Baltimore County Climate Action Plan

Greenhouse Gas Inventory and Mitigation Analysis of County Government Operations

2021

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Executive Summary

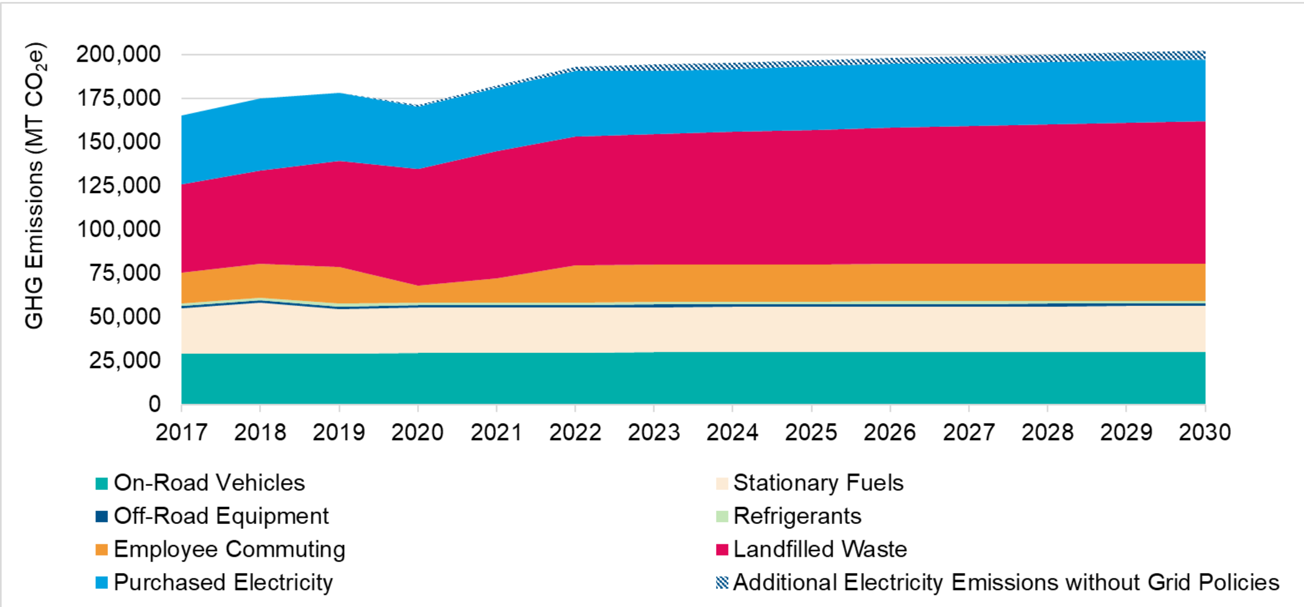
As one of the largest counties in the state, Baltimore County plays a pivotal role in both leading the community and in helping the State of Maryland advance climate goals, such as reducing its greenhouse gas (GHG) emissions by 40% below 2006 levels by 2030. The Baltimore County Government developed this climate action plan (CAP) of County government operations to serve as the foundation for the County's GHG reduction efforts and support the State's climate goals. The CAP was developed by characterizing and modeling current sources of GHG emissions from County operations and potential GHG reduction opportunities. This report contains the following two sections:

- **GHG Inventory and Projections.** This section discusses the County's current GHG emissions for the baseline year of 2017 and projects future emissions through 2030 under a business-as-usual (BAU) trajectory, forecasting what GHG emissions would occur if no additional actions were taken to reduce emissions by the County beyond what is happening today.
- **GHG Mitigation Analysis.** This section describes opportunities for further reducing GHG emissions within County operations through strategies in the energy, transportation, and waste sectors.

GHG Inventory and Projections through 2030

Baltimore County developed a greenhouse gas (GHG) inventory as the foundational step in developing its CAP. The County prepared a GHG inventory of County government operations for 2017, with projections through 2030 under a BAU scenario. Results are shown in Figure 1. The BAU scenario allows the County to understand the GHG emissions impact of its operations, identify key sources and drivers of emissions, set targets, and track progress toward reduction goals.

Figure 1: 2017 GHG Inventory and Business-as-Usual Projections Through 2030



In 2017, Baltimore County government operations emitted approximately165,337 metric tons of carbon dioxide equivalent (MT CO_2e) from government operations. Under the BAU Scenario, the County government's emissions are projected to increase by 19% to 197,453 MT CO_2e in 2030.

The 2017 inventory and annual projections through 2030 includes estimates for the following sources of emissions from County operations:

- On-site fuel combustion (natural gas, fuel oil, and propane) at County facilities (Scope 1),
- Mobile combustion in County fleet vehicles and non-fleet vehicles and equipment (Scope 1),
- Waste disposal in County-owned landfills (Scope 1),
- Fugitive emissions from refrigerant leakage (Scope 1)
- Purchased electricity in County facilities (Scope 2), and
- County employee commuting (Scope 3).

Landfilled waste at Eastern Sanitary Landfill, purchased electricity, and the government's on-road vehicle fleet were the largest sources of emissions in 2017, accounting for more than 70% of total emissions.

GHG Mitigation Analysis

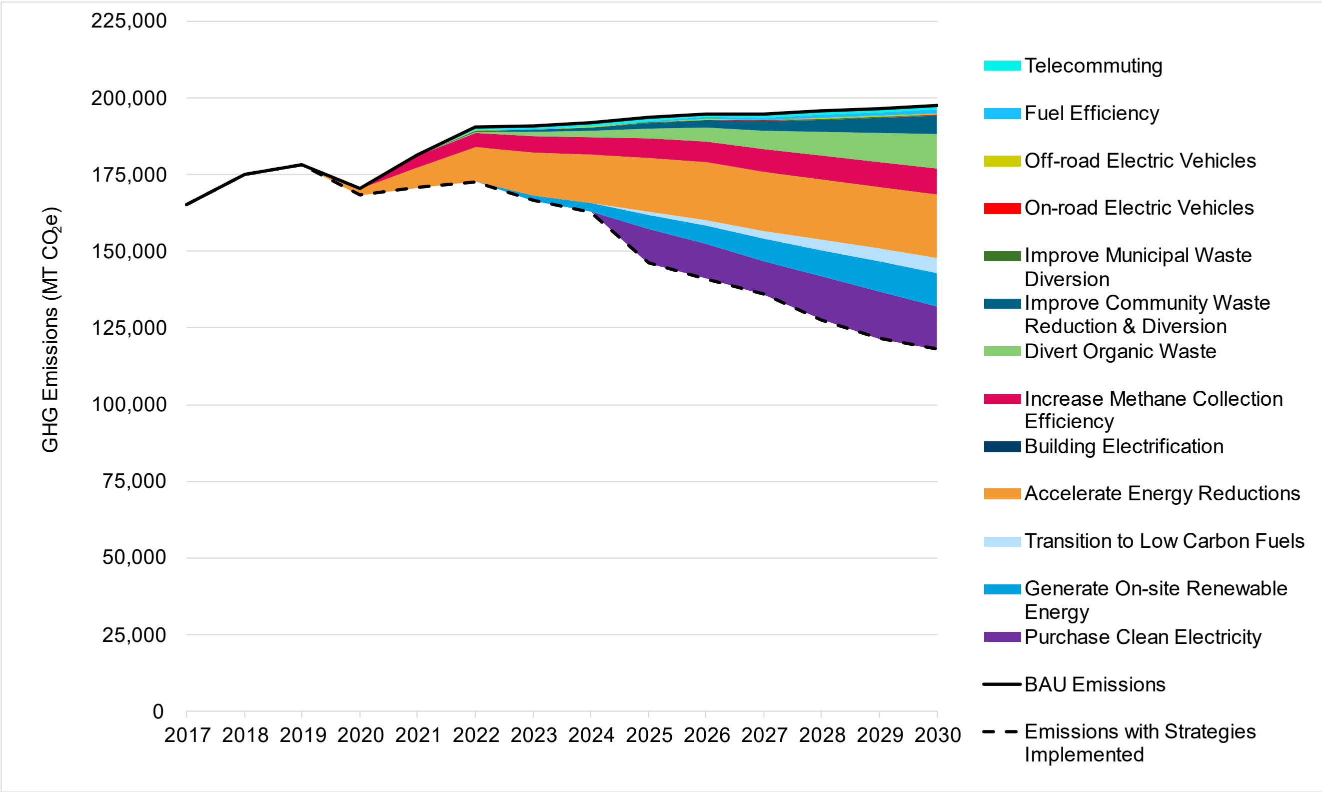
After developing the BAU emissions trajectory, the County conducted a GHG mitigation analysis to identify opportunities to reduce emissions. This included:

- Identifying actions already planned and/or currently being implemented by the County and additional actions that could be taken by the County to reduce GHG emissions in the energy, transportation, and waste sectors.
- Determining actions to include as part of the CAP based on including County government priorities, available resources, cost, ease of implementation, and potential to reduce emissions.
- Estimating the GHG reduction potential for these actions to understand their overall impact on the County government's future emissions.

Fourteen emission reduction strategies were included in the mitigation analysis, including a moderate and aggressive scenario for most. The moderate scenario largely reflects existing and planned actions, while the aggressive scenario expands on and accelerates several strategies to further reduce GHG emissions. The actions included in the CAP will reduce Baltimore County government's GHG emissions by 29% from 2017 levels by 2030 and by 40% from 2030 BAU levels under the moderate scenario, and 41% compared to 2017 levels and 50% compared to 2030 BAU levels in the aggressive scenario. In both scenarios, the energy and waste sectors represent the largest opportunity for reductions. Figure 2 shows results by strategy for the moderate scenario.

In the energy and waste sectors in particular, the aggressive scenario demonstrates that the County government could achieve even greater emission reductions than with current plans. The energy sector has the largest potential for reducing the County's emissions due to low carbon grid strategies and the option to purchase and/or generate zero-carbon energy for County government operations. Planned actions for the waste sector also offers significant opportunities for emission reductions for the County. The County has the opportunity to increase emission reductions by implementing more aggressive programs as resources, staffing, and infrastructure allow moving forward.

Figure 2: GHG Emission Reductions under the Moderate Mitigation Scenario



Next Steps

Implementation of this plan is the next step forward for the County government. Implementing this plan will require buy-in across agencies and sufficient funding and staffing to implement them. It is recommended that the County government start immediately with the low-cost scenarios and then build in the medium/high-cost strategies into planning efforts over the next 5 to 10 years, as resources allow. It is also recommended the County government conduct periodic updates to the GHG inventory and track its progress annually toward implementation of these goals and the status of implementation in order to readjust strategies as needed to meet the County's overall GHG reduction goals.

Introduction

Global greenhouse gas (GHG) emissions are driven largely by human actions such as the burning of fossil fuels for energy generation and transportation. Impacts from climate change, such as temperature extremes and more frequent and violent storms, are already occurring at the global and local level. As the level of CO_2 and other greenhouse gases in the atmosphere continues to increase, there will be increasingly significant climactic effects that will impact the environment and societies around the world.[1]

The State of Maryland has committed to reducing its GHG emissions by 40% below 2006 levels by 2030. To meet the state's climate goals, leadership and action is required by municipalities and organizations throughout the state. The development of this Climate Action Plan (CAP) for Baltimore County government operations is an example of the County doing its part to meet Maryland's climate goals and reduce the County's impact on current and future climate change. This CAP considers the causes of climate change (GHG emissions) and strategies to reduce GHG emissions (mitigation). There are three primary objectives of this CAP:

1. Assess the County's GHG footprint and baseline emissions through 2030.
2. Identify climate actions the County is committing to, including 2-, 5-, and 10-year milestones.
3. Estimate the anticipated impact of these actions on emissions through 2030.

The scope of the CAP includes County government operations. This includes:

- Buildings and other facilities that the County owns and operates,
- Eastern Sanitary Landfill,
- Fleet vehicles, and
- Non-fleet vehicles and equipment (e.g., lawn mowers, construction equipment).

This CAP focuses exclusively on emissions from county government operations and does not include the broader community, private sector, or households. While only representing a portion of Baltimore County's carbon footprint, this CAP demonstrates the County government's commitment to reduce GHG emissions and address the climate challenge through leading by example.

Greenhouse Gas Inventory and Projections

Conducting a greenhouse gas (GHG) inventory is the foundational step in developing a climate action plan. ICF assisted Baltimore County in preparing a GHG inventory of county operations for 2017, with projections through 2030. This GHG inventory allows Baltimore County to understand the emissions impact of its operations, identify key sources and drivers of emissions, set targets, and track progress toward reduction goals. Inventories are critical tools to inform decision-making and reduce the County's emissions over time. This document provides an overview of the County's 2017 GHG emissions inventory and projected emissions through 2030.

[1] Intergovernmental Panel on Climate Change (IPCC) 2018. *Global Warming of 1.5°C: Summary for Policymakers*. See: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_HR.pdf.

Overview

Greenhouse gases trap heat in the atmosphere and contribute to global climate change. Human activities, particularly the combustion of fossil fuels, are responsible for the majority of the increase in GHG emissions over the past 300 years.[2] A GHG inventory demonstrates the carbon footprint that results from an organization's activities. Specifically, a GHG inventory estimates emissions of GHGs (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated GHGs) from common sources of emissions such as electricity and building energy use and waste disposal.

This inventory follows the Local Governments for Sustainability's (ICLEI) Local Government Operations Protocol (LGOP) and best practices for GHG accounting and reporting. ICLEI is an organization that provides national-standard protocols for local-scale GHG emissions accounting.[3] The EPA's Local GHG Inventory Tool's (LGGIT) Government Operations module was also used as a supplementary tool to estimate emissions of solid waste landfilled at Eastern Sanitary Landfill. The inventory includes emissions of CO_2, CH_4, N_2O, and hydrofluorocarbons (HFCs). The County does not emit PFCs, SF_6, or NF_3 from its operations.

This inventory uses 100-year global warming potential (GWP) values from the IPCC's Fourth Assessment Report (AR4) to report emissions in metric tons (MT) of carbon dioxide equivalent (CO_2e). GWPs allow comparisons of the global warming impacts of different gases by measuring the relative impact to climate change of one ton of a gas relative to the emissions of one ton of CO_2.[4] Emission estimates using GWPs from the IPCC's Fifth Assessment Report (AR5) are also presented in Appendix B - Global Warming Potentials for informational purposes.

Textbox 1: Carbon Dioxide Equivalent and Global Warming Potentials

> Carbon dioxide equivalent (CO_2e) is a measure used to compare the emissions from various GHGs based upon their global warming potential (GWP). For example, the GWP for methane (CH_4) is 25, indicating that one metric ton (MT) of CH_4 is as effective as 25 MT of CO_2 at trapping heat in the atmosphere.

GHG Inventory Boundaries and Scope

Inventory boundaries establish what activities, sources of emissions, operations/buildings, and time period are considered as part of an inventory. This inventory includes emissions resulting from sources over which the County owns and/or has *operational control*—defined as any facility or operation for which the County has the full authority to introduce and implement changes in operational policies and processes.[5] This includes:

- Buildings and other facilities that the County owns and operates (e.g., County departmental offices, community centers, pumping stations, County-owned streetlights, and traffic signals),

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[2] EPA 2020f. "Sources of Greenhouse Gas Emissions." See https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[3] ICLEI 2020. "Greenhouse Gas Protocols." See https://icleiusa.org/ghg-protocols/.

[4] EPA 2020g. "Understanding Global Warming Potentials." See https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:~:text=The%20Global%20Warming%20Potential%20(GWP,carbon%20dioxide%20(CO2).

[5] ICLEI 2010. *Local Government Operations Protocol. Version 1.1.* See https://icleiusa.org/ghg-protocols/.

- Eastern Sanitary Landfill,
- Fleet vehicles, and
- Non-fleet vehicles and equipment (e.g., lawn mowers, construction equipment).

Due to data availability, this inventory excludes some minor sources of direct and indirect emissions that are under the County's operational control. Notable exclusions include emissions from business travel of County employees in non-County-owned vehicles, fugitive emissions from off-site wastewater treatment, emissions from activities of entities contracted by the County, and methane emissions from closed landfills. Of these exclusions, methane emissions from closed landfills are direct emissions and all other excluded sources are indirect emissions.

