)	35.33	21.45	211.7	313.56	398.4
2008	Amount reduced after engine upgrades (T/yr)	33.56	20.4	208.8	310.45	387.1
	Percent calculated reductions after upgrades	94.99	95.10	98.63	99.01	97.16
	Baseline for vehicles/engines (T/yr)	33.10	26.20	195.30	315.21	345.20
2009	Amount reduced after engine upgrades (T/yr)	30.10	24.30	194.10	311.20	340.20
	Percent calculated reductions after upgrades	90.94	92.75	99.39	98.73	98.55
	Baseline for vehicles/engines (T/yr)	32.90	29.10	216.90	316.10	375.60
2014	Amount reduced after engine upgrades (T/yr)	31.20	27.10	212.10	315.00	369.10
	Percent calculated reductions after upgrades	94.83	93.13	97.79	99.65	98.27
	Baseline for vehicles/engines (T/yr)	32.10	26.30	196.30	321.30	389.30
2015	Amount reduced after engine upgrades (T/yr)	31.02	24.90	185.30	319.20	388.20
	Percent calculated reductions after upgrades	96.64	94.68	94.40	99.35	99.72
	Baseline for vehicles/engines (T/yr)	41.30	26.30	245.30	123.80	390.20
2016	Amount reduced after engine upgrades (T/yr)	39.50	25.10	243.10	121.60	385.40
	Percent calculated reductions after upgrades	95.64	95.44	99.10	98.22	98.77
	Baseline for vehicles/engines (T/yr)	28.30	25.30	199.30	322.60	365.30
2018	Amount reduced after engine upgrades (T/yr)	25.10	24.10	196.10	318.11	362.50
	Percent calculated reductions after upgrades	88.69	95.26	98.39	98.61	99.23
	Baseline for vehicles/engines (T/yr)	38.60	26.50	232.00	315.30	389.12
2019	Amount reduced after engine upgrades (T/yr)	36.90	25.10	228.60	312.00	378.50
	Percent calculated reductions after upgrades	95.60	94.72	98.53	98.95	97.27
	Baseline for vehicles/engines (T/yr)	35.20	29.50	198.20	315.20	387.36
2020	Amount reduced after engine upgrades (T/yr)	34.00	28.60	194.60	312.60	379.40
	Percent calculated reductions after upgrades	96.59	96.95	98.18	99.18	97.95

Table 2: MPA Dray Truck Replacement Program

5.9 MES Headquarters Solar Array

MES has experience with design, planning, and installation of solar arrays, including at our headquarters building, located in Anne Arundel County. A ground mounted solar system was installed in late 2008. An additional 600-kilowatt solar array was built over the parking lot in 2016. There are 1,488 panels in the solar installation, and seven canopies (930 solar modules), along with one dual charging station in the parking lot. This project was carried out using private funds from Constellation Energy to construct and own the system. MES then executed a PPA with the project developer. The term of the PPA for both the ground mounted and parking lot installations is 15 years.

MEA announced the commencement of the FY22 Solar Canopy Grant Program (previously called the Parking Lot Solar PV Canopy with EV Charger Grant Program) on July 21, 2021[18]. The program provides funding to incentivize multiple use strategies for land already designated for parking - specifically the generation of clean, renewable electricity, electric vehicle charging capacity, and parking services.

a) Carbon Emission Reduction Calculation for Solar Arrays

Data from MES' solar array utility meters is presented in Table 3 below. The system generated a total of 1,310,632 kWh during the two-year period 2019-2020. The CO_2 offset calculation was performed using the EPA's Greenhouse Gas Equivalencies Calculator, which converts various metrics, such as kwh of electricity generated to CO_2 equivalencies.[20] For comparison, the 899 mt CO_2 e offset is equivalent to removing 199 passenger vehicles from the road for a one-year period.

Calendar Year	Electricity Produced (kwh)	CO_2 Emissions Offset Due to Solar Array (mt CO_2 e)
2019	644,532	454
2020	666,100	445
Totals =	1,310,632	899

Table 3: Assessment of Carbon Reduction Through Installed Solar Panels at MES Headquarters

Photo 6: Solar Panels

5.10 Sustainable Aviation Fuel Production

Using Sustainable Aviation Fuel (SAF) results in a reduction in carbon emissions compared to the traditional jet fuel it replaces. SAF is a cleaner alternative to fossil fuels with an impressive reduction of up to 80% in carbon emissions over the fuel's life cycle depending on the sustainable feedstock used, production method, and the airport supply chain.[21] SAF is made by blending conventional kerosene(fossil-based) with renewable hydrocarbons. Generating SAF from waste feedstocks such as MSW, cellulosic wastes or used cooking oil allow for even

greater carbon offsets than if the feedstocks originated from agricultural crops. This is because of the carbon offsets generated by avoidance of landfilling these wastes.

Conversion pathways are needed to meet the growing demand for SAF that leverage wet waste carbon and meet jet fuel property requirements. SAF production derived from food waste volatile fatty acids (VFA) is one such pathway to generating this fuel substitute. At the same time, a lifecycle analysis shows the environmentally friendly impact on the carbon footprint if food waste is rerouted from landfills to produce VFA-based SAF, highlighting the potential to meet jet fuel safety, operability, and environmental goals.

AD of wet waste is necessary to produce SAF VFAs successfully. Biogas production from AD is the leading technology used to recover energy from wet waste. The high moisture substance of wet waste limits transport and demands local processing, with most US AD services located near population-dense areas and airports.[22]

6. Conclusions

MES is committed to expanding its network of partnerships and developing new opportunities and environmental solutions that offer affordable, accessible services enhancing and conserving the environment. MES is fully capable of putting the experience, education, and skills of our many teammates to work on projects that mitigate and sequester carbon GHGes and lower carbon emissions, while improving the environment throughout Maryland and the surrounding region.

This report documents the many opportunities to institute practices to sequester carbon and help Maryland meet its GHG reduction goals. Our EDR group continues to establish wetlands practices to sequester carbon in soils. MES' Water and Wastewater Program plans to construct a pyrolysis facility to produce biochar from biosolids at our Dorsey Run AWWTP. This is planned for FY24. Biochar is a promising material that when used as a soil conditioner can sequester carbon for hundreds of years.

The Environmental Operations Group will continue to operate recycling, landfill, and composting facilities. Capturing fugitive methane from landfills will help meet the state's GHG reduction goals. Our very successful food waste composting facility produces a marketable product that diverts these wastes from landfilling.

Finally, MES will continue to incorporate EJ practices in our carbon sequestration efforts so that all Marylanders experience the environmental benefits of the future and a safe and clean Mid-Atlantic region for generations to come.

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