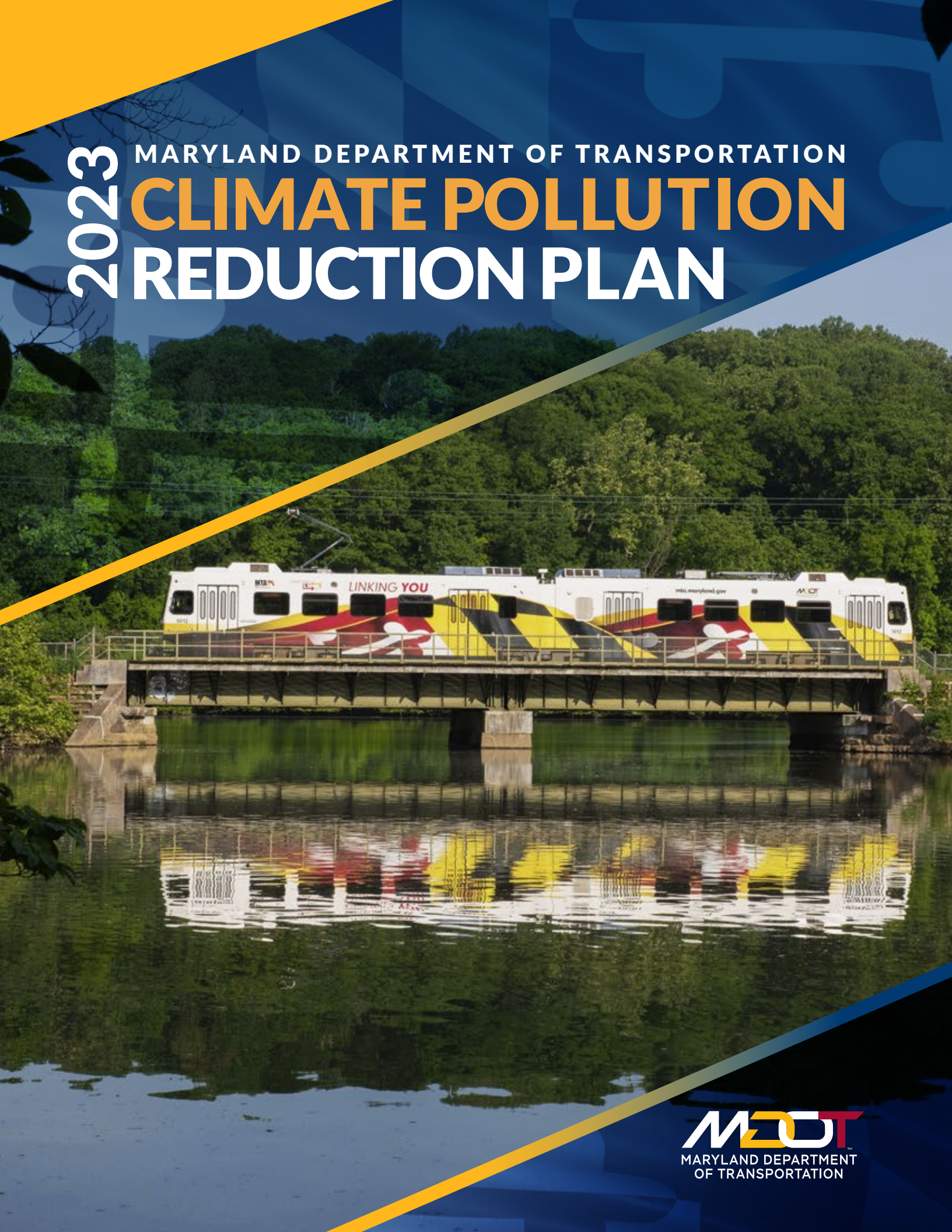
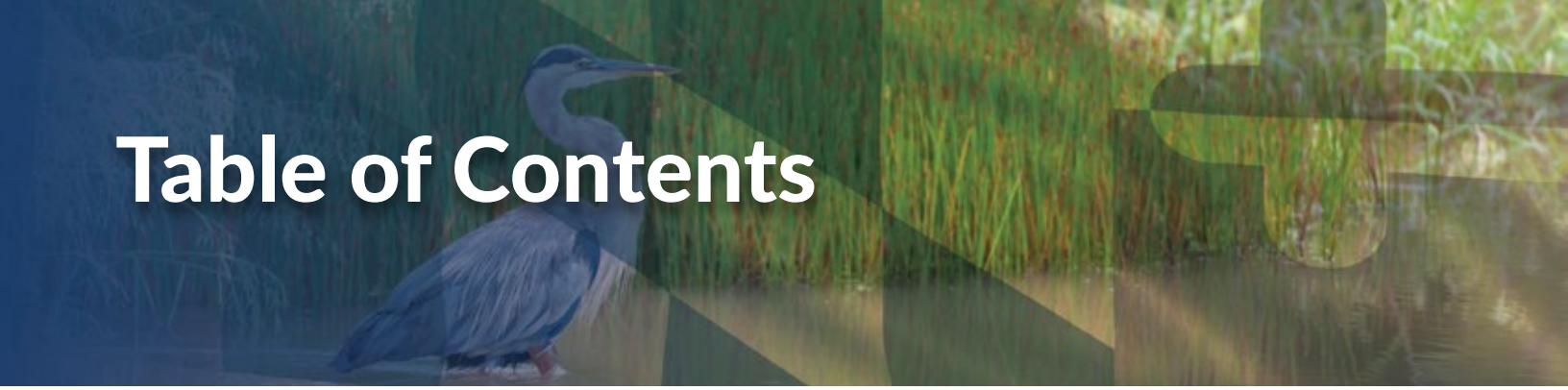
2023

MARYLAND DEPARTMENT OF TRANSPORTATION

CLIMATE POLLUTION REDUCTION PLAN



MDOT
MARYLAND DEPARTMENT OF TRANSPORTATION



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Executive Summary

The Maryland Department of Transportation (MDOT) Climate Pollution Reduction Plan ("the plan" or "this plan", hereafter) presents MDOT's approach to support the requirements of the Climate Solutions Now Act of 2022 (CSNA). The CSNA requires the Maryland Department of the Environment (MDE) to submit a plan that reduces statewide greenhouse gas (GHG) emissions by 60% from 2006 levels by 2031 ("60 by 31"). MDOT collaborated with MDE, other agencies and partners to develop sector-specific strategies to reduce transportation emissions in furtherance of this goal. This plan represents the outcome of those efforts.

The 2020 statewide emissions inventory[a] developed by MDE shows that transportation is the single largest GHG emissions generator in Maryland, representing 35% of total GHG emissions.

Constrained transportation revenues relative to needs create a major challenge for reducing emissions from the transportation sector. This analysis demonstrates how accounting for these challenges and by harnessing new opportunities, it is possible for Maryland's transportation sector to support meeting the statewide CSNA goal.

This analysis considers emission reduction outcomes from projected trendlines and effective implementation of current policies as well as a potential new initiatives scenario. It relies heavily on the Consolidated Transportation Program (CTP), and Maryland's two major Metropolitan Planning Organizations' (MPO) plans and programs (Baltimore and Washington D.C. regions), and is guided by the 2050 Maryland Transportation Plan (MTP).

Thanks to previous trends, laws and regulations, as well as policies enacted or promulgated in the 2020s, in this plan MDOT reports projected on-road transportation sector carbon emission reductions of **41.9%** by 2031. Further, reductions of 49% or more are possible, though they will require substantial shifts in currently programmed and planned investments as well as additional funding.

Achieving the projected emission reductions requires alignment and successful implementation of innovative and cost-effective approaches and the combination of these approaches. Enabling equitable access to technology will ensure that the benefits reach disadvantaged communities. This will advance and amplify the reach and impacts of decarbonization investments and support an improved quality of life for all Marylanders.