Emissions can be further categorized into "scopes," which identify direct and indirect sources of emissions, improve transparency, and avoid double counting of emissions across organizations.[6] Emission scopes are defined as:

- **Scope 1:** Direct emissions from sources within a local government's organizational boundaries (e.g., fuel use in government fleet vehicles).
- **Scope 2:** Indirect emissions associated with the use of purchased electricity, steam, heating, or cooling.
- **Scope 3:** All other indirect GHG emissions not covered in Scope 2, which occur outside the County's boundary but result from activities taking places within the County's boundary (for example, employee commuting).

The following sections describe how the County developed its GHG inventory, results of the inventory, and projected emissions through 2030.

2017 Emissions Inventory

Baseline years provide a historic point of comparison against which emissions performance is tracked over time. The base year of Baltimore County's updated inventory is calendar year 2017.[7] This inventory includes estimates for the following sources of emissions from County operations:

- On-site fuel combustion (natural gas, fuel oil, and propane) at County facilities (Scope 1),
- Mobile combustion in County fleet vehicles and non-fleet vehicles and equipment (Scope 1),
- Waste disposal in County-owned landfills (Scope 1),
- Fugitive emissions from refrigerant leakage (Scope 1)
- Purchased electricity in County facilities (Scope 2), and
- County employee commuting (Scope 3).

These emission sources span four sectors, presented in Figure 3.

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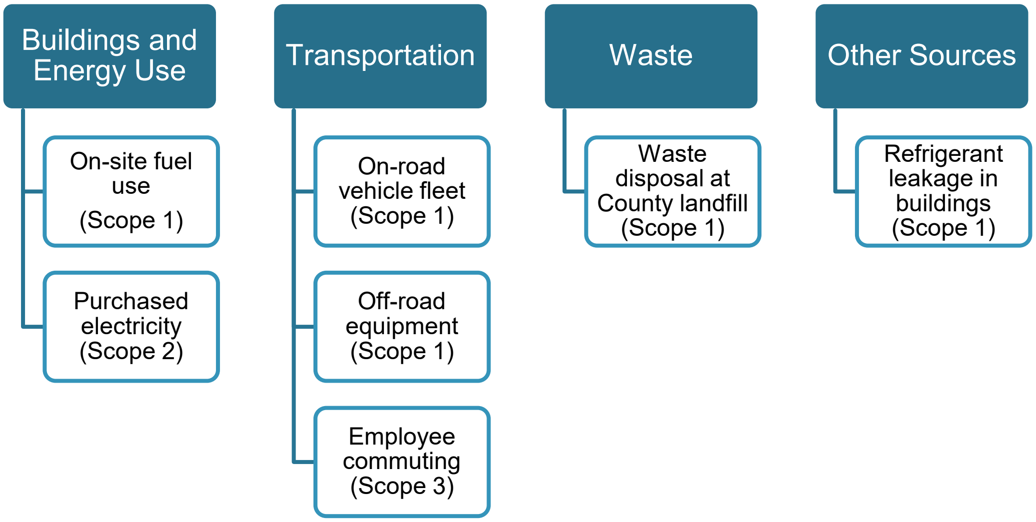
[6] ICLEI. 2010. *Local Government Operations Protocol. Version 1.1.* See https://icleiusa.org/ghg-protocols/.
[7] This inventory builds on the initial GHG inventory completed by Towson University in 2008 for Baltimore County's operations for years 2002 to 2006 with projections for 2012 but is not directly comparable.

Figure 3: GHG Inventory Sources by Sector



Textbox 2: Baltimore County's 2006 GHG Inventory

The County previously developed a GHG inventory for County operations in 2006.[1] Sources included in the 2006 inventory were largely the same as the 2017 inventory, with the exception of fertilizer use, refrigerant use, and off-road equipment. The scope of the County's 2006 GHG inventory included the County's general operations, public schools, the community college, public library, and revenue authority. Total emissions from the 2006 inventory for general operations, public library, and revenue authority (i.e., entities included in the scope of the 2017 inventory) were 198,627 MT CO_2e. The current inventory is not directly comparable to the 2006 inventory because of different methodologies and GWPs used.

Emissions for each source were estimated using methods from ICLEI's LGOP and emission factors from the U.S. EPA's Center for Corporate Climate Leadership's (CCCL) Emission Factors Hub,[8] unless otherwise specified (for example, where more localized or site-specific emission factors were available). Where data were unavailable, ICF used best practices to develop proxy data to develop the estimates.

Additional information on methodologies and assumptions for each emission source as well as a list of emission factors are available in Appendix A – Technical Documentation.

Overall Results

In 2017, Baltimore County emitted 165,337 MT of CO_2e from government operations. This is equivalent to emissions from approximately 19,000 average households.[9] Figure 4 and Table 1 show emissions by source. Methane emissions from landfilled waste at Eastern Sanitary Landfill were the

[8] EPA Center for Corporate Climate Leadership Emission Factors Hub. Available at https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[9] EPA Greenhouse Gas Equivalency Calculator. Available at https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

largest source of GHG emissions in 2017. The second largest source of emissions was purchased electricity, followed by the County's on-road vehicle fleet.

Scope 1 (direct) emissions comprised 66% of total emissions, driven by landfilled solid waste, on-road vehicle fuel use, and on-site stationary fuel use. Scope 2 (indirect) emissions from purchased electricity comprised 24% of total emissions. Finally, Scope 3 (indirect) emissions comprised the remaining 11% of total emissions from employee commuting.

Carbon dioxide comprised 68% of total emissions in 2017, followed by CH_4 which made up 31% of total emissions. Emissions of N_2O and HFCs each made up less than one percent of total emissions.

Figure 4: 2017 Emissions by Source

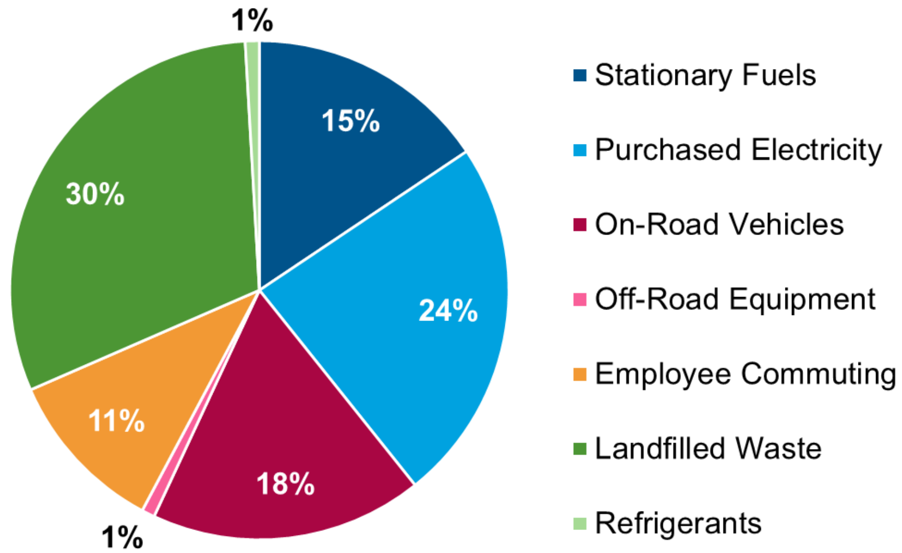


Table 1: 2017 GHG Emissions by Source (MT CO_2e)

Sector and Source	Emissions
Energy	**64,929**
Stationary Fuels	25,802
Purchased Electricity	39,128
Transportation	**48,276**
On-Road Vehicles	29,210
Off-Road Equipment	1,392
Employee Commuting	17,674
Waste	**50,629**
Landfilled Waste	50,629
Other	**1,502**
Refrigerants	1,502
Total	**165,337**

The following sections describe sector-specific results of the inventory.

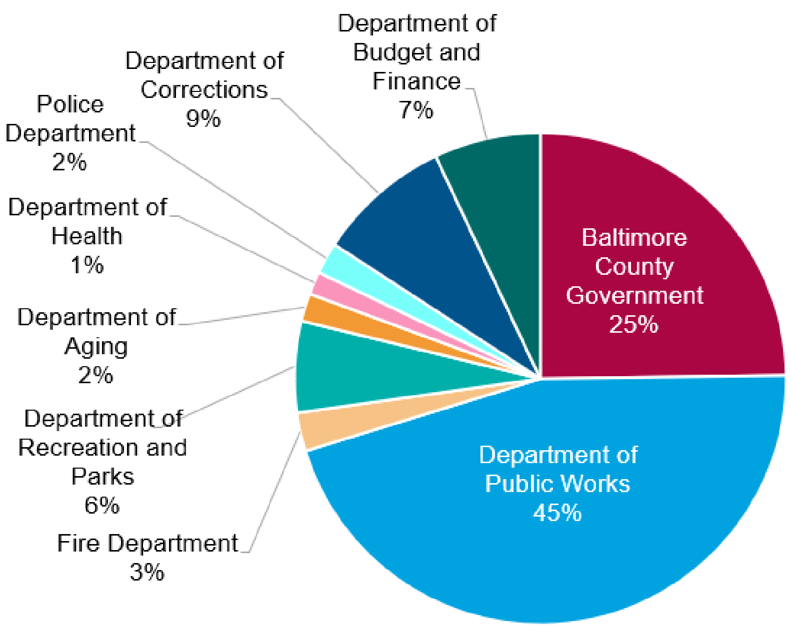
Buildings and Energy Use

Buildings and energy sector emission sources include on-site stationary fuel combustion (e.g., natural gas, petroleum heating oil, and propane) and purchased electricity in County-owned facilities. These facilities include office buildings, community centers, recreational centers, courthouses, fire stations, libraries, maintenance and service facilities, prisons and detention centers, nature centers, water treatment plants, pumping stations, agricultural centers, parks, historical centers and museums, landfills and associated facilities, police and emergency facilities (e.g., police precincts), golf courses, senior centers, and health centers.

Overall, energy-related activities emitted 64,929 metric tons of carbon dioxide equivalent (MT CO_2e) in 2017, 39% of total Baltimore County emissions. Emissions from the energy sector are impacted by the amount and type of fuel combusted on-site, on-site equipment technology and efficiency, County building construction and renovation standards (e.g., LEED), the amount of electricity used in buildings and other facilities, and the fuel mix of grid electricity generation (e.g., coal or natural gas).

The largest source of emissions in the energy sector is purchased electricity, responsible for 39,128 MT CO_2e in 2017. Figure 5 shows 2017 electricity emissions by County department. Stationary fuel use emitted 25,802 MT CO_2e in 2017. Emissions from stationary fuel use were primarily from the use of petroleum heating oil followed by natural gas use in facilities.

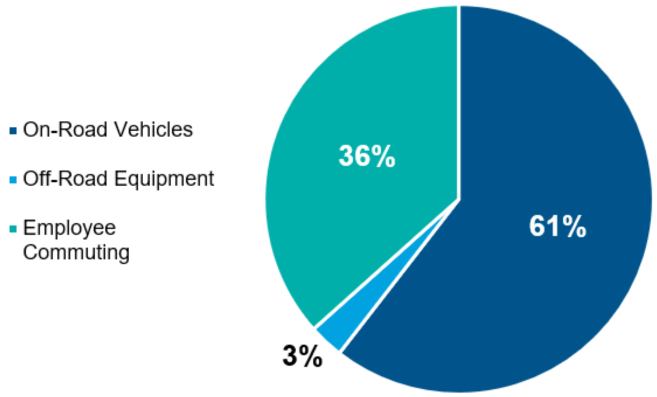
Figure 5: 2017 Purchased Electricity Emissions by Department



Transportation

Transportation sector emission sources include fuel use in on-road vehicles and off-road equipment and emissions from employee commuting. Travel in non-County-owned vehicles (e.g., contractors' vehicles) is excluded from emission estimates. Figure 6 shows the breakdown of transportation emissions for 2017.

Figure 6: 2017 Transportation Sector Emissions



Overall, transportation-related activities emitted 48,276 metric tons of carbon dioxide equivalent (MT CO_2e) in 2017, 29% of total Baltimore County emissions. Emissions from on-road vehicles accounted for 61% of transportation emissions, followed by commuting emissions which accounted for 36% and off-road equipment which accounted for the remaining 3% of transportation emissions. Emissions from the transportation sector are impacted by 1) the size, type, and efficiency of vehicles in the on-road fleet and off-road equipment inventory, 2) miles traveled by employees in County vehicles and in commuting to work, and 3) the fuel type consumed by vehicles and equipment (e.g., gasoline, diesel, diesel, or electric vehicles).

Waste

Waste sector emissions include waste landfilled at the Eastern Sanitary Landfill. This includes waste from both County government operations and generated by the community, since the County owns and operates the landfill.

The inventory does not include fugitive emissions from closed landfills due to lack of available data. Additionally, the inventory does not include emissions from commercial waste transferred out of the County by contracted waste haulers, as the waste is not generated by County operations, the destination of this waste is not under County control, and the waste would not otherwise be sent to Eastern Sanitary Landfill.

The Eastern Sanitary Landfill emitted 50,629 MT CO_2e in 2017, 31% of total Baltimore County emissions. Emissions are impacted by the amount of waste landfilled, the landfill gas (LFG) collection system, amount of LFG collected, fraction of CH_4 in the LFG, and the CH_4 collection efficiency.

Other Sources

Other emission sources include emissions from refrigerant leakage from HVAC systems, refrigerators, and other equipment. This inventory does not include emissions from decommissioning of HVAC or refrigeration equipment due to lack of available data, although refrigerants may be collected and not emitted as equipment is disposed.

The leakage of refrigerants emitted approximately 1,502 MT CO_2e in 2017, less than 1% of total Baltimore County emissions. Fugitive emissions from HVAC and refrigeration equipment are impacted by the type of equipment, amount refrigerant purchased or refilled into equipment each year, refrigerant type, and average and leakage rates of equipment.

Projections: 2018 to 2030

Following the development of the baseline GHG inventory, the County also developed projected emissions for 2018 to 2030 to serve as a baseline against which to measure the impact of emission reduction strategies. The emission projections represent the business-as-usual (BAU) scenario for the County's GHG emissions. The BAU scenario shows trends in the County's GHG emissions assuming operations do not change from today's status quo, and does not consider additional activities the County may undertake in the future to reduce GHG emissions such as additional energy conservation measures and renewable energy credits (RECs). These activities are evaluated in the mitigation analysis.

It was assumed that as the County population grows, the operations of County government (and emissions resulting from those activities) will increase to meet the needs of the community. As a result, projections for most emission sources are based on projected County population estimates from the Maryland Department of Planning applied to activity data (e.g., fuel use in County vehicles, amount of solid waste disposed) and emission factors. The emission factors used for the GHG projections can be found in Appendix A – Technical Documentation. Figure 7 and Table 2 shows GHG emission projections by source through 2030.

In the BAU scenario, estimates for two scenarios for emissions from purchased electricity were developed to analyze electricity emission projections under the same fuel mix as is currently used to generate electricity, and under anticipated changes to the electricity generation fuel mix resulting from energy market dynamics. These two scenarios are summarized below.

- **No Grid Policies:** In the No Grid Policies scenario, the 2018 eGRID[10] emission factor for the Reliability First Corporation East subregion (i.e., the geographic subregion that Baltimore County is categorized in for eGRID reporting) was held constant for years 2019 through 2030 in projections for purchased electricity.
- **Planned Grid Policies:** In the Planned Grid Policies scenario, the electricity emission factors between 2019 and 2030 were adjusted to capture the impact of relevant national, regional, and state policies on the electricity grid. These impacts are captured by scaling the 2018 emission factor with anticipated changes in the sources of electricity generation, using EIA's 2020 AEO data for the South Atlantic region (i.e., the geographic region that Baltimore County is categorized in for AEO reporting).

Figure 7 shows projected GHG emissions through 2030 under the Planned Grid Policies scenario and indicates the additional emissions from purchased electricity in the No Grid Policies Scenario (i.e., if no electricity grid changes occur through 2030). Unless otherwise noted, the Planned Grid Policies scenario is used in reported results throughout the CAP (e.g., Table 2 only shows results for the Planned Grid Policies scenario).

[10] The U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States, and tracks data on emissions, emission rates, generation, heat input, resource mix, and other attributes.