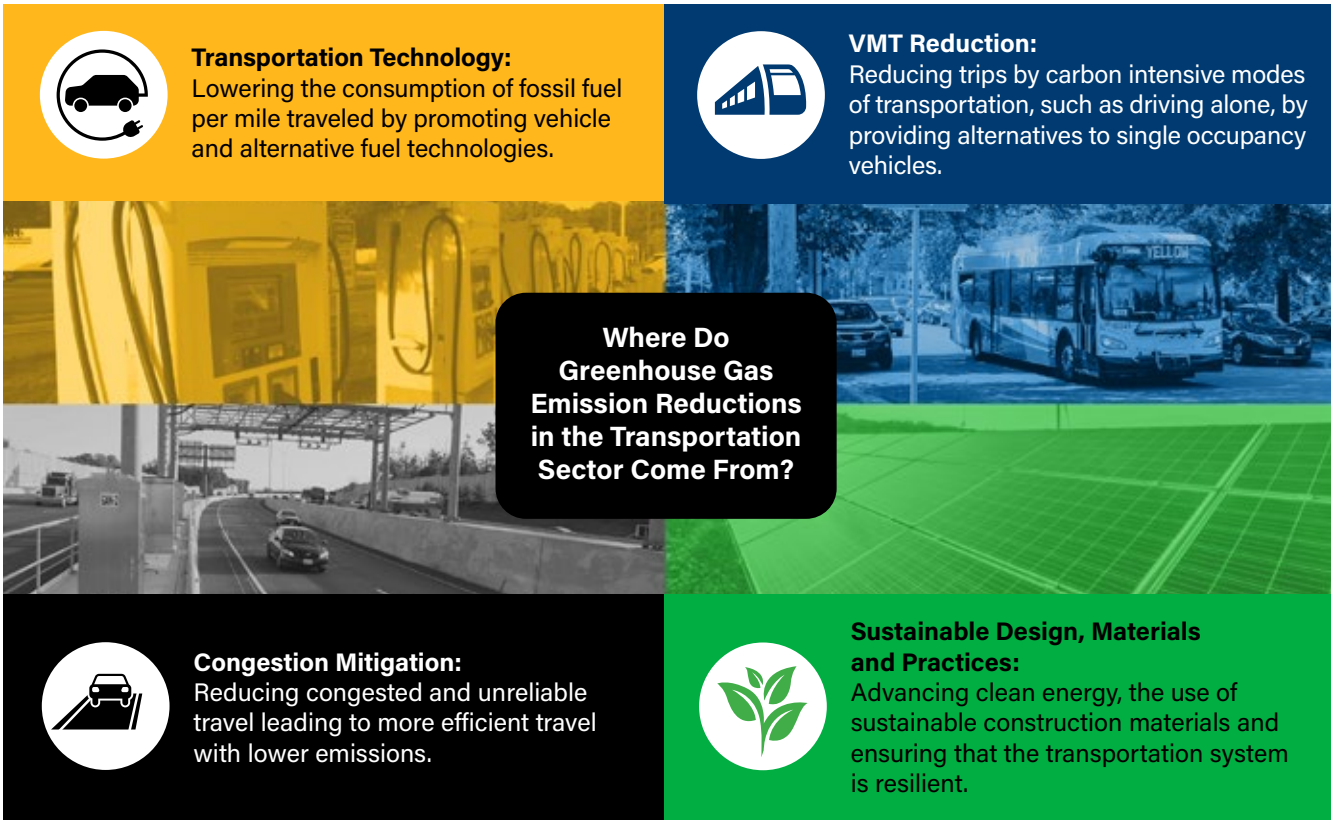
MDOT is developing its family of plans with an increased emphasis on decarbonization and climate change mitigation and is positioning itself and the state to invest in the state's transition to low-emissions development pathways.

MDOT takes a comprehensive approach to reducing emissions in the transportation sector, which is supported by four pillars of emission reductions (**Figure ES 1**).

[a] Greenhouse Gas Inventory, Maryland Department of Environment, https://mde.maryland.gov/programs/air/climatechange/pages/greenhousegasinventory.aspx

These pillars lead to the identification, selection and implementation of a range of strategies to reduce emissions through the adoption of transportation technologies, improving system resiliency and efficiency, reducing Vehicle Miles Traveled (VMT), mitigating congestion, and through sustainable design, infrastructure, and practices. We will execute these strategies while also ensuring that transportation infrastructure is resilient to the impacts of a changing climate.

Figure ES 1. GHG Emission Reductions Strategies



The 2006 Baseline Inventory established the benchmark for the GHG reduction goals in the CSNA (60% by 2031). The on-road portion of the transportation emissions inventory represents a "bottom-up" approach to estimating statewide GHG emissions based on measurements of roadway congestion levels, traffic volumes and vehicle fleet data. GHG emission estimates for on-road transportation reflect an alignment with actual conditions based upon the process for developing the U.S. Environmental Protection Agency's (EPA) National Emissions Inventory (NEI). Off-road transportation strategies and scenarios are developed and analyzed through a partnership approach between MDOT and MDE. MDOT continues to refine its off-road inventory and strategies (some of which are qualitatively included in this plan) to demonstrate a strong commitment to emission reductions in the transportation sector.

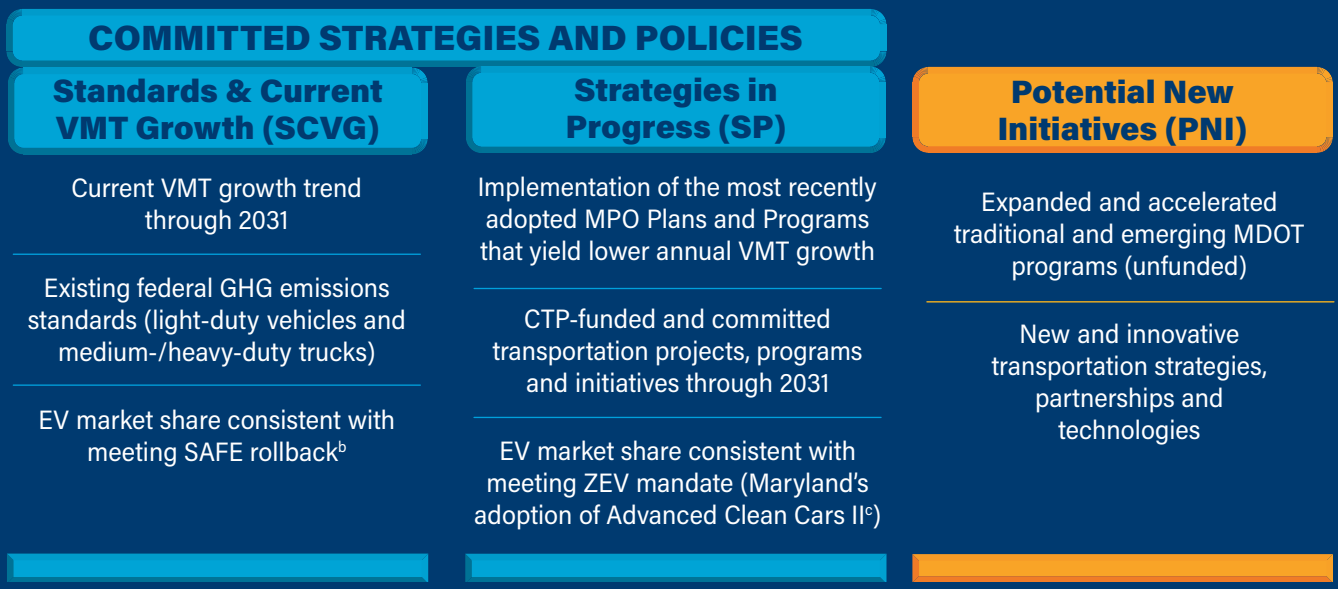
Analyzing the Emission Reductions Strategies

We begin by estimating the potential impacts of fuel economy standards and strategies on GHG emissions in the transportation sector. The purpose of this exercise is to categorize various policies and strategies that are currently on the books. (**Figure ES 2**). We do this in two steps: First, the **Standards and Current VMT Growth**

(SCVG) considers GHG trends based on reported VMT and a forecast of VMT through 2031.

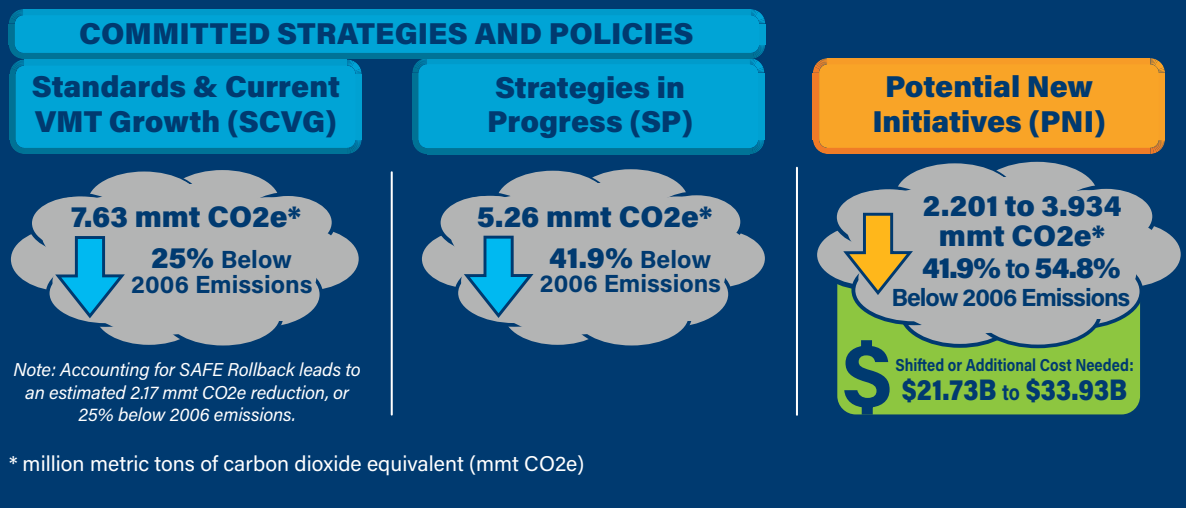
Second, **Strategies in Progress (SP)** extends the current policy and program framework within SCVG, including funded plans, projects and programs. We then built a scenario of **Potential New Initiatives (PNI)** including new programs and policies beyond SCVG and SP with strategies that are not currently funded or that may require technological maturity, market parity and evolution of travel behaviors before full implementation.

Figure ES 2. 2031 Scenarios and Strategies Approach



The results of emission reductions and costs associated with each modeled scenario are presented in **Figure ES 3**.

Figure ES 3. Summary of Emission Reductions

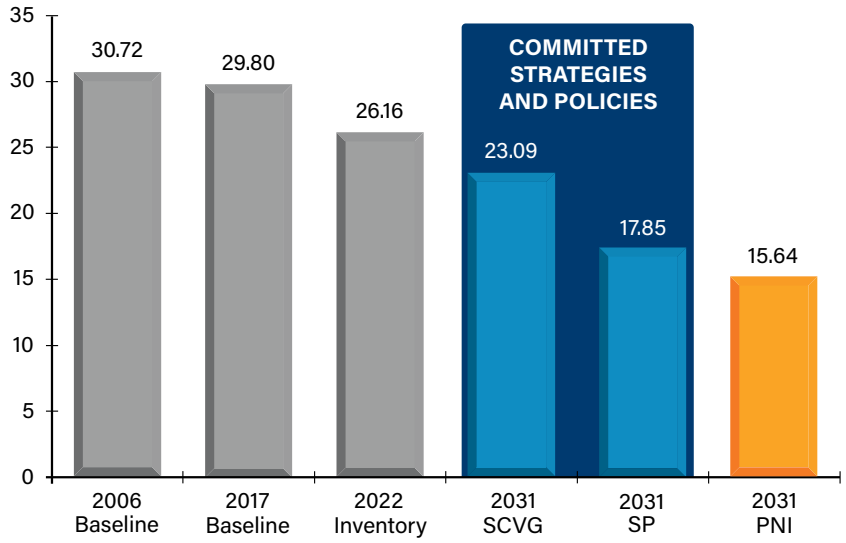


* million metric tons of carbon dioxide equivalent (mmt CO2e)

[b] SAFE rollback refers to the rollback of the SAFE Vehicles Rule, which was scheduled to increase carbon emissions standards for the nation's automakers by only 1.5% a year through model year 2026.

[c] The Advanced Clean Cars II (ACC II) regulations will rapidly scale down light-duty passenger car, pickup truck and SUV emissions starting with the 2027 model year through 2035 by limiting the number of passenger motor vehicles with an internal combustion engine that can be sold in the state of Maryland.

Figure ES 4. GHG Emission Reductions Strategy Outcomes



The modeling construct and the details of the strategy estimation also provide the emission reduction potential, cost and cost-effectiveness of each strategy considered. The ease of strategy deployment and MDOT's role as the facilitator of change, combined with the cost-effectiveness of the individual strategy, could support investment in emerging and innovative projects as additional funding becomes available. The transportation sector is complex and includes many public and private decisions on investment and priorities.

This plan also outlines the transportation sector's potential contributions to achieving net-zero GHG emissions statewide by 2045. A detailed plan for achieving net-zero emissions will be developed in the future. However, this plan includes a discussion of opportunities, challenges and uncertainty surrounding the longer-term projection and modeling.

This plan highlights the significant emission reductions Maryland's transportation sector has achieved since 2006 and identifies opportunities to expand and establish new reduction strategies. This plan shows that the path to "60 by 31" for the transportation sector hinges on several factors and implementation challenges and uncertainties. It acknowledges MDOT's role in shaping the response to climate change through policies, programs and investments within its direct control. The plan further recognizes opportunities where MDOT can leverage its more limited control or influence over strategies driven by market forces, economic futures, technological advances or jurisdictional decisions, such as land use. Within these limitations, MDOT's approach takes a careful, fact and research-driven approach to gauge what is realistic by 2031 and assesses transportation emission reductions. Given the transportation sector's vital role in maintaining and enhancing the economic prosperity of Maryland's citizens, balanced by its contribution as the single largest emissions generating sector, a firm commitment from the state to fulfilling the transportation sector's resource and implementation challenges will enable the state to meet the statewide CSNA goals.

The strategies presented as part of this plan will deliver multiple benefits beyond emission reductions. For example, investments in transit, bicycle and pedestrian infrastructure reduce VMT while also improving public health, increasing access to jobs and other necessities, and reducing pedestrian and bicyclist injuries and deaths. Such benefits are especially important and valuable for historically overburdened communities.

1.0 Background and Context

The Maryland Department of Transportation (MDOT) Climate Pollution Reduction Plan ("the plan" or "this plan", hereafter) presents MDOT's blueprint for reducing Greenhouse Gas (GHG) emissions from the transportation sector to support achieving the statewide targets set out by the Climate Solutions Now Act of 2022 (CSNA).

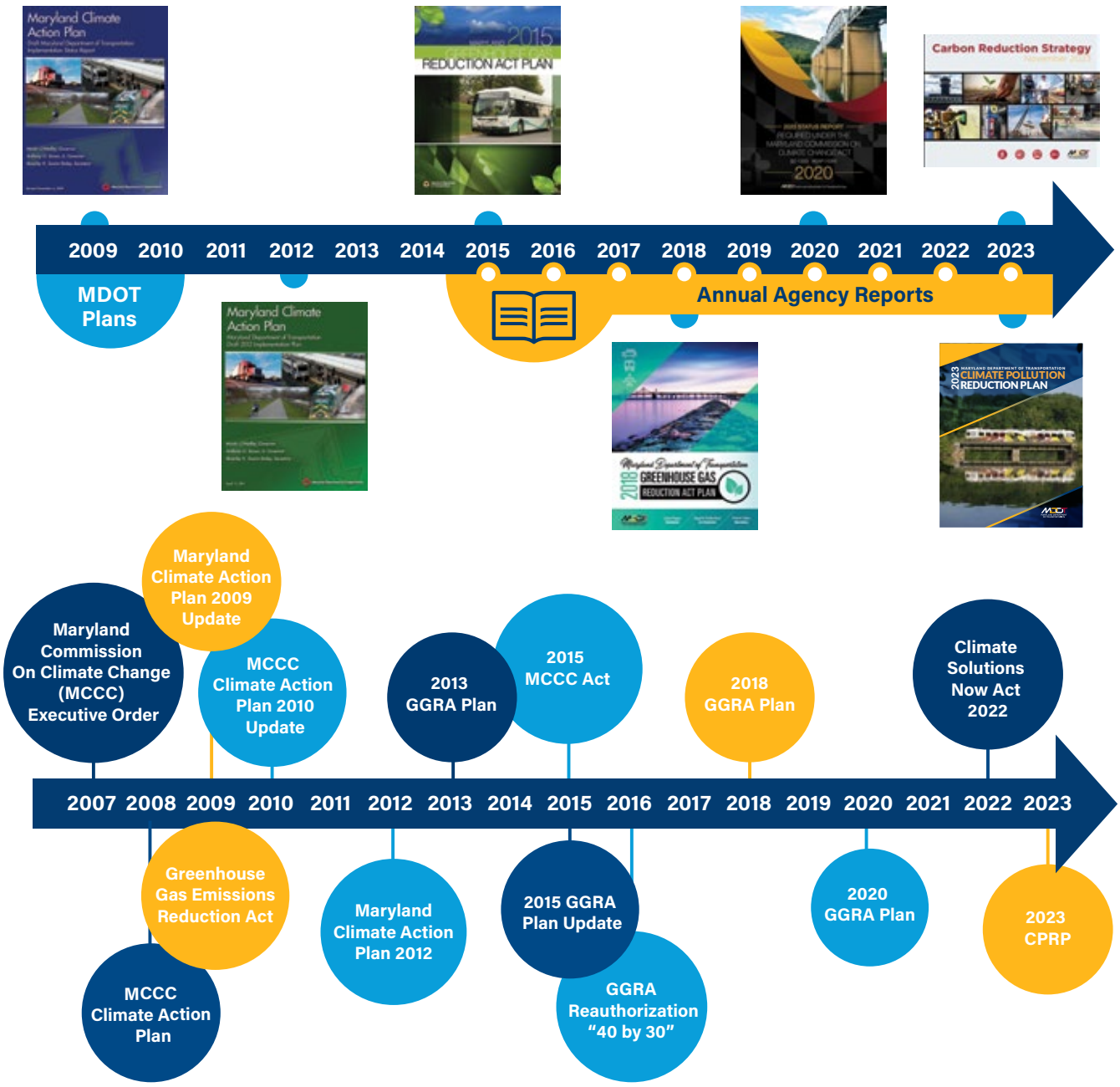
This plan provides details on potential emission reductions, co-benefits, implementation considerations and costs for a diverse and comprehensive set of strategies and scenarios developed in coordination with the Maryland Department of the Environment (MDE), other state agencies, and regional and local partners.