Figure 7: GHG Emissions by Source, 2017 through 2030

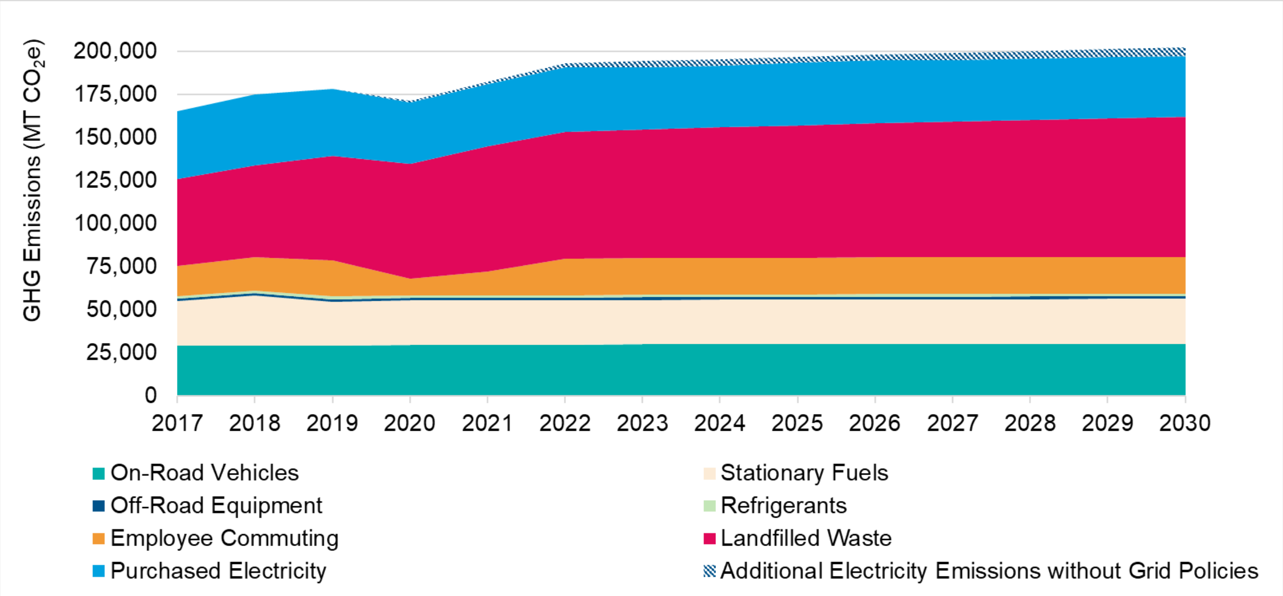


Table 2: Projected GHG Emissions by Source, 2017 through 2030 (MT CO_2e)

Sector and Source	2017	2020	2025	2030
Energy	**64,929**	**61,273**	**62,528**	**61,392**
Stationary Fuels	25,802	25,701	26,005	26,163
Purchased Electricity	39,128	35,571	36,523	35,229
Transportation	**48,276**	**40,914**	**52,789**	**53,113**
On-Road Vehicles	29,210	29,720	30,071	30,253
Off-Road Equipment	1,392	1,416	1,435	1,447
Employee Commuting	17,674	9,778	21,284	21,413
Waste	**50,629**	**66,694**	**76,855**	**81,446**
Landfilled Waste	50,629	66,694	76,855	81,446
Other	**1,502**	**1,502**	**1,502**	**1,502**
Refrigerants	1,502	1,502	1,502	1,502
Total	**165,337**	**170,383**	**193,675**	**197,453**

Baltimore County's GHG emissions are projected to increase by 19% from 165,337 MT CO_2e in 2017 to 197,453 MT CO_2e in 2030. While most emission sources are projected to increase from 2017 to 2030, some of these increases will be offset by lower emissions from purchased electricity as the regional electricity grid mix uses less carbon-intensive generation sources (for example, renewable energy sources). Emission sources that are projected to increase include stationary fuel use, vehicle and equipment fuel use, landfilled waste, and employee commuting.

Emissions from on-site fuel combustion are projected to increase by 1% from 25,802 MT CO_2e to 26,163 MT CO_2e in 2030 due to growth in the amount of energy used by facilities to meet Baltimore

County's anticipated population growth. All transportation emission sources are anticipated to grow in line with population growth by 2030 from 48,276 MT CO_2e in 2017 to 53,113 MT CO_2e in 2030, as demand for vehicle and equipment usage and employee commuting increase with Baltimore County operations. Emissions from on-road vehicles and off-road vehicles and equipment are projected to be 4% higher in 2030, and employee commuting emissions are projected to be 21% higher in 2030.

Emissions from landfilled waste are projected to increase by 61% from 50,629 MT CO_2e to 81,446 MT CO_2e in 2030. The business-as-usual projection assumes increased waste will be sent to the incinerator through the projection period. Still, emissions from the landfill will continue to rise as a result of increased waste generation due to increasing population and continued emissions from historical waste sent to landfill, assuming existing landfill gas capture levels through 2030. Emissions from waste sent to the incinerator are not included in inventory totals because they are outside of the County's geographic boundary and operational control since Baltimore County does not own or operate the incinerator. Emissions from incinerated waste are included for informational purposes in Textbox 2 and Appendix A – Technical Documentation since this waste would otherwise have been landfilled in the County's landfill.

Textbox 3: Incinerated Waste Emissions

Emissions from incinerated Baltimore County waste sent to the Wheelabrator incinerator are estimated to be 76,273 MTCO_2e in 2017 and to increase by 8% to 82,401 MTCO_2e by 2030. These emissions are outside of the County's geographic boundary and operational control but included for informational purposes. These emissions do not account for any avoided emissions from electricity generated by the incinerator and used outside the County government boundaries.

Emissions from purchased electricity are projected to decrease due to changes in the regional electricity grid. Although purchased electricity use is projected to increase in line with expanding County operations, changes in the electricity grid mix to have a greater share of generation from renewable sources will offset increased emissions from increased electricity use. The Energy Information Administration's (EIA) Annual Energy Outlook (AEO) anticipates an increase in electricity generation from renewable sources such as solar photovoltaic (PV) and a decrease in carbon-intensive energy sources such as coal and petroleum. The increased portion of renewable energy as part of the regional electricity generation mix will result in lower emissions from purchased electricity through 2030. As a result of these changes to activity data and emission factors for purchased electricity, emissions are projected to decrease by 10% from 39,128 MT CO_2e in 2017 to 35,229 MT CO_2e in 2030.

Emissions associated with refrigerants are assumed to remain constant at 1,502 MT CO_2e from 2017 through 2030 as it is anticipated that the County will retain a consistent building stock and balance replacing equipment that uses ozone depleting substances with the increased use of low-GWP alternatives, where feasible, given current Baltimore County initiatives. Baltimore County's Property Management Division has a preventative maintenance program in place to inspect all HVAC equipment twice per year for leaks and filter changes and is committed to eliminating and reducing the use of HFCs.

Overall, the County's baseline GHG emissions trend through 2030 shows an increase, driven by higher emissions from waste and transportation sectors that are partially offset by lower emissions from purchased electricity. This trend for electricity is supported by the expectation that grid emission factors will decrease through 2030 as more electricity is generated from renewable sources. Additionally, population growth will result in higher emissions-generating activity by the County for various sources despite lower emissions from purchased electricity.

GHG Emission Reductions

This section describes actions the County plans to take to reduce its GHG emissions over the coming decade. The list of actions included in this CAP were identified based on current and planned actions, as well as best practices for GHG reduction strategies that could be implemented over a 2-, 5-, and 10-year timeframe This list of actions was developed through conversations with key stakeholders and departments within Baltimore County government, including members of the County's Climate Action Team. The County considered various criteria to refine the list of potential reduction strategies for each sector, including County priorities, available resources, cost, ease of implementation, and potential to reduce emissions.

Overview

The County has already started implementing strategies to reduce building energy use and emissions from solid waste management. The strategies in this CAP build on the County's existing plans and include additional actions such as building electrification and feasible opportunities for the County's fleet that can further reduce the County's emissions.

Overall, this plan recommends 14 mitigation actions in the Buildings and Energy Use, Transportation, and Waste sectors. Table 3 lists the mitigation strategies considered for this Climate Action Plan. These strategies were developed in coordination with County stakeholders and take into account current and planned actions, feasibility, and County priorities. Where applicable, actions include both a moderate and an aggressive scenario. Textbox 5 explains the differences between moderate and aggressive scenario modeling. Unless otherwise noted, the numbers discussed in this narrative represent the moderate scenario.

Textbox 4: Moderate and Aggressive Scenarios

Moderate Scenario

Largely represents actions currently planned by the County government with some adjustments to achieve additional emission reductions.

Aggressive Scenario

Represents a stretch goal by expanding on the strategies outlined in current and forthcoming plans to include more ambitious commitments, accelerated timelines, and increased GHG emission reductions.

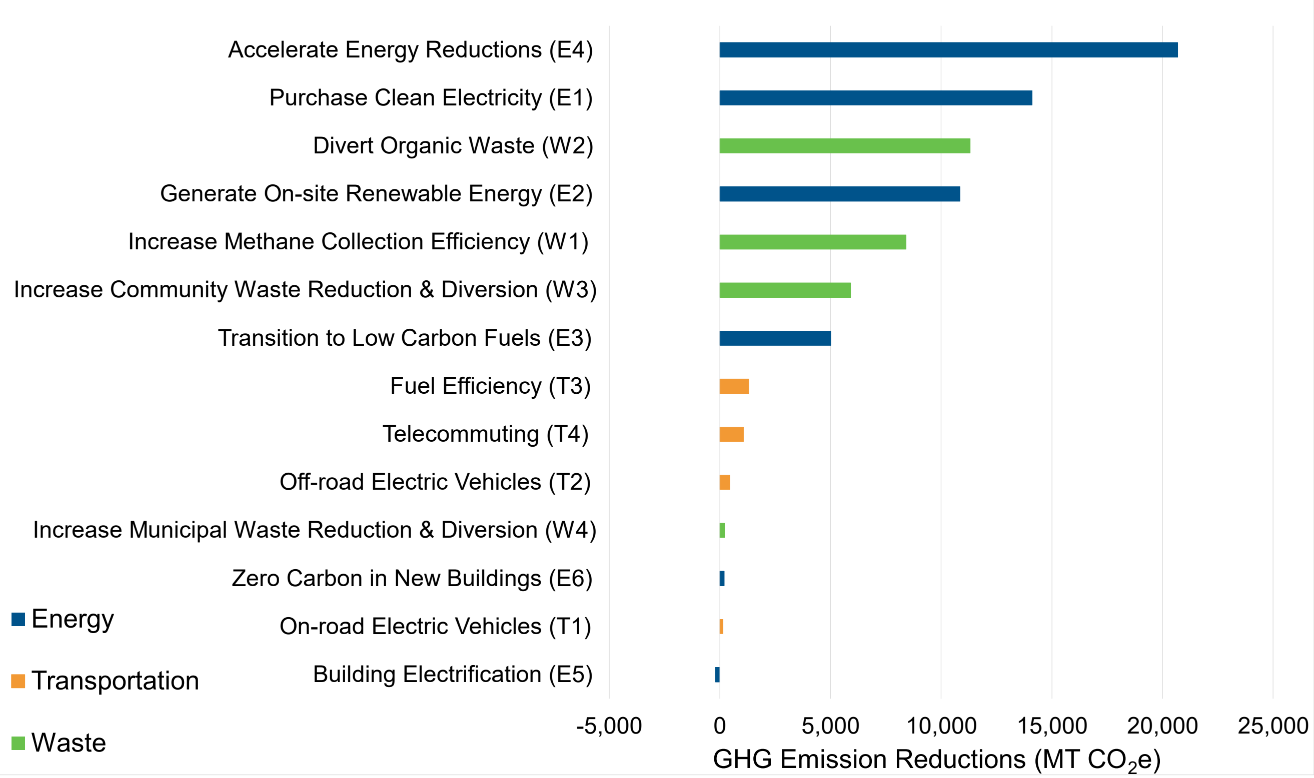
Table 3: Strategies Included in the GHG Mitigation Analysis

Strategy	Reduce Electricity Consumption	Reduce Natural Gas Consumption	Transition to Renewable Energy	Transition to Cleaner Mobile Fuel Use	Reduce Mobile Fuel Consumption	Reduce Waste Emissions
E1: Purchase Clean Energy			●			
E2: Generate On-Site Renewable Energy			●			
E3: Replace Stationary Fuels with Lower Carbon Alternatives		●				
E4: Accelerate Energy Reductions in County Buildings	●	●				
E5: Electrify Building Heating Systems		●				
E6: Implement a Zero Carbon Energy Standard in New Buildings	●	●	●			
T1: Electrify the On-Road Fleet				●		
T2: Electrify the Off-Road Fleet				●		
T3: Increase Fuel Efficiency of the On-Road Fleet				●	●	
T4: Expand Opportunities for Telecommuting					●	
W1: Increase Methane Collection Efficiency at Eastern Sanitary Landfill						●
W2: Divert Organic Waste from Landfills and Waste-to-Energy			●			●
W3: Improve Community-Wide Source Reduction and Increase Recyclable Waste Diversion						●
W4: Divert Government Waste Disposal through Source Reduction and Diversion						●

Moderate Reduction Scenario

Overall, the actions included in this plan will reduce Baltimore County government's emissions by 29% from 2017 levels by 2030 and by 40% from 2030 business-as-usual (BAU) levels under the moderate scenario. Figure 3 shows GHG reductions by strategy for the moderate scenario.

Figure 8: GHG Emission Reductions by Strategy under Moderate Reduction Scenario



The energy and waste sectors represent the largest opportunity for reductions. Of the planned actions included in this CAP, strategies in the buildings and energy sector make up 64% of emission reductions, followed by the waste sector making up 33% of emission reductions in 2030. The strategies with the largest impacts include energy and waste sector strategies, including generating renewable energy on-site, purchasing clean energy, and accelerating planned energy reductions in buildings, increasing methane collection efficiency at Eastern Sanitary Landfill, and diverting organic waste from landfill through aerobic digester or related technology. Figure 9 and Table 4 show the impact of each mitigation strategy over the 2017-2030 time period.