1.1 Climate Pollution Reduction Plan and Maryland Commission on Climate Change

In 2022, Maryland adopted an ambitious climate change law, the CSNA, which aims to reduce statewide GHG emissions by 60% by 2031 (compared to the 2006 baseline) and achieve net-zero emissions by 2045. While the CSNA does not establish sector specific reduction targets, this plan represents MDOT's approach toward achieving the statewide 2031 goal.

The Maryland Commission on Climate Change (MCCC) works with other state agencies, elected officials and experts who advise the Governor and General Assembly "on ways to mitigate the causes of, prepare for, and adapt to the consequences of climate change." An overview of the history, showing MDOT's ongoing role in supporting the activities of the MCCC, is highlighted in **Figure 1**.

Figure 1. MDOT's Contribution to Climate Change Planning in Maryland



1.2 Purpose of the Plan

This plan presents strategies and scenarios for the decarbonization of Maryland's transportation sector and also identifies the anticipated benefits of MDOT strategies to support the statewide "60 by 31" goal. The three main purposes of the plan are to:

- Discuss broad trends and projections impacting Vehicle Miles Traveled (VMT), vehicle technology and fuel use, as well as associated emission outcomes;
- Identify specific actions for realizing emission reductions, including potential costs involved, associated benefits and co-benefits; and
- Assess the transportation sector's contribution to the overall statewide 2031 emission reduction goal.

1.3 CSNA Requirements

Under the 2009 Greenhouse Gas Reduction Act (GGRA) (reauthorized in 2016), the state called for 40% GHG emission reductions by 2030. According to the 2022 progress report by MDE, the state achieved a 30% reduction in GHG (from 2006 levels) in 2020 and is on track to achieve a 40% reduction by 2030. The 2022 CSNA updated the objectives of the statewide Plan to achieving a 60% GHG reduction (from 2006 levels) by 2031 and net-zero emissions by 2045.

The CSNA includes several requirements for GHG reduction, including some that are specific to the transportation sector. The CSNA aims to reduce GHG emissions by transitioning the state fleet to zero-emission vehicles (ZEVs) or electric vehicles (EVs). The CSNA also requires all passenger cars purchased for the state fleet to be ZEVs by 2031, all light-duty vehicles purchased for the state fleet to be ZEVs by 2036 and all new contracts for the purchase or use of a school bus to be ZEVs, starting in 2025.

1.4 MDOT Mission, Vision, Goals & Guiding Principles

MDOT's approach to decarbonization is informed and guided by its plans and programs. Among them is the Maryland Transportation Plan (MTP), or the Playbook, which establishes a 20-year vision for multimodal transportation and outlines the state's transportation policies and priorities to proactively address a range of shifts that could potentially impact transportation demand. The MTP is then implemented through the six-year capital program and operating budgets, which are produced together annually as the Consolidated Transportation Program (CTP). The MDOT mission statement included in the MTP is:

MARYLAND DEPARTMENT OF TRANSPORTATION

"The Maryland Department of Transportation is a customer-driven leader that delivers safe, sustainable, intelligent, exceptional, and inclusive transportation solutions in order to connect our customers to life's opportunities."

The 2050 MTP establishes five guiding principles o guide MDOT's decision making to support the goals.

1. **Equity:** Integrate equity considerations in all aspects of transportation planning, programming and operational processes.
2. **Preservation:** Preserve the condition of the existing transportation system assets to provide safe and efficient movement.
3. **Resilience:** Improve the transportation system's ability to provide reliable service throughout natural weather events and man-made threats.
4. **Modernization:** Transform the transportation system by using proven technological improvements and exploring innovative new ideas.
5. **Experience:** Improve the experience of all transportation system users.

MDOT establishes the following goals in the 2050 MTP, which guides the vision for the transportation system in Maryland:

- **Enhance Safety and Security:** Protect the safety and security of all residents, workers and visitors.
- **Deliver System Quality:** Deliver a reliable, high-quality, integrated transportation system.
- **Serve Communities and Support the Economy:** Expand transportation options to allow Maryland's diverse communities to access opportunities and to support the movement of goods.
- **Promote Environmental Stewardship:** Minimize and mitigate the environmental effects of transportation.

However, the applicability of MDOT's goals is often limited by the extent of its jurisdiction and authority. The role of MDOT in addressing the different decarbonization initiatives varies significantly. In some aspects where the initiative is within MDOT's direct control, the agency's role extends through the implementation stage of the initiative. Other programs where MDOT has limited control would typically involve partnership with or support of another public agency or private partner. Here, MDOT's role is limited to coordinating with other partners and responsible agencies to work towards a common goal. Finally, there are innovations and developments in the private sector that can advance the decarbonization of transportation. Although MDOT has no direct control over the development of these initiatives identified in this Plan it can create and put in place policies that foster and facilitate private sector innovation.

1.5 Equity in Transportation

Overburdened and underserved communities are more likely to be impacted by negative health outcomes. These communities often have higher rates of fatalities and serious injuries due to lack of sufficient safety facilities such as sidewalks, bike lanes and crosswalks within their neighborhoods. These same neighborhoods may also be located close to highways and other high volume roadways and therefore suffer from acute air pollution from tailpipe emissions. The 2023, Equity in Transportation Sector - Guidelines and Analysis Act, requires MDOT to consider ways to achieve equity in the transportation sector when developing the state transportation plans, reports and goals.

MDOT is committed to equity in its transportation systems, policies and initiatives for all communities, especially those who have been historically marginalized or underserved. The CSNA includes provisions to reduce negative environmental impacts on overburdened and underserved communities. For example, the CSNA established the Climate Catalytic Capital Fund to support projects such as the electrification of the transportation sector and the use of sustainable alternative fuels. Reducing VMT from GHG emitting vehicles will reduce the release of other harmful pollutants from internal combustion engines, such as particulate matter, volatile organic compounds, nitrogen oxides and sulfur dioxide. These pollutants cause negative health effects that disproportionately impact underserved communities and also certain vulnerable populations, such as children and older adults. Thus, reducing VMT and improving vehicle technology will also deliver localized co-benefits to

these communities and populations, including reduced congestion and local air pollutants that harm public health.

Investing in low-emissions travel modes, especially in overburdened and underserved communities will provide more travel choices for such communities who are likely to not own a personal vehicle.

Equity in Transportation

1.6 Resilient Transportation

While mitigating the severity and extent of environmental impacts and climate change are the primary goals of the CSNA, developing infrastructure that is resilient to future weather events is vital. Environmental mitigation strategies are only effective when they are resilient to climate change impacts that we are already witnessing. Future infrastructure decisions should also consider the potential impact of climate change on transportation assets and investments.

Maryland has been a leader in integrating resilience measures and adaptability into agency processes. The state identifies existing vulnerabilities in the system, invests in targeted resilience building activities, coordinates with its partners and stakeholders in responding to the challenges and communicates the potential risks and benefits of such action to its users.

MDOT is also preparing a resilience improvement plan. Under the federal Promoting Resilient

Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT) program of the Infrastructure Investment and Jobs Act (IIJA), it is a voluntary opportunity for comprehensive resiliency planning. The resilience improvement plan will help to establish a system-wide approach to transportation resilience, including assessing vulnerabilities of transportation assets to current and future natural hazards.