Figure 9: GHG Emission Reductions by Strategy under a Moderate Scenario

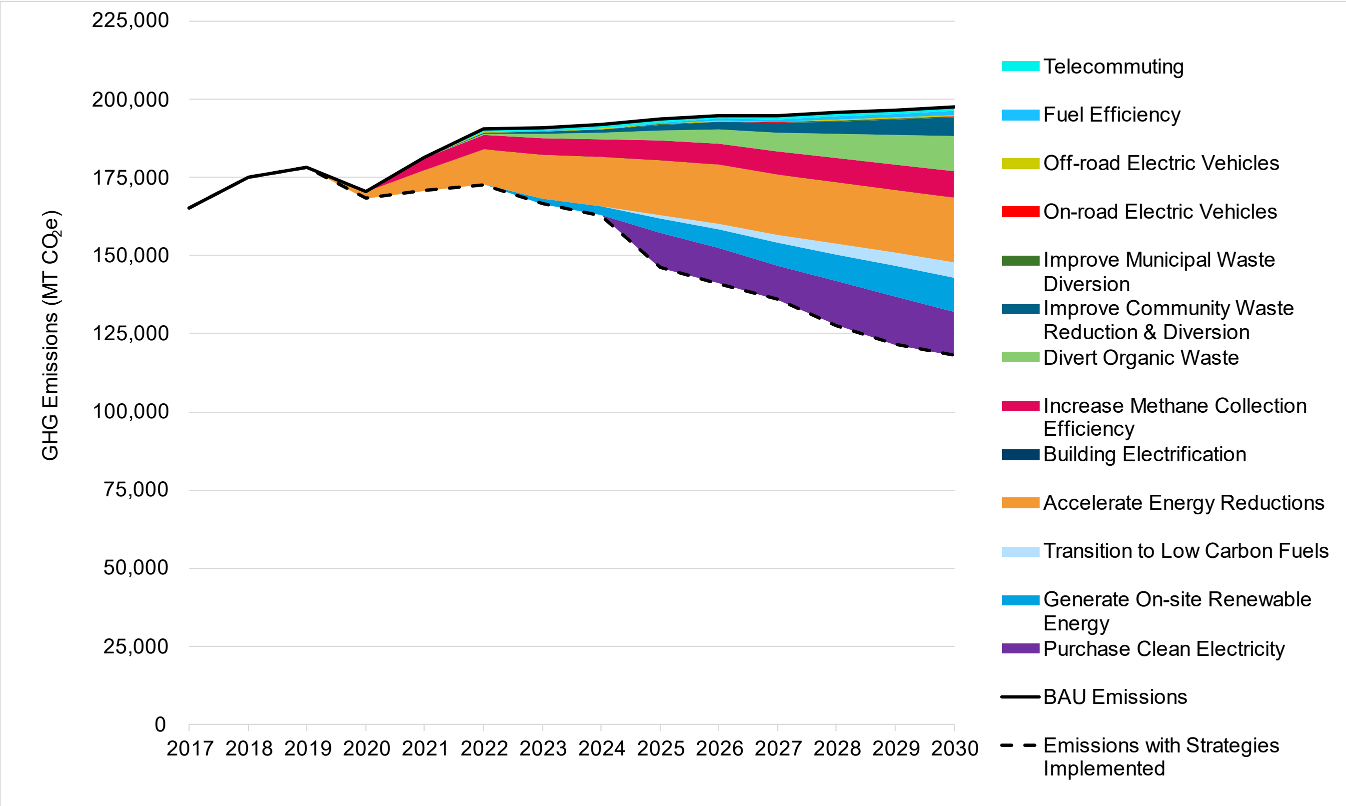


Table 4: GHG Emissions Summary under the Moderate Scenario

Sector	2017	2030 BAU	2030 Mitigation Scenario	Percent Change from 2017	Percent Change from 2030 BAU
Energy	**64,929**	**61,392**	**11,154**	**-83%**	**-82%**
Stationary Fuels	25,802	26,163	11,154	-57%	-57%
Purchased Electricity	39,128	35,229	0	-100%	-100%
Transportation	**48,276**	**53,113**	**49,751**	**3%**	**-6%**
On-Road Vehicles	29,210	30,253	28,517	-2%	-6%
Off-Road Equipment	1,392	1,447	891	-36%	-38%
Employee Commuting	17,674	21,413	20,342	15%	-5%
Waste	**50,629**	**81,446**	**55,612**	**10%**	**-32%**
Landfilled Waste	50,629	81,446	55,612	10%	-32%
Other	**1,502**	**1,502**	**1,502**	**0%**	**0%**
Refrigerants	1,502	1,502	1,502	0%	0%
Total	**165,337**	**197,453**	**118,020**	**-29%**	**-40%**

Table 5 shows a summary of emission reductions from BAU levels for 2-, 5-, and 10-year time frames for each GHG reduction strategy.

Table 5: Moderate Scenario Emission Reductions from BAU Levels by Sector and Strategy for 2-, 5-, and 10-Year Timeframes

Sector	2022	2025	2030
Buildings and Energy Use	**11,301**	**34,457**	**50,656**
E1: Purchase Clean Electricity	0	11,119	14,113
E2: Generate On-site Renewable Energy	0	4,568	10,847
E3: Replace Stationary Fuels with Lower-Carbon Alternatives	0	932	5,008
E4: Accelerate Energy Reductions in County Buildings	11,374	17,916	20,687
E5: Electrify Building Heating Systems	(72)	(130)	(195)
E6: Implement a Zero Carbon Energy Standard in New Buildings	0	52	197
Waste	**5,358**	**11,303**	**25,833**
W1: Increase Methane Collection Efficiency at ESL	4,391	6,265	8,407
W2: Divert organic waste from landfill and from waste-to-energy	621	3,249	11,304
W3: Improve community-wide source reduction & diversion	324	1,698	5,906
W4: Implement source reduction and diversion programs through municipal operations	22	91	216
Transportation	**1,283**	**1,802**	**2,975**
T1: On-road Electric Vehicles	8	54	142
T2: Off-road Electric Vehicles	105	195	454
T3: Fuel Efficiency	113	489	1,309
T4: Telecommuting	1,057	1,064	1,071
Total	**17,942**	**47,562**	**79,464**

Aggressive Reduction Scenario

As noted above, the aggressive GHG reduction scenario includes opportunities for greater emission reductions by the County. In the aggressive scenario, various strategies in the moderate scenario are expanded or accelerated to achieve greater emission reductions. Results from the aggressive GHG reduction scenario are provided below in Table 6 and Figure 10. In the aggressive GHG reduction scenario, the County would reduce GHG emissions by 41% compared to 2017 levels and 50% compared to 2030 BAU levels.

Figure 10: GHG Emission Reductions by Strategy under an Aggressive Reduction Scenario

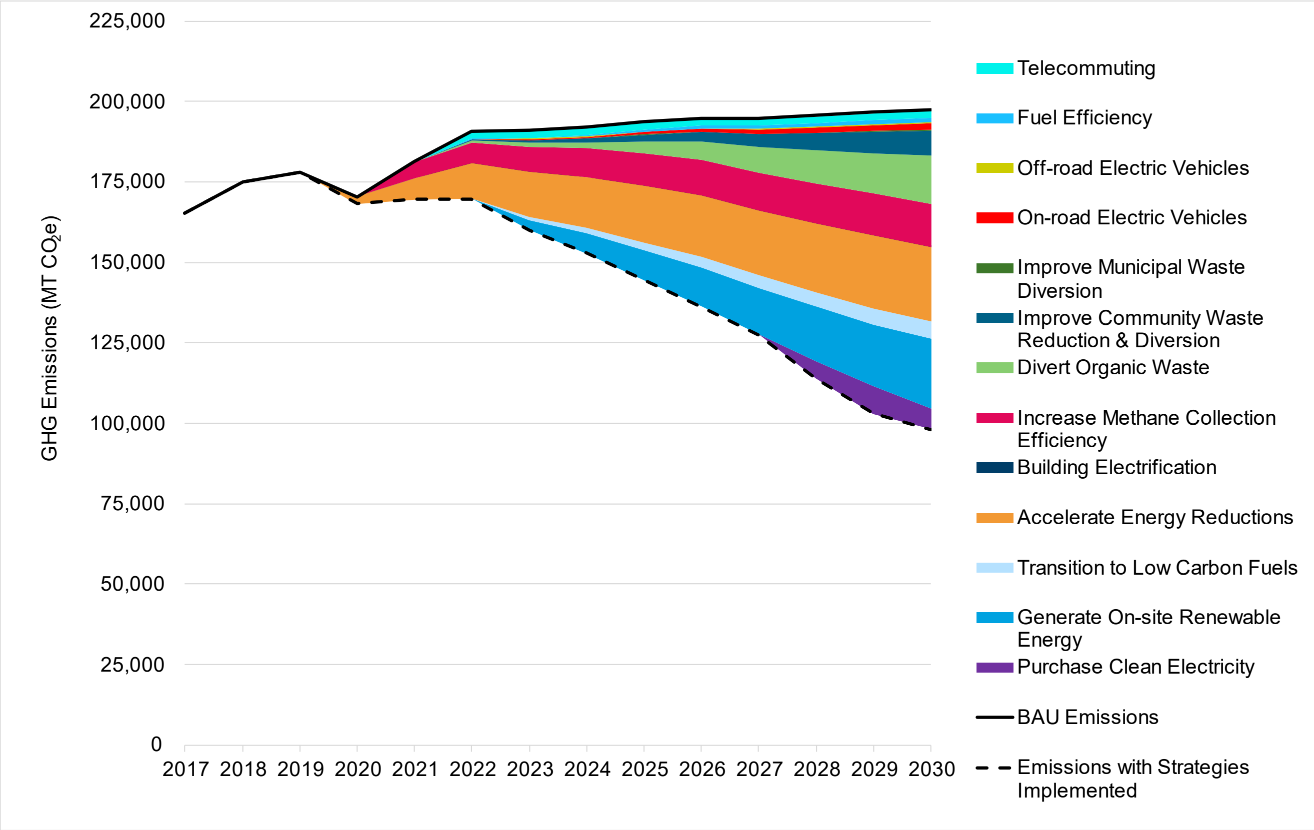


Table 6: GHG Emissions Summary under an Aggressive Reduction Scenario

Sector	2017	2030 BAU	2030 Mitigation Scenario	Percent Change from 2017	Percent Change from 2030 BAU
Energy	**64,929**	**61,392**	**8,338**	**-87%**	**-86%**
Stationary Fuels	25,802	26,163	8,338	-68%	-68%
Purchased Electricity	39,128	35,229	0	-100%	-100%
Transportation	**48,276**	**53,113**	**43,111**	**-11%**	**-19%**
On-Road Vehicles	29,210	30,253	22,949	-21%	-24%
Off-Road Equipment	1,392	1,447	891	-36%	-38%
Employee Commuting	17,674	21,413	19,272	9%	-10%
Waste	**50,629**	**81,446**	**45,165**	**-11%**	**-45%**
Landfilled Waste	50,629	81,446	45,165	-11%	-45%
Other	**1,502**	**1,502**	**1,502**	**0%**	**0%**
Refrigerants	1,502	1,502	1,502	0%	0%
Total	**165,337**	**197,453**	**98,117**	**-41%**	**-50%**

A summary of emission reductions from BAU levels for 2-, 5-, and 10-year time frames for each GHG reduction strategy in the Aggressive Scenario is provided below.

Table 7: GHG Emission Reductions from BAU Levels by Sector and Strategy for 2-, 5-, and 10-Year Timeframes under an Aggressive Scenario

Sector	2022	2025	2030
Buildings and Energy Use	**11,282**	**29,624**	**57,118**
E1: Purchase Clean Electricity	0	0	6,358
E2: Generate On-site Renewable Energy	0	9,137	21,694
E3: Replace Stationary Fuels with Lower-Carbon Alternatives	0	2,621	5,452
E4: Accelerate Energy Reductions in County Buildings	11,374	17,916	23,643
E5: Electrify Building Heating Systems	(142)	(257)	(388)
E6: Implement a Zero Carbon Energy Standard in New Buildings	50	207	360
Waste	**7,333**	**15,864**	**36,281**
W1: Increase Methane Collection Efficiency at ESL	6,366	10,007	13,386
W2: Divert organic waste from landfill and from waste-to-energy	621	3,787	14,897
W3: Improve community-wide source reduction & diversion	324	1,979	7,783
W4: Implement source reduction and diversion programs through municipal operations	22	91	216
Transportation	**2,379**	**3,730**	**5,951**
T1: On-road Electric Vehicles	20	713	2,047
T2: Off-road Electric Vehicles	105	195	454
T3: Fuel Efficiency	139	694	1,309
T4: Telecommuting	2,113	2,128	2,141
Total	**20,994**	**49,219**	**99,350**

Buildings and Energy Use Sector

The County identified six actions in the Buildings and Energy Use sector to include in this Climate Action Plan. These measures and their associated GHG reductions and energy savings for 2030 are shown in Table 8.

Table 8: Summary of Emission and Energy Use Reductions for the Buildings and Energy Use Sector under a Moderate Reduction Scenario in 2030

Strategy	GHG Emission Reductions	Electricity Reductions	Natural Gas Reductions	Other Fuel Reductions
E1: Purchase Clean Energy	14,113 MT CO_2e	NA	NA	NA
E2: Generate On-Site Renewable Energy	10,847 MT CO_2e	20,012 MWh	NA	NA
E3: Replace Stationary Fuels with Lower-Carbon Alternatives	5,008 MT CO_2e	NA	57,714 MMBTU	132,355 MMBTU (fuel oil)
E4: Accelerate Energy Reductions in County Buildings	20,687 MT CO_2e	41,671 MWh	66,432 MMBTU	69,779 MMBTU (fuel oil)
E5: Electrify Building Heating Systems	(195) MT CO_2e*	(3,691) MWh	1,095 MMBTU	123 MMBTU (fuel oil) 195 MMBTU (propane)
E6: Implement a Zero Carbon Energy Standard in New Buildings	197 MT CO_2e	(804) MWh	1,631 MMBTU	1,714 MMBTU (fuel oil)

*Net emission reductions from building electrification are negative as a result of increased electric load.

Textbox 6: Renewable Energy Credits

A renewable energy credit (REC) is a market-based instrument that represents the property rights to the environmental (e.g., GHG reduction) attributes of renewable electricity generation. They are issued when electricity is delivered to the electric grid from a renewable source. RECs can be retained for on-site renewable energy projects or purchased to offset emissions from purchased electricity.

As Baltimore County looks to grow its onsite and offsite renewable footprint, it will be important for leadership to review and agree on how renewable energy credits (RECs) from the project are being applied. RECs represent the environmental benefit associated with renewable electricity generation and are often a key component to project financing on renewable projects.[11] Maryland's Renewable Portfolio Standard requires a certain percentage of RECs be purchased by all electricity users which creates a market and value for RECs.[12] In current renewable electricity projects, such as the County's planned onsite solar projects at landfills and buildings, and the County's landfill gas electricity generation projects, the project developers have retained ownership of project RECs to support project economics. Through the sale, the County loses the ability to claim the carbon benefit associated with these investments. Going forward it is recommended that Baltimore County leadership explore pathways that allow it to retain ownership of RECs or if economics don't allow to pursue a "REC swap" in order to claim the environmental and carbon benefits associated with the onsite or offsite renewable projects. Where possible, the County should seek to retain higher value RECs that either meet Maryland RPS requirements, or provide regional carbon reduction benefit to the grid.

Strategy E1: Purchase Clean Energy

Through this strategy, the County would pursue 100% renewable electricity through power purchase agreements (PPAs) and renewable energy credit (REC) purchases. In this strategy, Baltimore County would pursue up to two separate large offsite PPAs and fill in remaining renewable electricity reduction needs with RECs. Off-site PPAs are 15- to 25-year commitments to purchase electricity from a specific utility scale renewable energy project. Entities enter PPAs to provide financial backing for a new regional solar or wind (or other renewable energy source) project that will provide power and regional RECs at a price comparable to or lower than the current cost of electricity. Spacing out the PPAs will allow Baltimore County to spread out any pricing risk associated with changing market prices.

This strategy overlaps with Energy Strategy 2, Generate On-site Renewable Energy; if a high amount of onsite solar is selected, only one offsite PPA is needed. If only a moderate amount of onsite solar is pursued, larger offsite commitments will be needed. An offsite PPA and regional renewable energy project has the potential for numerous direct local benefits, including an influence on GHG emissions in the regional electricity grid, improved air quality, local economic benefits, and lower costs. Project stakeholders should meet and coordinate to align contract goals and objectives prior to beginning procurement.

Scenario	Description	2030 GHG Emission Reductions	2030 Renewable Electricity Purchases
Moderate Scenario	2 offsite PPAs	14,113 MT CO_2e	49,090 MWh
Aggressive Scenario*	1 offsite PPA	4,113 MT CO_2e	14,306 MWh

*Under the aggressive scenario, it is assumed that more on-site renewable energy generation will occur under strategy E2, and therefore the emission reductions from strategy E1 will appear lower than the moderate scenario when less renewable energy is generated on-site and therefore an additional PPA is required.

[11] See https://www.epa.gov/greenpower/renewable-energy-certificates-recs#:~:text=A%20renewable%20energy%20certificate%2C%20or,attributes%20of%20renewable%20electricity%20generation
[12] See https://www.psc.state.md.us/electricity/maryland-renewable-energy-portfolio-standard-program-frequently-asked-questions/

Implementation Timeframe	Planning for a PPA should begin as soon as possible and work on procurement, legal review, approval, and contract management will be needed throughout the life of the projects. Initial project production would start in 2025, a second, if needed would start in 2028
Relative Cost of Implementation	**Low.** Renewable PPA prices have been shown to be comparable and potentially lower than conventional electricity prices.
Key Milestones	**2 years:** Procurement for an initial PPA has begun and a broad set of stakeholders for the project have identified. **5 years:** The project associated with the initial PPA will have started commercial operation and is providing renewable electricity to the County under a PPA. **10 years:** Both projects' associated PPAs will continue to provide renewable electricity. Baltimore County will purchase RECs on an annual basis to provide a balance of 100% renewable electricity.
Key Assumptions	PPAs will be cost effective and Baltimore County will be able to procure them through their BRPAC arrangement or as standalone financial projects.

Strategy E2: Generate On-Site Renewable Energy

Through this strategy, the County will install ground-mount, parking canopy and rooftop solar installations on County properties. The strategy assumes implementation is phased evenly until 2030 at sites determined by Baltimore County leadership and at rates of either 3.7 MW or 7.5 MW annually starting in 2023, depending on whether a moderate or aggressive scenario is selected.

Initial projects would be fit under Maryland's net metering rules and be applicable to a broad number of County facilities provided each individual project was under the 2MW cap. Projects could initially be implemented through onsite PPAs to take advantage of the Federal Investment Tax Credit. After expiration of the tax credit, the County would have the option to install, own and operate its own solar PV projects, or continue to allow third party operators through a PPA or similar contract.

Baltimore County has already begun screening its physical sites to understand where solar PV opportunities might fit best fit and should continue to prioritize implementation at its larger rooftop sites. In implementation, leadership should pursue phased projects that bundle multiple sites together to improve the economics of the projects and limit the legal and administrative work associated with implementation of complex projects.

Scenario	Description	2030 GHG Emission Reductions	2030 Renewable Electricity Generation
Moderate Scenario	30 MW onsite solar PV	10,847 MT CO_2e	23,312 MWh
Aggressive Scenario	60 MW onsite solar PV	21,694 MT CO_2e	40,025 MWh

Implementation Timeframe	Implementation is phased evenly until 2030 at sites determined by Baltimore County leadership and at a rate of either 3.7 or 7.5 MW annually
Relative Cost of Implementation	**Low.** Onsite solar PPA prices should be competitive with conventional power prices, especially when adequate space for solar PV can be found and while net metering is active.
Key Milestones	**2 years:** Initial projects are online, and an onsite solar plan has been developed to understand and deploy solar at specific sites. **5 years:** Projects have begun to come online and producing onsite renewable electricity. **10 years:** Full deployment of onsite solar PV (either 30MW or 60MW depending on chosen scenario)
Key Assumptions	Values for solar PV system capacity, project locations, and degradation rates based on data from the National Renewable Energy Lab (NREL). Sites modeled showed ample capacity for large onsite solar PV projects.

Strategy E3: Replace Stationary Fuels[13] with Lower-Carbon Alternatives

This strategy displaces natural gas and fuel oil use with lower-carbon fuel alternatives. Renewable natural gas is a biogas which has been upgraded to a quality similar to fossil natural gas and that can be used as a direct substitute. Renewable natural gas will displace 50% of total gas use and B20 biodiesel will displace 100% of fuel oil use in stationary energy sources (i.e., onsite building fuel use for heating) by 2030. Lower carbon alternative fuels would be purchased via long term contracts to reduce price exposure. When considering B20 biodiesel as an alternative fuel, leadership should ensure that its equipment can use B20 as some older equipment may have issues associated with burning B20 and should be transitioned to newer equipment or an alternative source (as outlined in strategy E5 below). As a cleaner fuel, B20 can help equipment last longer by reducing wear on furnaces and boilers.

Scenario	Description	2030 GHG Emission Reductions	2030 Fuel Reductions
Moderate Scenario	50% adoption of RNG for NG and 100% adoption of biodiesel for conventional diesel	5,008 MT CO_2e	57,714 MMBTU (natural gas) 132,355 MMBTU (fuel oil)
Aggressive Scenario	75% adoption of RNG for NG and 100% adoption of biodiesel for conventional diesel	6,533 MT CO_2e	86,571 MMBTU (natural gas) 132,355 MMBTU (fuel oil)

[13] Stationary fuels are solid, liquid, or gaseous fuels generally used to provide on-site heat or energy for a building.

Implementation Timeframe	Contracts for the purchase of low-carbon fuels should be set up in the near term.
Relative Cost of Implementation	**Medium.** B20 and RNG prices have traditionally cost more than conventional diesel and natural gas.
Key Milestones	**2 years:** Initial planning and setting up of contracts should take place **5 years:** Low carbon fuel purchases start and begin to ramp up to full deployment **10 years:** Full purchase of low carbon fuels
Key Assumptions	Low Carbon Fuels are used to displace convention fuels. Renewable natural gas displaces 50% of total gas use and B20 biodiesel displaces 100% of fuel oil use in stationary energy sources by 2030. Assumes all RNG and biodiesel fuels are made of biological sources and produce biogenic CO_2 (excluded from emission totals), in addition to CH_4 and N_2O emissions during combustion.

Strategy E4: Accelerate Energy Reductions in County Buildings

Through this strategy, the County will accelerate existing energy reduction goals and set an aggressive energy reduction goal for energy efficiency for heating and thermal energy needs. The County assumes that natural gas and fuel oil energy efficiency reductions are equivalent to electricity energy efficiency reductions as part of this strategy. Energy efficiency for electricity, natural gas and fuel oil continue to either a 35% or 40% reduction in 2030 depending on the scenario selected. This strategy builds on the County's existing Energy Conservation and Efficiency Action Plan and requires the energy management leadership to manage natural gas use and conservation with the same attention that is currently applied to the County's electricity portfolio.

Baltimore County's existing Energy Conservation and Efficiency Action Plan lays out an aggressive set of energy efficiency improvements for electricity with a goal to reduce electricity consumption by over 30% by FY2025. This work includes employee engagement programs, HVAC management and building tune ups, lighting retrofits and plug load management programs. As part of the plan, the County plans to work to retrofit its remaining streetlights to LED and has multiple planned HVAC retrofit projects in County facilities including capital projects at libraries, recreation centers, senior center and a variety of other facility types. The plan also includes energy performance contracts at larger facilities.

Beyond existing electricity savings energy efficiency measures, Baltimore County would pursue natural gas and fuel oil savings measures such as weatherization, insulation, and explore other building envelope improvements in facilities (with specific emphasis on those facilities with high heating and thermal load needs). Various HVAC control measures and equipment optimization may also play a role in reducing thermal loads and energy use. Reducing natural gas consumption can be challenging since energy efficiency measures often require more attention to be sustained following the retrofit. Local government and corporate leaders often use technology to closely monitor building automation systems and maintain energy savings in high use buildings.

Where possible, comprehensive energy efficiency approach that maximizes the savings opportunities available from a specific building or set of buildings, while minimizing the ratio of project management costs to the total savings produced from the project. Comprehensive energy efficiency projects will allow the County to blend measures that would not be economical to do on a stand-alone basis.

Scenario	Description	2030 GHG Emission Reductions	2030 Electricity Reductions	2030 Fuel Reductions
Moderate Scenario	35% reduction	20,687 MT CO_2e	41,671 MWh	66,432 MMBTU (natural gas) 69,779 MMBTU (fuel oil)
Aggressive Scenario	40% reduction	23,643 MT CO_2e	47,624 MWh	75,923 MMBTU (natural gas) 79,748 MMBTU (fuel oil)

Implementation Timeframe	Immediate action would be needed to identify and scale natural gas and fuel oil reducing projects in County owned facilities. Planning and implementation of the County's existing Energy Conservation and Efficiency Action Plan for electricity will need to continue and planning will need to expand to hit 2030 targets.
Relative Cost of Implementation	**Medium.** Many energy efficiency measure will be cost-effective, however, to reach deeper energy efficiency retrofits, longer payback measures will need to be adopted.
Key Milestones	**2 years:** Implementation of existing plan continues, planning for natural gas energy efficiency is developed. **5 years:** Implementation of plans continues **10 years:** Full deployment of energy efficiency and conservation.

Strategy E5: Electrify Building Heating Systems

Through this strategy, the County will pursue electrification of building heating systems. This strategy applies only to facilities under 20,000 square feet by 2030 and assumes the electrification of 25-50% of total fuel oil and propane heated use and up to 12.5-25% of natural gas heated use from those facilities. The strategy also assumes no new fuel oil or propane-fueled heating systems from the BAU scenario and assumes the BAU natural gas growth. The strategy assumes an 18% average efficiency gain from conversion to electric (heat pumps, variable refrigerant flow (VRF)) from combustion systems (boilers and furnaces)[14]. While this measure appears to increase emissions, once it is combined with renewable energy purchasing and onsite solar PV deployment it will reduce emissions by 2030. To provide a scale of this work, under the moderate scenario, Baltimore County would need to retrofit approximately 10,000-15,000 square feet of space annually. As an example, the Texas Fire Station at 9835 York Rd is a 10,000 square foot building and uses approximately 10,000 therms of natural gas annually. In the moderate scenario, one natural gas building, or similar size would need to be electrified along with up to 2 smaller buildings that run on fuel oil annually. This work would be dependent on the County's capital construction schedule as many of the projects would require significant design and construction efforts.

As an alternative to major retrofits, Baltimore County could pursue targeted technology retrofits across several buildings. Examples include infrared heating in vehicle bays or storage spaces, heat pump water heaters in buildings, or induction heated stoves for cooking. Project implementation should focus on learning lessons and developing best practices for electrification of small/medium sized buildings as a Climate Action Plan (for planning beyond 2030) will likely emphasize this strategy further as a lower carbon grid is available and technologies mature.

Strategy	Description	2030 GHG Emission Reductions	2030 Increased Electricity	2030 Natural Gas Reductions
Moderate Scenario	25% fuel oil replacement, 12.5% natural gas replacement in small and medium sized facilities	(195) MT CO_2e	3,691 MWh	11,862 MMBTU
Aggressive Scenario	50% fuel oil replacement, 25% natural gas replacement in small and medium sized facilities	(388) MT CO_2e	7,046 MWh	23,725 MMBTU

Implementation Timeframe	Electrification planning and implementation should start immediately, at a modest pace and prioritize County facilities with high thermal loads or that are less complex and ready for a major HVAC retrofit or replacement.
Relative Cost of Implementation	**High.** Electrification technologies are still emerging, and major retrofits often may involve multiple system replacements (heating, cooling, building envelope and controls) that will require modification.

[14] 18% average efficiency gain for conversion was taken from "Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges" by ACEEE October 2020, page 56 https://www.aceee.org/sites/default/files/pdfs/b2004.pdf

Key Milestones	**2 years:** Implement 1-2 preliminary projects and develop lessons learned from initial projects. **5 years:** Implementation of higher payback electrification strategies (less than 5 years) continues. **10 years:** Planning in place for a fuller implementation of electrification strategies post 2030.

Strategy E6: Implement a Zero Carbon Standard in New Buildings

Through this strategy, the County will implement a Zero Carbon Standard for any new facilities by 2025 in which new high efficiency buildings that only use clean electricity for fuel and thus emit zero carbon in their operations. This measure builds on Baltimore County's existing LEED Silver requirement for new buildings. New high efficiency buildings should maximize passive strategies and reduce amount of electricity needed to power them. By building electric only facilities, this measure is effective in deep decarbonization when enacted in coordination with the purchase and on-site generation of carbon free electricity. Precise rules the County policy should be determined by a set of County stakeholders familiar with County buildings and local building challenges. A new standard should be adopted in line with building codes and Baltimore County Department of Public Works standards and in alignment with the numerous types of building operational standards available in the marketplace.

Scenario	Description	2030 GHG Emission Reductions	2030 Increased Electricity	2030 Fuel Reductions
Moderate Scenario	Implementation of policy starting in 2025	197 MT CO_2e	804 MWh	1,631 MMBTU (natural gas) 1,714 MMBTU (fuel oil)
Aggressive Scenario	Implementation of policy starting in 2022	360 MT CO_2e	1,474 MWh	2,991 MMBTU (natural gas) 3,141 MMBTU (fuel oil)

Implementation Timeframe	Policy stakeholders should meet and determine the precise policy**.** Since new buildings design and engineering takes a considerable amount of time, new designs should be immediately taken into account a change in standards to allow for the 2025 target to be met.
Relative Cost of Implementation	**Low**. Most green building standards put an emphasis on cost-effectiveness and provide savings and benefits that offset higher initial costs.

Key Milestones	**2 years**: New policy is put in place. **5 years:** Policy starts for all new buildings. **10 years:** Continued implementation of net zero new buildings.

Transportation Sector

The County identified four actions in the transportation sector as part of this Climate Action Plan. These measures and their associated GHG reductions and fuel savings are shown in the table below.

Table 9: Summary of Emission and Energy Use Reductions for the Transportation Sector under a Moderate Reduction Scenario in 2030

Strategy	GHG Emission Reductions	Fuel Reductions	Increased Electricity Use
T1: On Road Electrification	142 MT CO_2e	28,121 gal (gasoline) 17,329 gal (diesel)	987 MWh
T2: Off Road Electrification	454 MT CO_2e	8,344 gal (gasoline) 46,360 gal (diesel)	354 MWh
T3: Increase Fuel Efficiency	1,309 MT CO_2e	1,309 MT CO_2e gal (gasoline)	NA
T4: Telecommuting	1,071 MT CO_2e	NA	NA

NA: Not Applicable

Strategy T1: On-Road Electrification

Under this strategy, the County will increase the adoption of electric vehicles and plug-in hybrids for its fleet. This strategy will reduce the number of gasoline-powered passenger vehicles, light-duty trucks, and diesel-powered heavy-duty trucks in the County's on-road vehicle fleet, increasing the number of zero emission vehicles. It is assumed that by 2030, the County will have electrified 10% of the fleet, using both electric vehicles (EV) and plug-in hybrid vehicles (PHEV). An aggressive scenario will double this. In the moderate scenario, 20% of passenger cars, 5% of light-duty trucks, and 1% of heavy-duty trucks will be converted to EVs or PHEVs by 2050.

Scenario	GHG Emission Reductions	Fuel Reductions	Increased Electricity Use
Moderate Scenario	142 MT CO_2e	28,121 gal (gasoline) 17,329 gal (diesel)	987 MWh
Aggressive Scenario	2,047 MT CO_2e	177,741 gal (gasoline) 433,216 gal (diesel)	13,783 MWh

Implementation Timeframe	Immediate

Relative Cost of Implementation	High
Key Milestones (Moderate Scenario)	**5 years:** 5% of passenger cars will be converted into EVs or PHEVs **10 years:** 10% of passenger cars and 1% of light-duty trucks and heavy-duty vehicles will be converted to EVs or PHEVs **30 years:** 20% of passenger cars, 5% of light-duty vehicles, and 1% of heavy-duty vehicles will be converted into EVs or PHEVs
Key Assumptions (Moderate Scenario)	➢ 50% conversion split between EVs and PHEVs for each goal ➢ All diesel vehicles are assumed to be heavy duty vehicles between class 3 – 8

Strategy T2: Off-Road Electrification

Under this strategy, the County will begin to electrify certain types of off-road vehicles, namely mowers and forklifts. This strategy will begin reducing the number of gasoline and diesel-powered off-road vehicles in the County's fleet. No aggressive scenario was modeled for this strategy.

Scenario	2030 GHG Emission Reductions	2030 Fuel Reductions	2030 Increased Electricity Use
Moderate Scenario	454 MT CO_2e	8,344 gal (gasoline) 46,360 gal (diesel)	354 MWh

Implementation Timeframe	Immediate
Relative Cost of Implementation	Medium
Key Milestones	**2 years:** ➢ All gasoline forklifts are replaced with electric ➢ 16% of mowers are replaced with electric **5 years:** ➢ Begin replacement of diesel forklifts with electric ➢ 33% of mowers are replaced **10 years:** ➢ All gasoline and diesel forklifts purchased prior to 2019 are replaced with electric ➢ 80% of mowers are replaced with electric **20 years:** ➢ All gasoline and diesel mowers and forklifts are replaced with electric

Key Assumptions	➢ Assumes a forklift runs 2,000 hours per year ➢ Assumes a mower runs 1,000 hours per year

Strategy T3: Increase Fuel Efficiency

Under this strategy, the County will increase the overall fuel efficiency of its fleet through the increased purchase of hybrid vehicles and more fuel-efficient gasoline or diesel vehicles as existing fleet vehicles are retired. The strategy excludes vehicles that have already transitioned to EVs or PHEVs, and only applies to passenger cars and light-duty trucks. The aggressive strategy will assume all new vehicles purchased in 2025 will be hybrids, while the moderate strategy pushes this back to 2030. As a result, both strategies result in the same reductions by 2030.