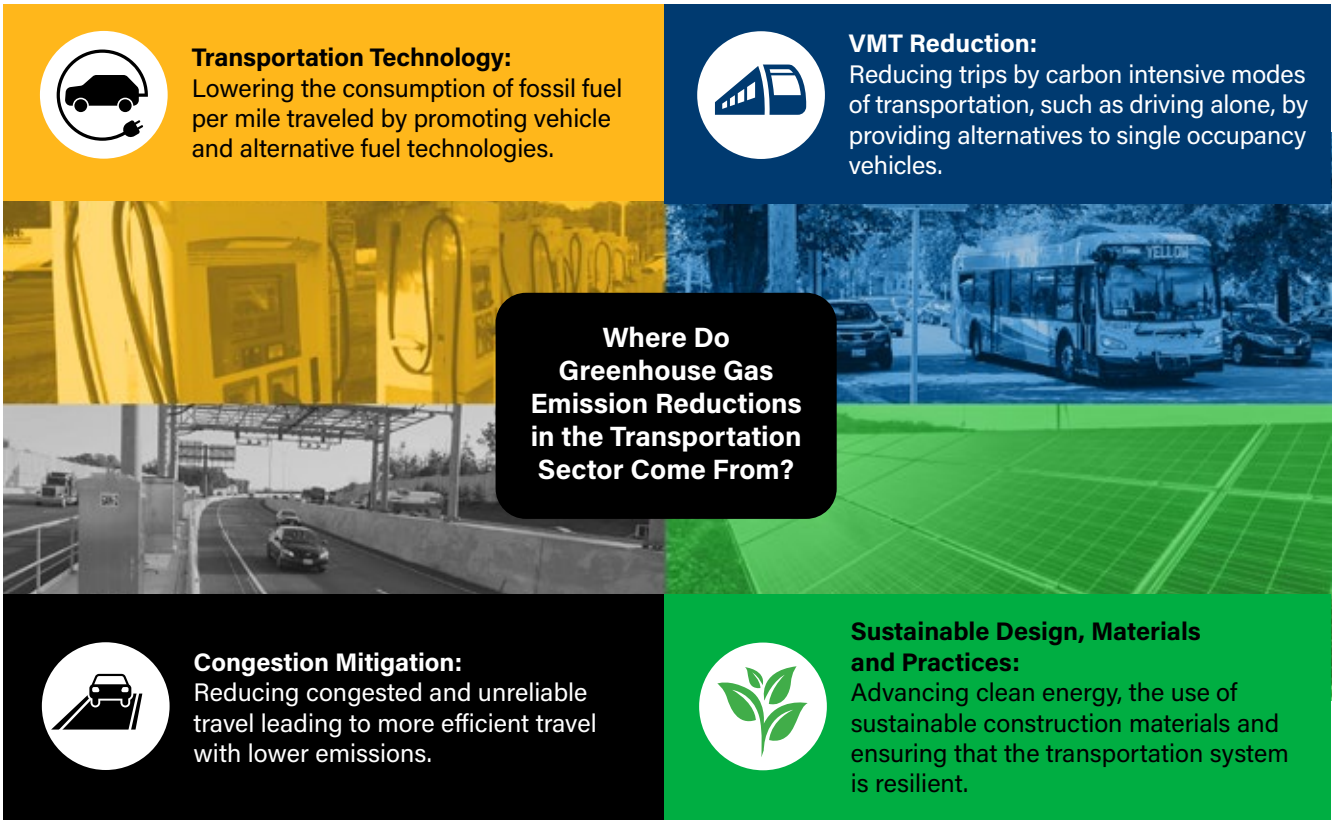
Climate change adaptation and resilience are built into MDOT's 2050 MTP, which is reflected in the guiding principle of resiliency, which is described as improving the transportation system's ability to provide reliable service throughout natural weather events and man-made threats.

1.7 Recent and Ongoing Transportation Actions

MDOT, through annual status reports to the Governor's Office and General Assembly, provides a review of recent, ongoing and planned activities aimed towards mitigating the impacts of climate change and reducing transportation sector GHG emissions.

MDOT continues to take a comprehensive approach to GHG emission reductions, which rests on the four pillars of emission reductions, seen in **Figure 2**, and forms its GHG mitigation strategy that covers a wide range of emission reductions approaches and methods in supporting GHG mitigation in the transportation sector.

Figure 2. GHG Emission Reductions Strategies



2.0 2031 Committed Strategies and Policies

2.1 Background

Emission reductions strategies and scenarios in this modeling process pivot from the 2006 baseline GHG emissions inventory. The 2006 baseline inventory established the base conditions for the CSNA's GHG reduction goals for this plan (60% by 2031) and previous GGRA reduction goals (25% by 2020 and 40% by 2030). MDOT coordinated with MDE to establish scenario methodologies and strategy assumptions that are consistent with the MCCC's Mitigation Working Group and this plan. These all begin with a 2022 starting point of GHG emissions that is 15% lower, or 4.56 million metric tons (mmt) of carbon dioxide equivalent (CO2e), than the 2006 baseline transportation sector emissions. These frameworks of strategies and assumptions are:

2031 Committed strategies and policies: This represents emission reductions based on GHG trends and VMT forecasts for 2031, and additional measures that MDOT has already committed to with plans, programs and business-as-usual investment levels and funding allocations. They can be explained as two parts: Standards and Current VMT Growth (SCVG) and Strategies in Progress (SP).

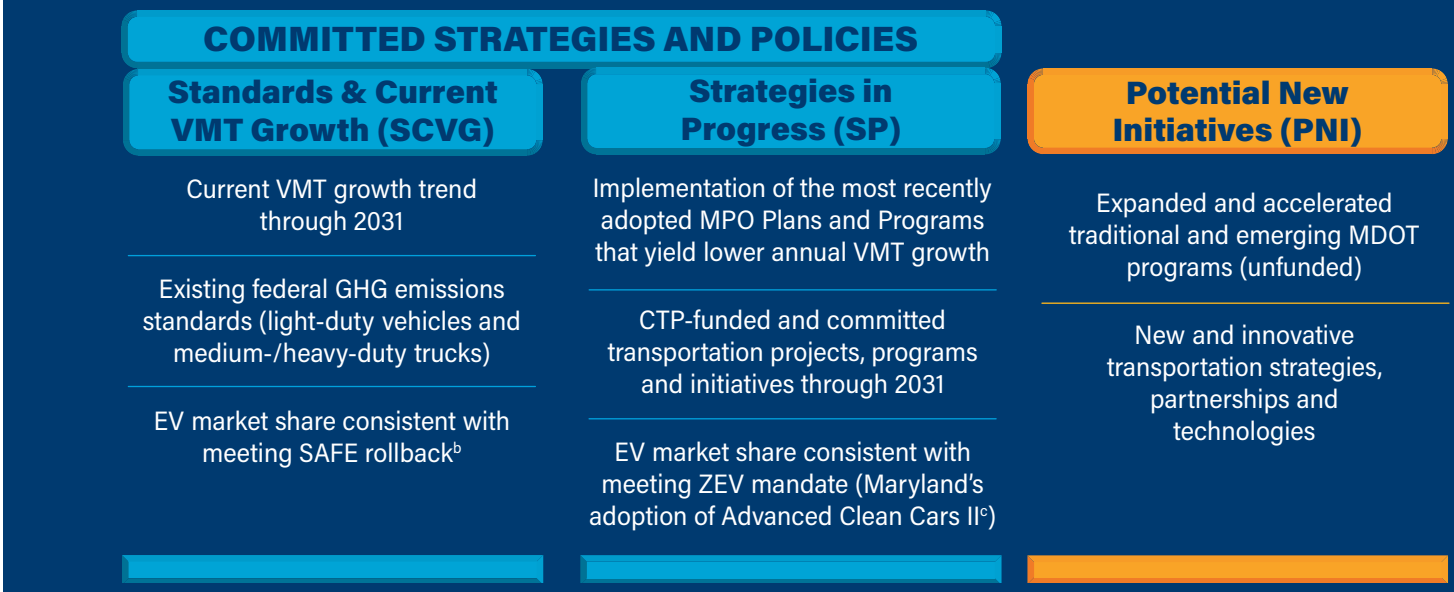
SCVG: Federal and state fuel economy and vehicle technology standards such as the Corporate Average Fuel Economy (CAFE) and rollback of the Safer Affordable Fuel-Efficient (SAFE) rule that are projected to decrease on-road emissions below the 2022 starting point by 2031.

SP: These reductions can be attributed to the implementation and continuation of strategies that reduce VMT growth, improve transportation system performance and increase sales of ZEVs in the state of Maryland. These strategies have documented funding availability, primarily through the CTP, or are mandates that original equipment manufacturers are expected to follow.

Potential New Initiatives (PNI): These are new programs and policies that could deepen emission reductions through increased funding for existing strategies and consideration of new and innovative transportation strategies, partnerships and technologies. Some of the innovative policies will require a demonstration of their viability and technological maturity for their wider adoption. All of these new initiatives are currently unfunded.

Figure 3 depicts the overall modeling strategy and high-level definitions for this scenario approach focused on the on-road transportation sector. **Appendix B** lists each GHG mitigation strategy evaluated under SP and PNI with strategy descriptions, underlying assumptions and coordination needed to achieve the emission reductions.

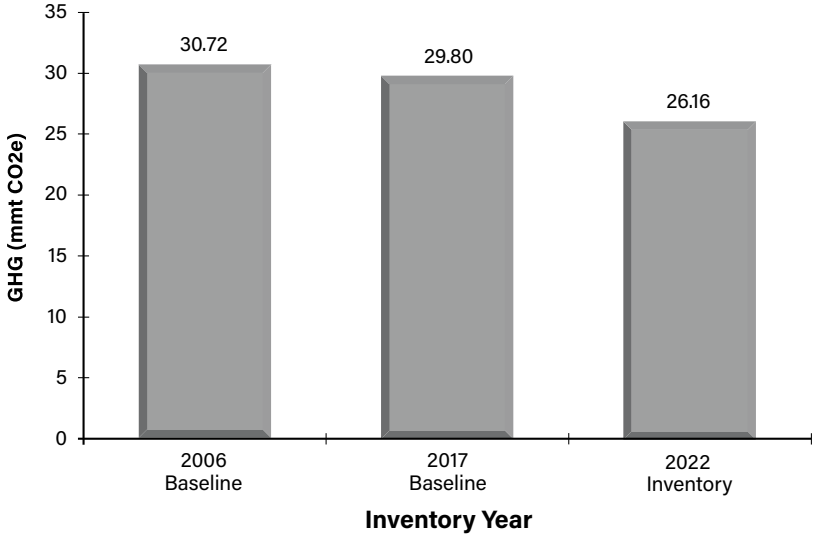
Figure 3. 2031 Scenarios and Strategies Approach



2.2 2022 Starting Point

The 2022 Starting Point begins with modeling the GHG trends for Maryland statewide. The GHG emission estimates for on-road sources for 2006, 2017 and 2022 are shown in **Figure 4**, and reflect the actual traffic conditions. These conditions are based on the MDE National Emissions Inventory (NEI) submittals, the vehicle technology standards in place for each inventory, roadway segment vehicle counts and speed data reported by State Highway Administration (SHA) through the Highway Performance Monitoring System (HPMS). The inventories also include the federal vehicle technology, emissions standards and Maryland's EV market share in 2022. The results show a 15% reduction in GHG emissions in 2022 from the 2006 Baseline.

Figure 4. Maryland Statewide Transportation GHG Trends from 2006 to 2022



[b] SAFE rollback refers to the rollback of the SAFE Vehicles Rule, which was scheduled to increase carbon emissions standards for the nation's automakers by only 1.5% a year through model year 2026.

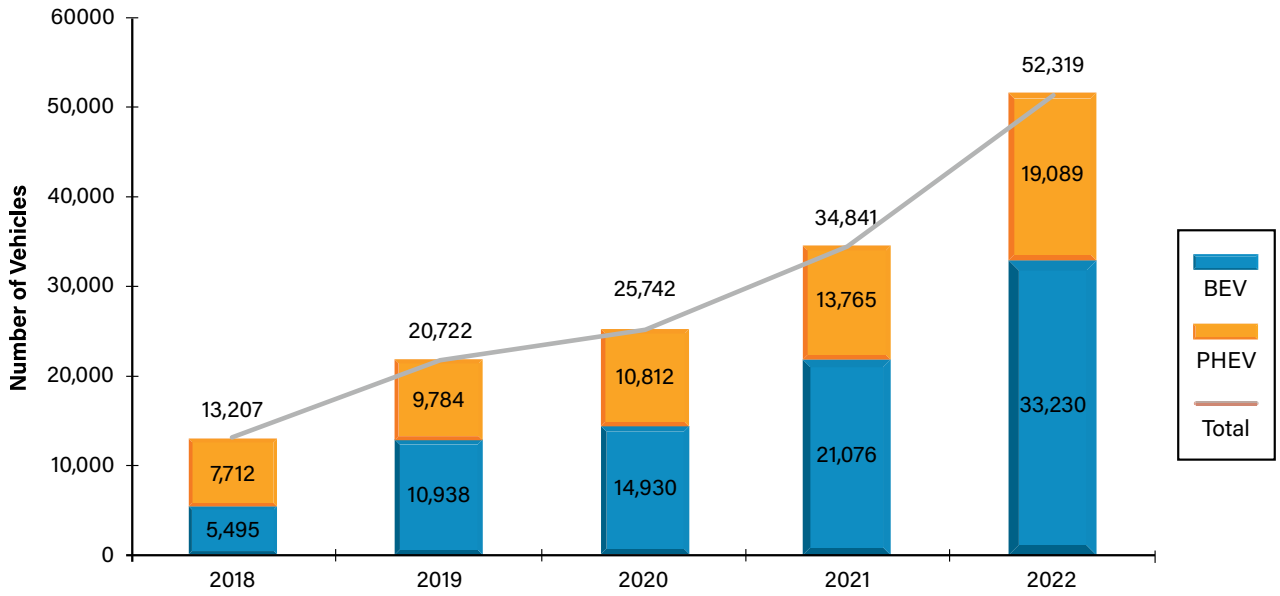
[c] The Advanced Clean Cars II (ACC II) regulations will rapidly scale down light-duty passenger car, pickup truck and SUV emissions starting with the 2027 model year through 2035 by limiting the number of passenger motor vehicles with an internal combustion engine that can be sold in the state of Maryland.

2.2.1 Progress of Electric Vehicles or Adoption of Electric Vehicles

MDOT has been a leader in promoting adoption of EVs by communicating the benefits of EVs, education about charging options and charging locations throughout the state, and encouraging the adoption of EVs among Maryland residents. Under MDOT's Leadership, the Zero Emission Electric Vehicle Infrastructure Council (ZEEVIC) is dedicated to accelerating the adoption of EVs and expanding EV infrastructure to support EVs. MDOT developed and launched the EV Charger Siting Tool to assist potential applications to the National Electric Vehicle Infrastructure (NEVI) and Charging and Fueling Infrastructure (CFI) programs. The interactive tool consolidates data from a variety of state and federal agencies to help determine whether a site would be a good candidate for grant funding.

Maryland's market share of new car sale purchases of Battery Electric Vehicles (BEVs) and Plug-in Hybrids Electric Vehicles (PHEVs) continues to increase with over 52,000 vehicles in 2022. Consumers are taking advantage of the amended Maryland EV Tax Credit incentive, which allows buyers to claim a state tax credit up to $3,000 for their purchase of a new EV. MDOT completed the Maryland NEVI Plan that outlines the approach for deploying charging infrastructure and achieving the goals of the federal NEVI Program.

Figure 5. Total Electric Vehicles Registered In Maryland



Maryland has established 23 Electric Vehicle Alternative Fuel Corridors (EV-AFC) as part of the national AFC program. EV drivers can find publicly accessible EV charging stations in close proximity to EV-AFCs. In 2022, there were more than 1,400 publicly accessible charging stations in Maryland with more than 3,900 charging ports. About 20% of publicly accessible charging ports are direct current fast chargers.

2.3 2031 Standards and Current VMT Growth

2.3.1 Projected Carbon Emission Reductions

The first set of committed strategies and policies includes federal and state fuel economy and vehicle technology standards such as CAFE and the rollback of the SAFE rule. It also accounts for the current VMT growth trend to 2031. With the full implementation of federal light-, medium- and heavy-duty standards through 2031, total on-road GHG emissions could decrease by **5.46 mmt CO2e** compared to 2006, bringing the 2031 SCVG emissions to **18% below 2006 emissions**. When the additional impact of the rescinding of the SAFE rule is included, which covers only the light-duty fleet only, emissions could decrease another **2.17 mmt CO2e** to **25% below 2006 emissions**. Together, the SCVG policies could therefore reduce emission by **7.63 mmt CO2e**. The remainder of this section identifies how these projected 2031 carbon emission reductions were calculated assuming federal and state standards and current VMT growth.