While the fleet is working toward these EV, PHEV, and hybrid purchasing goals, and new gasoline or diesel vehicles purchase will still be cleaner than the vehicle they replaced. New vehicles have improved fuel efficiency due to the U.S. Department of Transportation's Corporate Average Fuel Economy (CAFE) standards requiring fuel economy and tailpipe[15] GHG emission standards for passenger cars and light-duty trucks, that requires all light-duty vehicles to increase the stringency of fuel efficiency at 1.5% per year from 2020 levels over years 2021 through 2026.[16]

Scenario	Description	2030 GHG Emission Reductions
Moderate Scenario	56% adoption for new vehicles by 2025	1,309 MT CO_2e
Aggressive Scenario	100% adoption for new vehicles by 2025	1,309 MT CO_2e

Implementation Timeframe	Until 2030
Relative Cost of Implementation	Low
Key Milestones (Moderate Scenario)	**2 years:** 29% hybrid vehicle adoption for passenger car and light-trucks **5 years:** 56% hybrid vehicle adoption for passenger car and light-trucks **10 years:** 100% hybrid vehicle adoption for passenger car and light-trucks
Key Assumptions (Moderate Scenario)	➢ Excludes vehicles that will be converted into EVs

[15] Tailpipe emissions are emissions from the tailpipes of vehicles that combust fuel.
[16] EPA 2020e. The Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 202-2026. Available at: https://www.govinfo.gov/content/pkg/FR-2020-04-30/pdf/2020-06967.pdf

	➢ Assumes a fleet turnover rate of 5% and starting with 20% of new fleet vehicles will be hybrid ➢ Assumed an annual 1.5% increase in stringency of fuel economy and tailpipe GHG emission standards for vehicles sold from 2021 through 2026 under the SAFE Rule

Strategy T4: Telecommuting

This strategy includes expanded opportunities for telecommuting for County employees. As a result of shifts in workforce commuting patterns from the COVID-19 pandemic, the County is already considering some procedures and processes to improve telecommuting opportunities. This strategy can reduce GHG transportation emissions by reducing the daily need for employees to commute to work, typically by private passenger vehicles. Increased telecommuting may reduce facility energy usage and shift that usage to the residential sector, which would be excluded from Baltimore's footprint. However, as office buildings will still need to be running, this is assumed to be nominal and not included in the modeling.

Strategy	Percentage Telecommuting	2030 GHG Emission Reductions
Moderate Scenario	5%	1,071 MT CO_2e
Aggressive Scenario	10%	2,141 MT CO_2e

Implementation Timeframe	Immediate
Relative Cost of Implementation	Low
Key Milestones (Aggressive Scenario)	**2 years:** 10% of the work force begins telecommuting. **5 years:** 10% of the work force continues to telecommute. **10 years:** 10% of the work force continues to telecommute.
Key Assumptions (Aggressive Scenario)	➢ From 2021 onwards, assumes 10% of all employees will be telecommuting ➢ Assumes that all employees commuting into work at the City travel by passenger cars using gasoline and that all employees travel on their own (i.e., do not carpool)

Waste Sector

The County identified four actions in the waste sector to include as part of this Climate Action Plan. These measures and their associated GHG and waste reductions are shown in the table below.

Table 10: Summary of Emission and Landfilled Waste Reductions for the Waste Sector under a Moderate Reduction Scenario in 2030

Strategy	GHG Emission Reductions	Landfilled Waste Reductions
W1: Increase Methane Collection Efficiency at Eastern Sanitary Landfill	8,407MT CO_2e	NA
W2: Divert Organic Waste from Landfills and Waste-to-Energy	11,304 MT CO_2e	78,606 MT
W3: Improve Community-Wide Source Reduction and Increase Recyclable Waste Diversion	5,906 MT CO_2e	96,794 MT
W4: Divert Government Waste Disposal through Source Reduction and Diversion	216 MT CO_2e	2,316 MT
Total	**25,833 MT CO_2e**	**177,716 MT**

NA: Not Applicable

Strategy W1: Increase Methane Collection Efficiency at Eastern Sanitary Landfill

The County has taken measures in recent years to modernize the Eastern Sanitary Landfill. In line with these improvements, the landfill collection efficiency at Eastern Sanitary Landfill is already above the national average of 65%.[17] Through this strategy, the County will increase the methane collection efficiency at Eastern Sanitary Landfill from an average of 72%, based on Baltimore County's 2017 and 2018 reports to EPA's GHGRP,[18] to an average between 73 and 75% by 2022, between 75 and 78% by 2025, and 78% by 2030. A collection efficiency target of 78% was identified as an ambitious and feasible target that is in line with landfill management based on California regulatory requirements.[19]

The emission reductions resulting from increased methane collection efficiency depends on the amount of waste sent to landfill throughout the projection period. As the County pursues efforts to increase source reduction and diversion, the amount of waste sent to landfill is expected to decrease and therefore landfill gas would decrease over time as well. As a result, emission reductions presented here show reductions based on business-as-usual (BAU) waste tonnage sent to landfill as

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[17] EPA 2020b. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Management Practices Chapter. https://www.epa.gov/sites/production/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf

[18] EPA 2020c. GHGRP Data for Eastern Sanitary Landfill. https://ghgdata.epa.gov/ghgp/service/facilityDetail/2018?id=1004330&ds=E&et=&popup=true

[19] EPA 2020b. Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM). Management Practices Chapter. https://www.epa.gov/sites/production/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf

well as reductions based on waste sent to landfill after community-wide source reduction and diversion efforts under Strategy W2 and Strategy W3.

Emission reductions from BAU waste sent to landfill ("BAU waste") and including changes in waste sent to landfill under Strategy W2 (diversion of organic waste) and Strategy W3 (community-wide source reduction and diversion) are shown in the table below.

Scenario	Description	2030 GHG Emission Reductions (BAU waste)	2030 GHG Emission Reductions (reduced waste)
Moderate Scenario	73-75% collection efficiency	10,815 MT CO_2e	8,407 MT CO_2e
Aggressive Scenario	75-78% collection efficiency	18,926 MT CO_2e	13,386 MT CO_2e

Implementation Timeframe	Immediate
Relative Cost of Implementation	Medium to High
Key Milestones	**2 years:** 73-75% **5 years:** 75-78% **10 years:** 78%
Key Assumptions	➢ While the metric for this strategy is a collection efficiency range, for modeling purposes, a linear increasing trend in collection efficiency was assumed, resulting in a collection efficiency of 74% by 2022, 75% by 2025, and 78% by 2030 for the aggressive scenario. For the moderate scenario, assumed collection efficiencies are 73% by 2022, 74% by 2025, and 75% by 2030. ➢ Overall waste generation will increase in line with county population growth ("BAU waste") or will decrease based on community-wide source reduction and diversion efforts under Strategy W2 and Strategy W3 ("reduced waste"). ➢ 215,000 tons of waste will be sent to the incinerator in Baltimore City throughout the projection period.

Strategy W2: Divert Organic Waste from Landfills and Waste-to-Energy

Through this strategy, the County will divert residential and commercial organic waste from landfill and waste-to-energy facilities. Methane is produced in landfills when organic waste breaks down through anaerobic decomposition. In order to maximize emission reductions, the County should focus on reducing and diverting organic waste, defined as food and yard waste, from the landfill. Based on the County's most recent waste characterization study,[20] approximately 31% of the waste stream is made up of food and yard waste. This strategy focuses on diverting 90% of organic waste to facilities with anaerobic digestion or composting operations by 2030.

The target set under this strategy aligns with projects that have already been proposed by the County. The County has indicated it will conduct an organic waste characterization study in both the residential and commercial sectors. Based on the results of the study, the County would decide on the best way to divert and manage organic material. Options for organics management include anaerobic digestion and composting. In addition, the County is considering investing in a mixed waste processing facility to collect and separate higher amounts of organic and recyclable material for diversion.

The emission reductions presented in this plan assume an anaerobic digestion facility will come on-line in 2024 with diversion of 90% of organic waste by 2030. Emissions from anaerobic digestion as well as from composting, an alternative organics management option, are presented below. While direct emissions from composting are higher than anaerobic digestion, co-benefits of composting include increased carbon storage, greater water retention in soil, and reduced need for chemical fertilizers.

Management Options	Emissions by 2030
Anaerobic Digestion	946 MT CO_2e
Composting	13,721 MT CO_2e

Source: U.S. EPA WARM Version 15

Additionally, the County envisions a redesign of its yard waste drop-off program. Improvements to the yard waste program may include the purchase of depackaging equipment to remove plastic bag contamination and expansion of accepted materials beyond yard waste, which would require consideration of potential PFAS contamination[21] and its impact on the use and value of finished compost product.

In addition to a large-scale organics management solution, it is recommended that the County diversify management of organic material by engaging with the community and implementing composting programs at community sites such as recreation centers and schools. The County should also pursue revision of local regulation to allow for backyard composting and a restart of the compost bin sales program to encourage residents to compost at home.

[20] Baltimore County Waste Characterization Study Draft Summary Rev 0.pdf (2016). Provided to ICF by Baltimore County staff.
[21] Per- and polyfluoroalkyl substances (PFAS) are a group of persistent man-made chemicals that are common in items such as food packaging.

Scenario	Description	2030 GHG Emission Reductions	2030 Landfilled Waste Reduction
Moderate Scenario	60% organic waste diversion	11,304 MT CO_2e	78,606 MT
Aggressive Scenario	90% organic waste diversion	14,897 MT CO_2e	105,497 MT

Implementation Timeframe	Immediate
Relative Cost of Implementation	High
Key Milestones	Organic waste diversion **Moderate Scenario:** ➢ **2 years:** 0% diversion of organics ➢ **5 years:** 20% diversion of organics ➢ **10 years:** 60% diversion of organics **Aggressive Scenario:** ➢ **2 years:** 0% diversion of organics ➢ **5 years:** 40% diversion of organics ➢ **10 years:** 90% diversion of organics
Key Assumptions	➢ Assumes a 78% collection efficiency by 2030, in alignment with the waste strategy to increase methane collection efficiency at Eastern Sanitary Landfill (Strategy W1). ➢ 0.48 metric tons of waste per capita in 2017 based on county population in 2017 and total waste in 2017 (202,445 tons of waste sent to landfill and 200,000 tons of waste sent to incinerator). ➢ Assumes organic waste is sent to an anaerobic digestion facility starting in 2024; Accounts for methane emissions; nitrous oxide emissions from anaerobic digestion are assumed to be negligible per IPCC (2006).

Strategy W3: Improve Community-Wide Source Reduction and Increase Recyclable Waste Diversion

Through this strategy, the County will improve community-wide source reduction and diversion rates. This strategy encompasses two actions that reduce overall waste generation which include source reduction, or waste reduction per capita; and diversion of recyclable waste.

Source Reduction

Source reduction is a key component to any waste management strategy. The source reduction target to reduce municipal generation per capita by at least 15% from a 2017 baseline by 2030 is in line with the level of ambition defined by C40 Cities' *Zero Waste Declaration*. Examples of best practices from cities with successful source reduction programs include:

- Public outreach campaigns to reduce food waste through actions such as clarifying food date labeling, educating the public about tax benefits for food donation, and providing resources for businesses, residents to track and reduce food waste. Activities that reduce food waste before it is generated contribute to landfill reductions under Strategy W3.
- Assistance for large generators of waste, such as hospitals and universities.
- Investment in local reuse programs such as physical or virtual lending libraries, repair workshops, and repair and reuse stores.

Diversion

The County has a strong public outreach and education program to encourage residents to reduce, reuse, and divert solid waste. Through its efforts, the County's diversion rate in the baseline year of 2017 was 35%, which increased to approximately 39% in 2019.[22] The U.S. EPA has set a national diversion target of 50% by 2030 and the Maryland statewide target is 40% diversion by 2030. This strategy aims to be more ambitious and achieve an 80% diversion rate by 2030. This more ambitious goal is in line with cities across the country that are taking ambitious action toward greenhouse gas reduction goals.

Strategy	Description	2030 GHG Emission Reductions	2030 Landfilled Waste Reduction
Moderate Scenario	5% reduction in waste per capita; 60% waste diversion	5,906 MT CO_2e	96,794 MT
Aggressive Scenario	15% reduction in waste per capita; 80% waste diversion	7,783 MT CO_2e	108,194 MT

Implementation Timeframe	Immediate
Relative Cost of Implementation	High
Key Milestones	Source reduction: ➢ **2 years:** 6% reduction in waste per capita ➢ **5 years:** 11% reduction in waste per capita ➢ **10 years:** 15% reduction in waste per capita

[22] The diversion rates referred to here are the Maryland Department of Environment (MDE) recycling rates, which include a source reduction credit. These diversion rates are not representative of the actual rate of waste recycled after accounting for contamination and process loss.

	Diversion: ➢ **2 years:** 35% diversion of recyclables ➢ **5 years:** 50% diversion of recyclables ➢ **10 years:** 80% diversion of recyclables
Key Assumptions	➢ Assumes a 78% collection efficiency by 2030, in alignment with the waste strategy to increase methane collection efficiency at Eastern Sanitary Landfill (Strategy W1). ➢ 0.48 metric tons of waste per capita in 2017 based on county population in 2017 and total waste in 2017 (202,445 tons of waste sent to landfill and 200,000 tons of waste sent to incinerator).

In order to maximize emission reductions, the County should focus on reducing and diverting material with degradable organic carbon, including corrugated boxes, office paper, and newspaper. Based on the County's most recent waste characterization study,[23] 34% of the waste stream is made up of material types with degradable organic carbon, with an additional 31% of the waste stream composed of food and yard waste, which is accounted for under Strategy W2. The composition of waste with degradable organic carbon in the County's waste stream is presented below along with the percent of anaerobically degradable organic carbon (ANDOC) by material type.

Table 11: Baltimore County Waste Characterization by Waste Type and Percent ANDOC

Material	% of Baltimore County Waste Stream	% ANDOC
Food	24.2%	3.10%
Corrugated Boxes	8.7%	1.73%
Office Paper	7.3%	2.46%
Textiles	4.9%	0.59%
Diapers	4.3%	0.51%
Newspaper	3.3%	0.24%
Coated Paper	2.9%	0.23%
Grass	2.9%	0.18%
Branches	2.9%	0.29%
Leaves	0.07%	0.02%
Lumber	1.7%	0.17%
Construction/Demolition	0.6%	0.01%
Total	**64.4%**	**9.53%**

[23] Baltimore County Waste Characterization Study Draft Summary Rev 0.pdf (2016). Provided to ICF by Baltimore County staff.

ANDOC - anaerobically degradable organic carbon
Sources: Baltimore County Waste Characterization Study (2016). Yard waste was disaggregated into grass, branches, and leaves based on the 2016 Maryland Statewide Waste Characterization Study (2017). ANDOC values are from the California Air Resources Board (CARB) Landfill Methane Emissions Tool.

Strategy W4: Divert Government Waste Disposal through Source Reduction and Diversion

Through this strategy, the County will divert government-generated waste from the landfill through source reduction, procurement policies, reuse, recycling, and composting programs. It is important for the government to lead the community by example and increase its diversion rate and source reduction activities. There is also an opportunity to pilot programs within government operations that could subsequently be expanded to the community.

Procurement policies and strategies can help the government implement this strategy such as buying products in bulk, buying products with less packaging, purchasing durable and reusable products, and renting products rather than purchasing products to own. Additionally, when designing new government buildings, there are best practices for maximizing proper waste separation and logistics in the buildings which can assist in reaching the diversion rate target in government buildings. Examples of best practices include ensuring enough storage space for recyclable materials and carts both in the building and loading dock area, co-locating trash and recycling bins, and installing free standing waste stations rather than built-in cabinets, which limit the ability of building managers to shift to evolving recycling markets.

Due to limited data availability, this strategy accounts for waste generation by county employees and does not consider construction & demolition (C&D) waste. Because a large contributor to government-generated waste is C&D waste related to utility work, highway development, and infrastructure replacements, it is recommended that reuse and recycling are integrated into construction contracts in order to reduce C&D materials sent to the landfill.

Scenario	Description	2030 GHG Emission Reductions	2030 Landfilled Waste Reduction
Moderate Scenario	80% diversion	216 MT CO_2e	2,316 MT

Implementation Timeframe	Immediate
Relative Cost of Implementation	Low
Key Milestones	**2 years:** 40% diversion **5 years:** 60% diversion **10 years:** 80% diversion
Key Assumptions	➢ 78% collection efficiency by 2030, in alignment with the waste strategy to increase methane collection efficiency at Eastern Sanitary Landfill (Strategy W1).

	➢ Commercial waste generation rate of 0.39 metric tons of waste per capita based on the Baltimore County Ten-Year Solid Waste Management Plan (2018).[24] ➢ Because of the high volume and weight of construction materials, construction and demolition (C&D) waste generated by the government are expected to make up a large portion of the government-generated waste stream. However, due to lack of data, government-generated C&D waste is not included in this analysis.

Conclusions

Overall, the County has identified 14 actions through this CAP that will achieve estimated reductions of 29% below 2017 levels or 40% below business-as-usual emissions in 2030 under a moderate reduction scenario, and 41% below 2017 levels or 50% below BAU emissions in 2030 under an aggressive scenario. In the energy and waste sectors in particular, the aggressive scenario demonstrates that the County could achieve even greater emission reductions than with current plans. The energy sector has the largest potential for reducing the County's emissions due to low carbon grid strategies and the option to purchase and/or generate zero-carbon energy for County operations. Planned actions for the waste sector also offers significant opportunities for emission reductions for the County. The County has the opportunity to increase emission reductions by implementing more aggressive programs as resources, staffing, and infrastructure allow moving forward.

As one of the largest counties in the state, the County plays a pivotal role in both leading the community and in helping the State of Maryland advance climate goals, such as the Renewable Portfolio Standard's goal to supply 50% of electricity with renewable sources by 2030. With plans already in motion including energy reduction and renewable energy procurement, the County is already providing leadership to guide others throughout the state in undertaking climate action to mitigate the impacts of GHG emissions on the community.

Implementation of this plan is the next step forward for the County. Implementing this plan will require buy-in across agencies and sufficient funding and staffing to implement them. We recommend starting immediately with the low-cost scenarios and then building in the medium/high-cost scenarios into planning efforts over the next 5 to 10 years as resources allow. We also recommend periodic updates to the GHG inventory and tracking progress annually toward implementation of these goals and the status of implementation in order to readjust goals as circumstances change.

[24] Baltimore County Ten-Year Solid Waste Management Plan 2018. Table III-1 Annual Waste Disposed / Recycling Generation and Population Data.
https://www.baltimorecountymd.gov/Agencies/publicworks/recycling/tenyearplan.html

References

ACEEE 2020. "Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges." October 2020, page 56. Available at: https://www.aceee.org/sites/default/files/pdfs/b2004.pdf

Baltimore County Government 2008. *Baltimore County Government, Greenhouse Gas Inventory 2002 – 2006, Projections for 2012.* Available at: http://resources.baltimorecountymd.gov/Documents/Environment/Sustainability/patybradysreporttobcsn.pdf.

Baltimore County Government 2018. *Ten-Year Solid Waste Management Plan.* Available at: https://www.baltimorecountymd.gov/Agencies/publicworks/recycling/tenyearplan.html

EPA Center for Corporate Climate Leadership Emission Factors Hub. Available at: https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

EPA Emissions & Generation Resource Integrated Database (eGRID). Available at: https://www.epa.gov/egrid.

EPA Greenhouse Gas Equivalency Calculator. Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

EPA 2020a. "Basic Information of Air Emissions Factors and Quantification." Accessed October 23, 2020. Available at: https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification%23About%20Emissions%20Factors.

EPA 2020b. *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM).* Management Practices Chapter. November 2020. Available at: https://www.epa.gov/sites/production/files/2020-12/documents/warm_management_practices_v15_10-29-2020.pdf

EPA 2020c. GHGRP Data for Eastern Sanitary Landfill. Available at: https://ghgdata.epa.gov/ghgp/service/facilityDetail/2018?id=1004330&ds=E&et=&popup=true

EPA 2020d. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018.* Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018

EPA 2020e. The Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 202-2026. Available at: https://www.govinfo.gov/content/pkg/FR-2020-04-30/pdf/2020-06967.pdf

EPA 2020f. "Sources of Greenhouse Gas Emissions." Accessed October 23, 2020. Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

EPA 2020g. "Understanding Global Warming Potentials." Accessed October 23, 2020. Available at: https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:~:text=The%20Global%20Warming%20Potential%20(GWP,carbon%20dioxide%20(CO2).

ICLEI 2010. *Local Government Operations Protocol. Version 1.1.* Available at: https://icleiusa.org/ghg-protocols/.

Intergovernmental Panel on Climate Change (IPCC) 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

IPCC 2018. Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_HR.pdf

Appendix A – Technical Documentation

To develop the GHG inventory, ICF collected data from County stakeholders on GHG generating processes (for example, fuel use used on-site at County facilities, amount of purchased electricity by the County, tons of waste disposed in the County landfill). These data are referred to as "activity data."

Activity data were then multiplied by emission factors to estimate GHG emissions from each source. Emission factors relate the quantity of a GHG emitted in the atmosphere with an activity and are expressed as the quantity of a GHG divided by a unit for the activity (for example, kilograms of carbon dioxide emitted per gallon of motor gasoline burned).[25] This inventory relies on emission factors developed by EPA's Center for Corporate Climate Leadership and the Local Government for Sustainability's (ICLEI) Local Government Operations Protocol (LGOP).

Buildings and Energy

Purchased Electricity

Monthly electricity use data were provided by the County for fiscal years 2017, 2018, and 2019 Electricity use was projected for 2020 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning. Electricity use estimates included in the BAU scenario do not account for any energy conservation measures, energy efficiency programs or policies, or renewable energy credits (RECs), or other programs or initiatives.

To account for the COVID-19 pandemic, ICF adjusted projected electricity consumption estimates for 2020 and 2021 based on data provided by the County on observed reductions in energy use. Overall, it was assumed that electricity use in 2020 was approximately 10% lower than BAU levels for nine months of the year, and 4.8% lower in 2021 from BAU levels for the entire year, before returning to BAU levels in 2022.

After projecting electricity use for 2018 through 2030, ICF estimated emissions by applying regional emission factors. ICF used the U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID) as the foundation for developing electricity emission estimates. eGRID is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States, and tracks data on emissions, emission rates, generation, heat input, resource mix, and other attributes.[26] eGRID publishes data every two years.

To estimate emissions of carbon dioxide (CO_2), ICF estimated a baseline electricity emission factor for 2017 using linear interpolation of the eGRID data for the Reliability First Corporation East (RFCE) subregional for 2016 and 2018. To estimate emission projections after 2018, the most recent year for which eGRID has published emission factors, CO_2 emission factors were developed using the Energy Information Administration (EIA)'s 2020 Annual Energy Outlook (AEO) data for two scenarios. ICF developed the two following scenarios to analyze electricity emission projections under the same fuel

[25] EPA 2020a. "Basic Information of Air Emissions Factors and Quantification." See https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification%23About%20Emissions%20Factors.

[26] EPA Emissions & Generation Resource Integrated Database (eGRID). See: https://www.epa.gov/egrid.

mix as is currently used to generate electricity, and under anticipated changes to the electricity generation fuel mix resulting from energy market dynamics.

- **No Grid Policies:** The 2018 eGRID emission factor for the RFCE subregion was held constant for years 2019 through 2030.
- **Planned Grid Policies:** The electricity emission factors between 2019 and 2030 were adjusted to capture the impact of relevant national, regional, and state policies on the electricity grid. These impacts are captured by scaling the 2018 emission factor with anticipated changes in the sources of electricity generation, using EIA's 2020 AEO data for the South Atlantic region.

To estimate emissions of methane (CH_4) and nitrous oxide (N_2O), baseline emission factors were developed for 2017 through the same method as the baseline emission factor for CO_2, described above.

Emission projections for the Planned Grid Policies scenario are described throughout this report.

On-site Fuel Use

Data for on-site use of propane, petroleum heating oil, and natural gas were provided by the County. Monthly petroleum heating oil purchase data were provided by the County for fiscal years 2017, 2018, 2019, and 2020. Monthly propane purchase data were provided by the County for fiscal years 2017 and 2018. Monthly natural gas use data were provided by the County for fiscal years 2017, 2018, and 2019. System characteristic data on stationary generators that use natural gas was provided by the County in an inventory of County equipment.

ICF used monthly purchase data for propane, natural gas, and petroleum heating oil to develop fuel use totals for calendar years 2017 (propane, natural gas, and petroleum heating oil), 2018 (propane, natural gas, and petroleum heating oil), and 2019 (petroleum heating oil and natural gas). Natural gas and petroleum heating oil use was projected for 2020 through 2030 and propane use was projected for 2019 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning.

After compiling fuel use estimates for propane and petroleum heating oil, ICF multiplied the annual fuel use by emission factors specific to each fuel type. ICF assumed that fuel purchases are equivalent to consumption (i.e., fuel purchased in a given month was used in the same month).

Emission factors for stationary sources (i.e., on-site fuel use) do not typically vary substantially over time and were held constant through the time series.

Transportation Sector

On-Road Vehicles

Annual fuel use and vehicle miles traveled (VMT) data for motor gasoline and diesel and a fleet inventory with on-road vehicle characteristics were provided by the County. The annual fuel use data provided information on all on-road vehicles using a specific fuel type (e.g., gasoline), and was not disaggregated to provide information specific to each vehicle included in the on-road vehicle inventory.

ICF estimated CO_2 emissions from on-road vehicles based on 2017 fuel use data. On-road fuel use was projected for 2018 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning.

After compiling fuel use estimates for motor gasoline and diesel, ICF multiplied fuel use for each fuel type by fuel-specific emission factors to calculate annual CO_2 emissions.

To estimate emissions of CH_4 and N_2O, ICF categorized vehicles by vehicle class (e.g., passenger car, light-duty vehicle) and model year to assign appropriate emission factors to each vehicle in the on-road fleet. ICF estimated total annual VMT for each vehicle class and fuel type. Finally, ICF multiplied the VMT for each vehicle class, model year, and fuel type combination by the appropriate emission factor.

Off-Road Equipment

Annual fuel use data for gasoline and diesel off-road equipment and an inventory of off-road equipment characteristics were provided by the County. The annual fuel use data provided was aggregated for all off-road equipment by specific fuel type (e.g., gasoline).

ICF estimated CO_2 emissions from off-road equipment based on 2017 fuel use data for gasoline and diesel. Off-road fuel use estimates were projected for 2018 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning.

To estimate emissions of CH_4 and N_2O, each vehicle was assigned an equipment class (e.g., construction, recreational and utility, agricultural) and fuel use estimate. ICF assumed that annual fuel use for each unit of equipment was constant over the lifetime of each unit and apportioned 2017 fuel use data to each equipment class based on the proportion of lifetime hours for each class. Finally, ICF multiplied the fuel use for each equipment class and fuel type combination by the appropriate emission factor.

Employee Commuting

Activity data were collected through an employee survey. The survey response rate was 24%.

ICF estimated emissions from employee commuting by multiplying average daily VMT by transportation mode by emission factors by mode of transportation. Daily VMT estimates by transportation mode were projected for 2018 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning.

To account for the COVID-19 pandemic, methodological adjustments were made to 2020 and 2021 estimates based on survey responses. Fifty nine percent of respondents reported working from home at some point during the COVID-19 pandemic. It was assumed that the subset of employees who worked from home during 2020 did so for nine months of the year. For 2021, it was assumed that about half as many employees will telecommute compared to 2020 before returning to BAU levels in 2022.

Waste Sector

Solid Waste

Data for Eastern Sanitary Landfill was collected from the U.S. EPA's Greenhouse Gas Reporting Program (GHGRP) and used as inputs in EPA's Landfill Gas Emissions Model (LandGEM). The solid waste methodology in LandGEM is based on the First Order Decay method recommended by the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Emissions from active landfills are affected by the landfill gas (LFG) collection system, type of LFG collection system, amount of LFG collected, historical waste tonnage sent to landfill, fraction of CH_4 in the LFG, and the CH_4 collection efficiency. These data were all collected from GHGRP and conversations with the County.

ICF projected the amounts of landfilled waste for 2021 through 2030 using County population estimates from the U.S. Census Bureau and the Maryland Department of Planning. Emissions were projected using LandGEM based on projected waste tonnage (based on population growth) and a collection efficiency of 71% through the projection period, based on the County's 2019 GHGRP report. The County indicated that, resuming in October 2020, 215,000 tons of waste will be sent to the incinerator annually throughout the projection period. As a result, the projected landfilled waste tonnage accounts for the waste sent to the incinerator, with the remaining waste tonnage assumed to go to landfill.

Waste Sent to Incineration

In addition to managing community waste in Eastern Sanitary Landfill, the County sends a portion of community waste to the Wheelabrator incinerator in Baltimore City instead of the landfill. These emissions are not included in inventory totals because they are outside of the County's geographic boundary and operational control since Baltimore County does not own or operate the incinerator. They are included for informational purposes since this waste would otherwise have been landfilled in the County's landfill.

The County indicated that about half of waste generated by the County (approximately 200,000 tons) was sent to the incinerator in 2017. The waste sent to the incinerator emitted approximately 76,273 MT CO_2e in 2017. These emissions do not account for avoided emissions from electricity generated and used outside the boundaries of the County.

ICF assumed waste sent to incinerator will remain constant for 2021 to 2030, at 215,000 tons annually as indicated by the County. Emission projections for incinerated waste are presented in Table 12.

Table 12: Projected GHG Emissions for Incinerated Waste, 2017 through 2030 (MT CO_2e)

Sector and Source	2017	2020 [c]	2025	2030
Incinerated Waste[a,b]	76,273	20,600	82,401	82,401

[a] Incinerated waste is included as an informational item and not included in County totals.
[b] These emissions do not account for avoided emissions from electricity generated by the incinerator and used outside the boundaries of the County.
[c] The annual 215,000 tons sent to incinerator are scaled down to 3 months in 2020, since the County resumed sending waste to the incinerator on October 1, 2020.

Other Sources

Refrigerants

The County provided partial data on refrigerant purchases made by the County but did not have data available on all purchases (for example, those by contractors servicing the equipment). An inventory of refrigerant equipment was also provided.

Fugitive emission estimates from the leakage of refrigerants from HVAC and refrigeration systems are affected by the amount refrigerant purchased or refilled into equipment each year. In the absence of these data, ICF estimated fugitive emissions based on the County's inventory of equipment and standard assumptions on the charge size, refrigerant type, lifetime, and average leakage rates of the equipment using U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. ICF used these assumptions in conjunction with data on the County's HVAC and refrigeration equipment. Where not specified, ICF made assumptions about the refrigerants used based on refrigerants reportedly used in the same unit type (e.g., air handling unit). ICF's assumptions are documented in Table 13 below.

ICF assumed that emissions from refrigerants will remain constant for 2018 through 2030, assuming a consistent building stock and balance of replacing equipment that uses ozone depleting substances with the increased use of low-GWP alternatives, where feasible.

Estimates in this inventory do not include emissions from mobile air conditioning units.

Table 13: Refrigerant Distribution by Type of Unit

Unit Type	Refrigerants	Percentage
Air Handling Unit		
	HCFC-22	66%
	HFC-134a	3%
	R-404A	1%
	R-410A	31%
Chiller		
	HCFC-123	14%
	HCFC-22	34%
	HFC-134a	14%
	R-410A	38%
Condensing Unit		
	HCFC-22	59%
	R-401A	0%
	R-410A	41%
Freezer		
	HFC-134a	60%
	R-290	20%
	R-404A	60%
Furnace		
	HCFC-22	79%
	R-410A	21%
Mini Split System		

	HCFC-22	15%
	R-410A	85%
Package Unit		
	HCFC-22	36%
	R-407C	6%
	R-410A	58%
Refrigerator		
	CFC-12	11%
	HFC-134a	81%
	R-290	5%
	R-404A	3%
Watercooler		
	CFC-12	19%
	HFC-134a	81%
HPHG	R-407C	100%
Variable Refrigerant Flow System	R-404A	100%
Cooling Tower	HCFC-22	100%

Non-HFC refrigerants in this table (i.e., CFC-12, HCFC-22, HCFC-123, R-290) are not included in inventory totals per standard greenhouse gas reporting guidelines.