2.3.2 Technical Approach

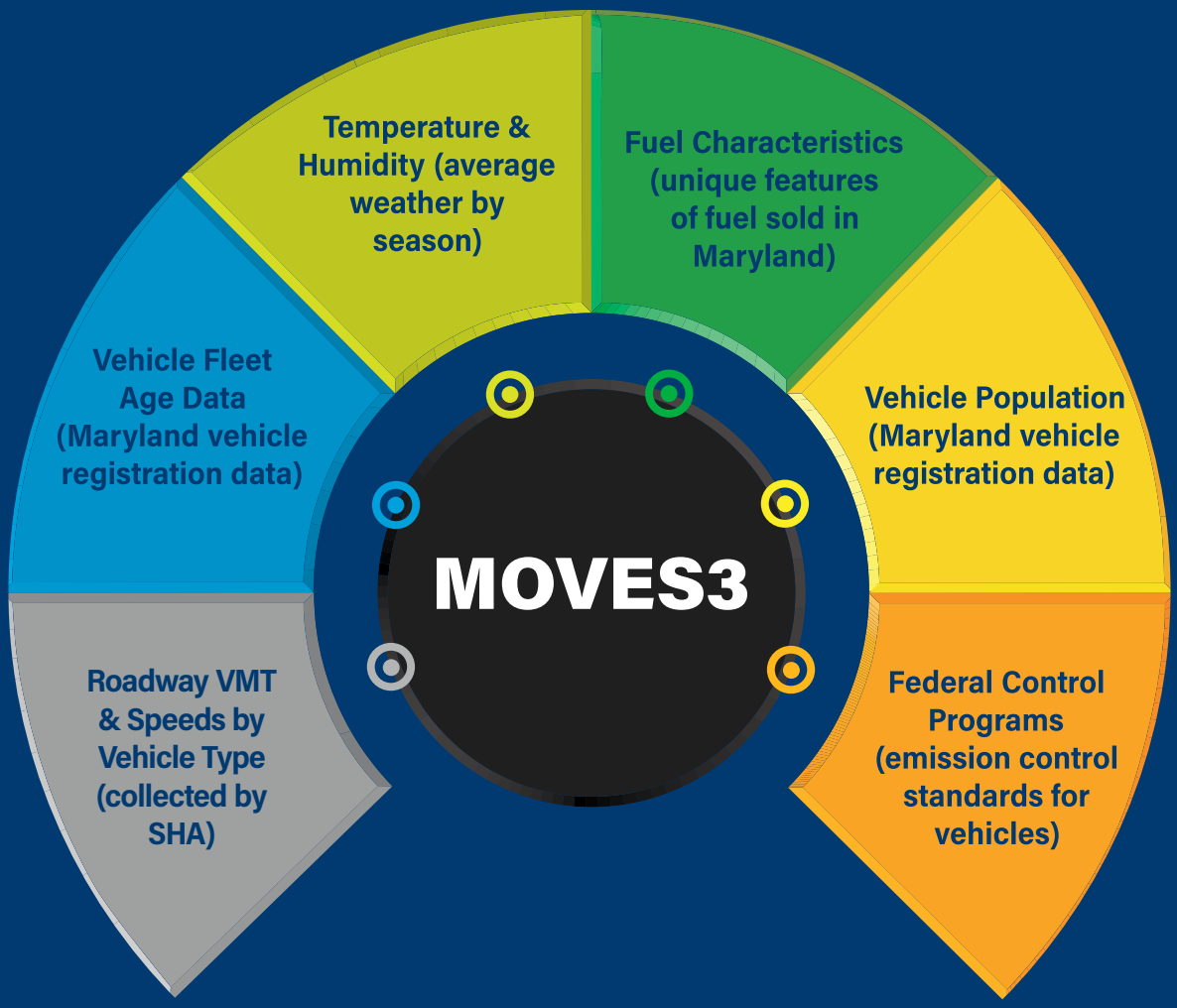
MDOT's approach to modeling GHG emissions used the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator[3] (MOVES3), which is federally required by EPA for on-road emissions modeling needed for State Implementation Plans and transportation conformity. The MOVES3 model is a state-of-the-science emission modeling system that estimates GHG emissions from Maryland's roadways and accounts for federal emissions standards and controls. The process incorporates local traffic activities, Maryland vehicle registrations and county-level fuel and environmental data that were recently updated in conjunction with the 2020 NEI.

MDOT's MOVES3 on-road modeling methodology represents a "bottom-up" approach to estimating statewide GHG emissions based on roadways characteristics, traffic volumes and speeds to estimate VMT. This approach utilizes emission rates from MOVES3 and is calibrated for consistency to Maryland's HPMS reported VMT. This model has updated emission rates from previous versions and produced slightly different results from previous modeling efforts for the GGRA. **Appendix A** provides a more detailed explanation of the MOVES3 emissions modeling process methodology and data inputs.

The on-road transportation emissions inventory includes emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) converted to CO2e that are measured in units of million metric tons (mmt) of CO2e based on each pollutant's global warming potential. Carbon dioxide represents about 97% of the transportation sector's GHG emissions. The data sets, input values, analysis tools and methodologies employed to conduct the on-road vehicle GHG emissions inventory were developed in consultation with MDE and are consistent with EPA guidance. **Figure 6** highlights the primary inputs into the MOVES3 model.

[3] MOVES3 (version 3.1) was the most current version available at the time of modeling. EPA recently released MOVES4, and Maryland has two years to transition to the new model. Details can be found here: https://www.epa.gov/moves/previous-moves-versions-and-documentation

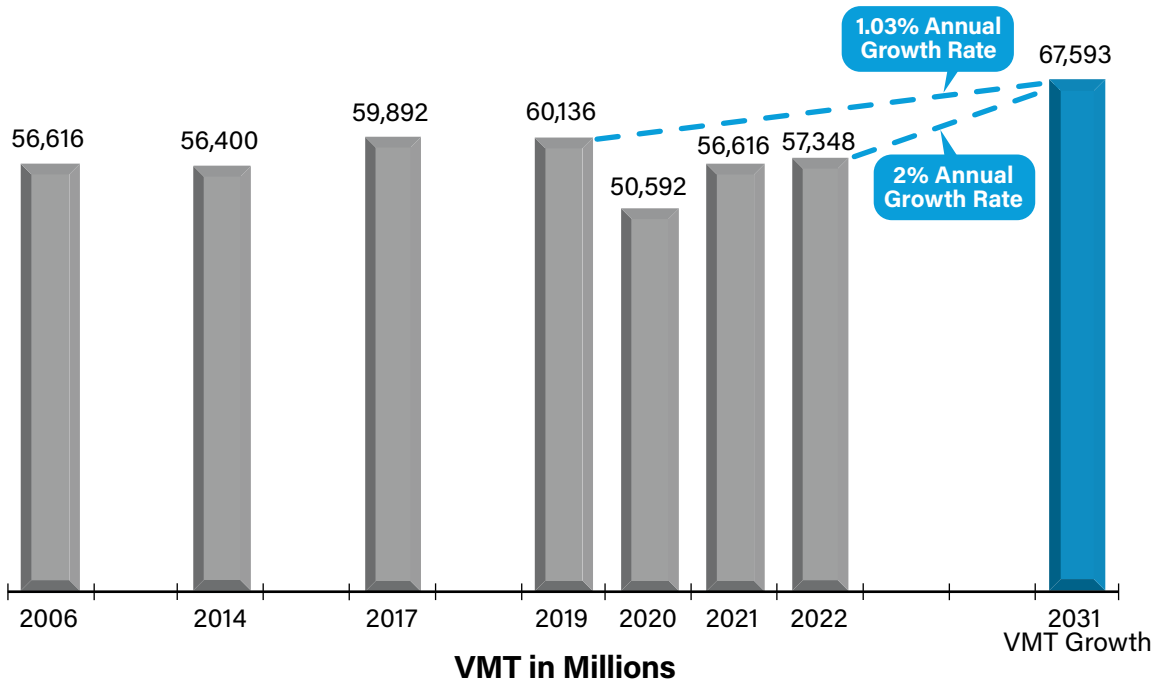
Figure 6. Emissions Inventory Modeling and Inputs



2.3.3 VMT Growth

VMT is a major indicator of transportation sector GHG emissions, given its correlation with travel and economic activity, demographic change and land-use changes. It has a significant impact on potential decarbonization pathways for the transportation sector and statewide emissions overall. **Figure 7** reflects the actual VMT between 2006 and 2022 and a VMT forecast to 2031 based on historic HPMS VMT trends between 2000 and 2019. The VMT shows steady growth between 2006 and 2019 followed by unprecedented travel reduction in 2020 due to the pandemic. By 2022, the travel demand continues to recover but remains below 2019 levels. Using HPMS's historic VMT growth between 2000 and 2019 and forecasting VMT to 2031, the VMT is expected to reach 67.6 billion without any additional strategies or controls. This represents a **1.03%** annual growth rate from 2019 or a **2.0%** annual growth rate from 2022 VMT as the economy and travel patterns continue to recover from the 2020 pandemic.

Figure 7. VMT Trends and Forecast to 2031 *(in Millions)*



2.3.4 Transportation Technology Improvements

Vehicle technologies are critical to reducing GHG emissions. The vehicle standards in place by 2022 include the Maryland Clean Cars Program and federal vehicle technology, fuel economy standards and federal renewable fuels standards. Only the standards that have been adopted through EPA Final Rulemakings at the time the MOVES3 model was released in December 2020 are reflected in the modeling results. The technological advances are designed to improve vehicle fuel economy and reduce average GHG emissions per mile. The benefits will increase over time as older vehicles are replaced with newer vehicles. A summary of these standards including light-duty vehicles, medium- and heavy-duty trucks, and fuel standards are listed in **Table 1**.