Emission Factors

Purchased Electricity

Table 14: Electricity Emission Factors, Planned Policies Scenario (kg/MWh)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO_2	334	325	325	317	315	306	297	294	298	299	289	288	287	286
CH_4	0.025	0.028	0.028	0.027	0.027	0.026	0.025	0.025	0.025	0.025	0.025	0.025	0.024	0.024
N_2O	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Source: eGRID 2016, eGRID 2018. Emission factors for 2019 through 2030 are projected using U.S. EIA, AEO 2020, Table 54. Electric Power Projections by Electricity Market Module Region, South Atlantic Region.

Table 15: Electricity Emission Factors, No Policies Scenario (kg/MWh)

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO_2	334	325	325	325	325	325	325	325	325	325	325	325	325	325
CH_4	0.025	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
N_2O	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004

Source: eGRID 2016, eGRID 2018.

Stationary Fuels

Table 16: Stationary Fuel Emission Factors (kg/MMBtu)

Fuel	CO_2	CH_4	N_2O
Natural Gas	53.06	0.001	0.0001
Digester Gas	52.07	0.0032	0.00063
Diesel	73.25	0.003	0.0006
Petroleum Heating Oil	73.96	0.003	0.0006
LPG	61.71	0.003	0.0006
Gasoline	70.22	0.003	0.0006
Residual Fuel Oil No. 5	72.93	0.003	0.0006
Residual Fuel Oil No. 6	75.1	0.003	0.0006
Propane	62.87	0.003	0.0006
Butane	64.77	0.003	0.0006
Jet Fuel	72.22	0.003	0.0006
Bituminous Coal	93.28	0.011	0.0016

Source: Table 1, Stationary Combustion. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Mobile Fuels

Table 17: CO_2 Emission Factors for Mobile Fuels

Other Fuels	kg CO_2 per unit	Unit
Aviation Gasoline	8.31	gallon
B100	9.45	gallon
CNG	0.05	scf
Diesel	10.21	gallon
E100	5.75	gallon
Kerosene-Type Jet Fuel	9.75	gallon
Liquefied Natural Gas (LNG)	4.50	gallon
Liquefied Petroleum Gases (LPG)	5.68	gallon
Motor Gasoline	8.78	gallon
Residual Fuel Oil	11.27	gallon
Gasoline	8.78	gallon

Source: Table 2, Mobile Combustion CO_2. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Table 18: CH_4 Emission Factors for Highway Vehicles by Model Year (g/mi)

Vehicle Type and Year	Gasoline				Diesel		
	Passenger Car	Light Truck (Vans, Pickup Trucks, SUVs)	Heavy-Duty Vehicle	Motorcycle	Passenger Car	Light Truck (Vans, Pickup Trucks, SUVs)	Heavy-Duty Vehicle
1980	0.1326	0.1594	0.4604	0.0899	0.0006	0.0011	0.0051
1981	0.0802	0.1479	0.4604	0.0899	0.0006	0.0011	0.0051
1982	0.0795	0.1442	0.4492	0.0899	0.0006	0.0011	0.0051
1983	0.0782	0.1368	0.4492	0.0899	0.0005	0.0009	0.0051
1984	0.0704	0.1294	0.4492	0.0899	0.0005	0.0009	0.0051
1985	0.0704	0.122	0.409	0.0899	0.0005	0.0009	0.0051
1986	0.0704	0.1146	0.409	0.0899	0.0005	0.0009	0.0051
1987	0.0704	0.0813	0.3675	0.0899	0.0005	0.0009	0.0051
1988	0.0704	0.0813	0.3492	0.0899	0.0005	0.0009	0.0051
1989	0.0704	0.0813	0.3492	0.0899	0.0005	0.0009	0.0051
1990	0.0704	0.0813	0.3246	0.0899	0.0005	0.0009	0.0051
1991	0.0704	0.0813	0.3246	0.0899	0.0005	0.0009	0.0051
1992	0.0704	0.0813	0.3246	0.0899	0.0005	0.0009	0.0051
1993	0.0704	0.0813	0.3246	0.0899	0.0005	0.0009	0.0051
1994	0.0617	0.0646	0.3246	0.0899	0.0005	0.0009	0.0051
1995	0.0531	0.0517	0.3246	0.0899	0.0005	0.0009	0.0051
1996	0.0434	0.0452	0.1278	0.0672	0.0005	0.001	0.0051
1997	0.0337	0.0452	0.0924	0.0672	0.0005	0.001	0.0051
1998	0.024	0.0412	0.0655	0.0672	0.0005	0.001	0.0051
1999	0.0215	0.0333	0.0648	0.0672	0.0005	0.001	0.0051
2000	0.0175	0.034	0.063	0.0672	0.0005	0.001	0.0051
2001	0.0105	0.0221	0.0577	0.0672	0.0005	0.001	0.0051
2002	0.0102	0.0242	0.0634	0.0672	0.0005	0.001	0.0051
2003	0.0095	0.0221	0.0602	0.0672	0.0005	0.001	0.0051
2004	0.0078	0.0115	0.0298	0.0672	0.0005	0.001	0.0051
2005	0.0075	0.0105	0.0297	0.0672	0.0005	0.001	0.0051
2006	0.0076	0.0108	0.0299	0.0672	0.0005	0.001	0.0051
2007	0.0072	0.0103	0.0322	0.0672	0.0302	0.029	0.0095
2008	0.0072	0.0095	0.034	0.0672	0.0302	0.029	0.0095
2009	0.0071	0.0095	0.0339	0.0672	0.0302	0.029	0.0095
2010	0.0071	0.0095	0.032	0.0672	0.0302	0.029	0.0095
2011	0.0071	0.0096	0.0304	0.0672	0.0302	0.029	0.0095
2012	0.0071	0.0096	0.0313	0.0672	0.0302	0.029	0.0095
2013	0.0071	0.0095	0.0313	0.0672	0.0302	0.029	0.0095
2014	0.0071	0.0095	0.0315	0.0672	0.0302	0.029	0.0095
2015	0.0068	0.0094	0.0332	0.0672	0.0302	0.029	0.0095
2016	0.0065	0.0091	0.0321	0.0672	0.0302	0.029	0.0095
2017	0.0054	0.0084	0.0329	0.0672	0.0302	0.029	0.0095
2018	0.0052	0.0081	0.0326	0.0672	0.0302	0.029	0.0095
2019*	*0.0052*	*0.0081*	*0.0326*	*0.0672*	*0.0302*	*0.029*	*0.0095*
2020*	*0.0052*	*0.0081*	*0.0326*	*0.0672*	*0.0302*	*0.029*	*0.0095*

Source: Table 3 and 4, Mobile Combustion CH_4. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf
*2019 and 2020 emission factors are proxied to 2018 factors.

Table 19: N_2O Emission Factors for Highway Vehicles by Model Year (g/mi)

Vehicle Type and Year	Gasoline				Diesel		
	Passenger Car	Light Truck (Vans, Pickup Trucks, SUVs)	Heavy-Duty Vehicle	Motorcycle	Passenger Car	Light Truck (Vans, Pickup Trucks, SUVs)	Heavy-Duty Vehicle
1980	0.0499	0.0555	0.0497	0.0087	0.0012	0.0017	0.0048
1981	0.0626	0.066	0.0497	0.0087	0.0012	0.0017	0.0048
1982	0.0627	0.0681	0.0538	0.0087	0.0012	0.0017	0.0048
1983	0.063	0.0722	0.0538	0.0087	0.001	0.0014	0.0048
1984	0.0647	0.0764	0.0538	0.0087	0.001	0.0014	0.0048
1985	0.0647	0.0806	0.0515	0.0087	0.001	0.0014	0.0048
1986	0.0647	0.0848	0.0515	0.0087	0.001	0.0014	0.0048
1987	0.0647	0.1035	0.0849	0.0087	0.001	0.0014	0.0048
1988	0.0647	0.1035	0.0933	0.0087	0.001	0.0014	0.0048
1989	0.0647	0.1035	0.0933	0.0087	0.001	0.0014	0.0048
1990	0.0647	0.1035	0.1142	0.0087	0.001	0.0014	0.0048
1991	0.0647	0.1035	0.1142	0.0087	0.001	0.0014	0.0048
1992	0.0647	0.1035	0.1142	0.0087	0.001	0.0014	0.0048
1993	0.0647	0.1035	0.1142	0.0087	0.001	0.0014	0.0048
1994	0.0603	0.0982	0.1142	0.0087	0.001	0.0014	0.0048
1995	0.056	0.0908	0.1142	0.0087	0.001	0.0014	0.0048
1996	0.0503	0.0871	0.168	0.0069	0.001	0.0015	0.0048
1997	0.0446	0.0871	0.1726	0.0069	0.001	0.0015	0.0048
1998	0.0389	0.0787	0.175	0.0069	0.001	0.0015	0.0048
1999	0.0355	0.0618	0.1724	0.0069	0.001	0.0015	0.0048
2000	0.0304	0.0631	0.166	0.0069	0.001	0.0015	0.0048
2001	0.0212	0.0379	0.1468	0.0069	0.001	0.0015	0.0048
2002	0.0207	0.0424	0.1673	0.0069	0.001	0.0015	0.0048
2003	0.0181	0.0373	0.1553	0.0069	0.001	0.0015	0.0048
2004	0.0085	0.0088	0.0164	0.0069	0.001	0.0015	0.0048
2005	0.0067	0.0064	0.0083	0.0069	0.001	0.0015	0.0048
2006	0.0075	0.008	0.0241	0.0069	0.001	0.0015	0.0048
2007	0.0052	0.0061	0.0015	0.0069	0.0192	0.0214	0.0431
2008	0.0049	0.0036	0.0015	0.0069	0.0192	0.0214	0.0431
2009	0.0046	0.0036	0.0015	0.0069	0.0192	0.0214	0.0431
2010	0.0046	0.0035	0.0015	0.0069	0.0192	0.0214	0.0431
2011	0.0046	0.0034	0.0015	0.0069	0.0192	0.0214	0.0431
2012	0.0046	0.0033	0.0015	0.0069	0.0192	0.0214	0.0431
2013	0.0046	0.0035	0.0015	0.0069	0.0192	0.0214	0.0431
2014	0.0046	0.0033	0.0015	0.0069	0.0192	0.0214	0.0431
2015	0.0042	0.0031	0.0021	0.0069	0.0192	0.0214	0.0431
2016	0.0038	0.0029	0.0061	0.0069	0.0192	0.0214	0.0431
2017	0.0018	0.0018	0.0084	0.0069	0.0192	0.0214	0.0431
2018	0.0016	0.0015	0.0082	0.0069	0.0192	0.0214	0.0431
2019*	*0.0016*	*0.0015*	*0.0082*	*0.0069*	*0.0192*	*0.0214*	*0.0431*
2020*	*0.0016*	*0.0015*	*0.0082*	*0.0069*	*0.0192*	*0.0214*	*0.0431*

Source: Table 3 and 4, Mobile Combustion N_2O. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories.
*2019 and 2020 emission factors are proxied to 2018 factors. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Table 20: CH_4 Emissions for Other Vehicles (g/gallon fuel)

Vehicle Types	Gasoline	Diesel	Residual Fuel	Jet Fuel	Aviation Gasoline	LPG
Agricultural Equipment	7.24	0.28				2.19
Construction Equipment	5.58	0.2				1.05
Lawn and Garden Equipment	5.84	0.33				0.35
Utility and Recreational Equipment	8.45	0.41				2.98
Aircraft				0	7.06	
Ships and Boats	4.88	0.31	0.55			
Locomotives		0.8				

Source: Table 5, Mobile Combustion for Non-Road Vehicles. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Table 21: N_2O Emissions for Other Vehicles (g/gallon fuel)

Vehicle Types	Gasoline	Diesel	Residual Fuel	Jet Fuel	Aviation Gasoline	LPG
Agricultural Equipment	0.21	0.49				0.39
Construction Equipment	0.2	0.47				0.41
Lawn and Garden Equipment	0.18	0.47				0.41
Utility and Recreational Equipment	0.19	0.41				0.38
Aircraft				0.3	0.11	
Ships and Boats	0.23	0.5	0.55			
Locomotives		0.26				

Source: Table 5, Mobile Combustion for Non-Road Vehicles. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Employee Commuting

Table 22: Emission Factors for Employee Commuting

Vehicle Type	CO_2 Factor (kg / unit)	CH_4 Factor (g / unit)	N_2O Factor (g / unit)	Units
Passenger Car	0.335	0.009	0.008	vehicle-mile
Light-Duty Truck	0.461	0.012	0.010	vehicle-mile
Motorcycle	0.184	0.070	0.007	vehicle-mile
Intercity Rail (i.e., Amtrak) Northeast Corridor	0.058	0.0055	0.0007	passenger-mile
Commuter Rail	0.148	0.0123	0.0030	passenger-mile
Transit Rail (i.e., Subway, Tram)	0.099	0.0089	0.0013	passenger-mile
Bus	0.053	0.0206	0.0009	passenger-mile

Source: Table 10, Employee Commuting. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf

Waste

Table 23: CH_4 Emission Factor from EPA's LandGEM

	MT CH_4/MMSCF
CH_4 Emissions per Amount of Landfill Gas Collected	19.125

Source: EPA LandGEM

Table 24: Incinerated Waste Emission Factor

Wheelabrator Facility Data	2017	2018
Emissions ($MTCO_2e$)	270,731	266,968
Waste incinerated (short tons)	709,904	693,146
2017-2018 Average emissions per metric ton of waste incinerated ($MTCO_2e$/metric ton)		0.42

Source: EPA's GHGRP for Wheelabrator. https://ghgdata.epa.gov
Table 11. Maryland Solid Waste Management and Diversion Reports. https://mde.maryland.gov/programs/land/pages/landpublications.aspx. Waste incinerated tonnage data for Wheelabrator are not yet available for 2019.

Table 25: Alternative Waste Combustion Emission Factors

Waste Type	Combustion Emission Factor ($MTCO_2e$/metric ton)
Corrugated Containers	0.03
Office Paper	0.03
Newspaper	0.03
Mixed Paper (general)	0.03
Mixed Metals	0.00
PP	3.06
PET	2.24
Mixed Plastics	2.56
LLDPE	3.06
Food Waste	0.03
Yard Trimmings	0.03
Wood flooring	0.07
Mixed Electronics	0.94
Mixed MSW (municipal solid waste)	0.45
Weighted combustion emission factor based on Baltimore County waste characterization	**0.60**

Source: Table 9. U.S. EPA Center for Corporate Climate Leadership Emission Factors for Greenhouse Gas Inventories. Based on WARM Version 15, without avoided emissions impact and adjusted to exclude transport to landfill emissions. https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf
Combustion emissions include combustion-related non-biogenic CO_2 and N_2O.

Appendix B - Global Warming Potentials

This inventory uses GWPs from IPCC's Fourth Assessment Report (AR4) for consistency with other regional inventories. This appendix presents emissions using GWPs from the IPCC's Fifth Assessment Report (AR5) in Table 27 for informational purposes.

Table 26: Global Warming Potential for Gases Used in this Inventory

Chemical Formula	100-year GWP (AR4)	100-year GWP (AR5)
CO_2	1	1
CH_4	25	28
N_2O	298	265
HFC-134a	1,430	1,300
R-401a	20	18
R-404a	3,922	3,943
R-407c	1,774	1,624
R-410a	2,088	1,924

*Note that non-HFC gases (i.e., CFC-12, HCFC-22, HCFC-123, R-290) are not included in inventory totals per standard greenhouse gas reporting guidelines.

Table 27: Projected GHG Emissions by Source, 2017 through 2030, using AR5 Global Warming Potentials (MT CO_2e)

Sector and Source	2017	2020	2025	2030
Energy	**64,921**	**61,266**	**62,521**	**61,386**
Stationary Fuels	25,799	25,699	26,003	26,160
Purchased Electricity	39,122	35,567	36,519	35,225
Transportation	**48,258**	**40,901**	**52,768**	**53,092**
On-Road Vehicles	29,205	29,715	30,066	30,249
Off-Road Equipment	1,390	1,414	1,433	1,445
Employee Commuting	17,662	9,772	21,269	21,399
Waste	**56,705**	**74,698**	**86,078**	**91,219**
Landfilled Waste	56,705	74,698	86,078	91,219
Other	**1,385**	**1,385**	**1,385**	**1,385**
Refrigerants	1,385	1,385	1,385	1,385
Total	**171,268**	**178,250**	**202,752**	**207,081**