Table 1. 2031 Approach Overview – Standards and Programs

LIGHT-DUTY VEHICLE (PASSENGER CARS AND TRUCKS) STANDARDS

- **The Maryland Clean Car Program (Model Year 2011)** – Implements California's Low-Emission Vehicle (LEV) standards for vehicles purchased in Maryland. The California LEV program also includes goals for the sale of EVs (adopted in 2007).
- **CAFE Standards (Model Years 2008-2011**) – Vehicle model years through 2011 are covered under existing CAFE standards that will remain intact under the new national program.
- **National Program (Model Years 2012-2016)** – The light-duty vehicle fuel economy standards for model years between 2012 and 2016. The fuel economy improvements increase over time until an average near 35 miles per gallon (mpg) is met in model year 2016 (published May 2010).
- **National Program Phase 2 (Model Years 2017-2020)** – The light-duty vehicle fuel economy standards for model years between 2017 and 2025. The standards are phased-in and projected to result in 54.5 mpg by model year 2025 (published October 2012).
- **SAFE Vehicle Rule (Model Years (2021-2026)** – The light-duty fuel economy standards for model years 2021-2026. SAFE replaces the Phase 2 National Fuel Economy Program. Under SAFE, the rollback to standards equates to estimated miles per gallon efficiency of 40.4 mpg in the model year 2026 (published April 2020).
- **The SAFE Rollback Rulemaking (Model Years 2023-2026)** – Revises fuel economy standards beginning in model year 2023 and increases in stringency year over year through model year 2026 providing additional GHG benefits. The projected industry fleet-wide CO2 target is 161 grams/mile in 2026, which equates to an average fuel economy of 55 mpg. The final rule significantly accelerates the stringency rate to between five and 10% each year from 2023 through 2026. Under the previous SAFE Rule standards, the stringency increased at a rate of 1.5% per year and would reach 40 mpg by 2026.

MEDIUM-/HEAVY-DUTY VEHICLE (TRUCKS AND BUSES) STANDARDS

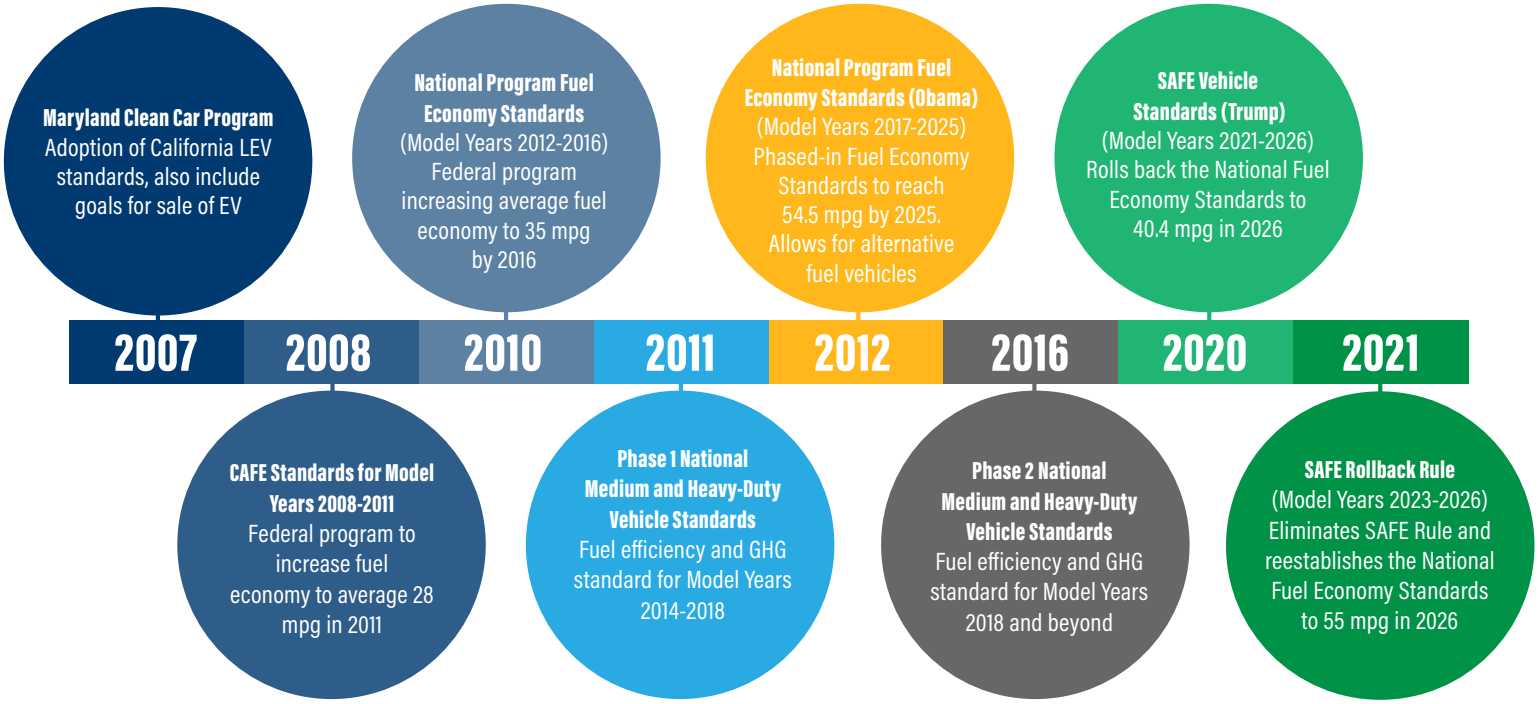
- **Phase 1 National Medium- and Heavy- Vehicle Standards (Model Years 2014-2018)** – Fuel efficiency and GHG standards for model years 2014 to 2018 medium- and heavy-duty vehicles. The rulemaking adopted standards for three main regulatory categories: combination tractors, heavy-duty pickups and vans, and vocational vehicles (published September 2011).
- **Phase 2 National Medium- and Heavy- Vehicle Standards (2018 and Beyond)** – The Phase 2 fuel efficiency and GHG standards for medium- and heavy-duty vehicles for the model year 2018 and beyond. The standards apply to four categories of medium- and heavy-duty vehicles: combination tractors, heavy-duty pickups and vans, vocational vehicles, and trailers to reduce GHG emissions and improve fuel efficiency. The standards phase in between model years 2021 and 2027 for engines and vehicles, and between model years 2018 and 2027 for trailers (published October 2016).

FUEL STANDARDS

- **Tier 3 Vehicle and Fuel Standards** – The rule establishes more stringent vehicle emissions standards and will reduce the sulfur content of gasoline from the current average level of 30 parts per million (ppm) to 10 ppm beginning in 2017. The gasoline sulfur standard will make emission control systems more effective for both existing and new vehicles and will enable more stringent vehicle emission standards. The vehicle standards will reduce both tailpipe and evaporative emissions from gasoline-powered vehicles (published April 2014).
- **The Federal Renewable Fuel Standard Program (RFS2)** – Mandates the use of 36 billion gallons of renewable fuel annually by 2022 (published March 2010).

CAFE standards are regulated by the U.S. Department of Transportation's National Highway Traffic and Safety Administration (NHTSA). NHTSA sets and enforces the CAFE standards, while the EPA calculates average fuel economy levels for manufacturers and sets related GHG standards. NHTSA establishes CAFE standards under the Energy Policy and Conservation Act of 1975, as amended by the Energy Independence and Security Act of 2007, while the EPA establishes GHG emissions standards under the Clean Air Act. Due to its vehicle regulations that preceded the federal Clean Air Act of 1970 and its particularly severe motor vehicle-related air quality issues, the state of California retains the unique authority as a U.S. state to set emission standards. As a result, under federal law, any California vehicle emissions standards must meet or exceed federal emission regulations. Although states besides California are not permitted to develop their own emissions standards, Section 177 of the Clean Air Act authorizes other states to choose to adopt California's standards in lieu of federal requirements. States are not required to seek EPA approval before adopting California's standards. There are over a dozen such "Section 177 States," including Maryland. The history of these CAFE standards since 2007 is shown in **Figure 8**.

Figure 8. Timeline of CAFE Standards (2007-2023)



2.4 Strategies in Progress (SP)

SP, the other collection of committed strategies and policies, includes projects and programs that are planned for funding within MDOT's 2023-2028 CTP, expected continued investments in MDOT emission reduction strategies, as well as projects in Metropolitan Planning Organizations' (MPO) fiscally constrained transportation plans that are scheduled for implementation by 2031. SP also includes projects and programs that are funded via federal legislation like the IIJA and Inflation Reduction Act (IRA), such as NEVI. Overall, the three distinct components of SP are the MPO plans and programs that are projected to decrease VMT by 2031, the collection of CTP-funded strategies and the increasing sales of ZEVs in the state.

Strategies in Progress (SP)

Implementation of the most recently adopted MPO Plans and Programs that yield lower annual VMT growth

CTP-funded and committed transportation projects, programs and initiatives through 2031

EV market share consistent with meeting ZEV mandate (Maryland's adoption of ACC II)

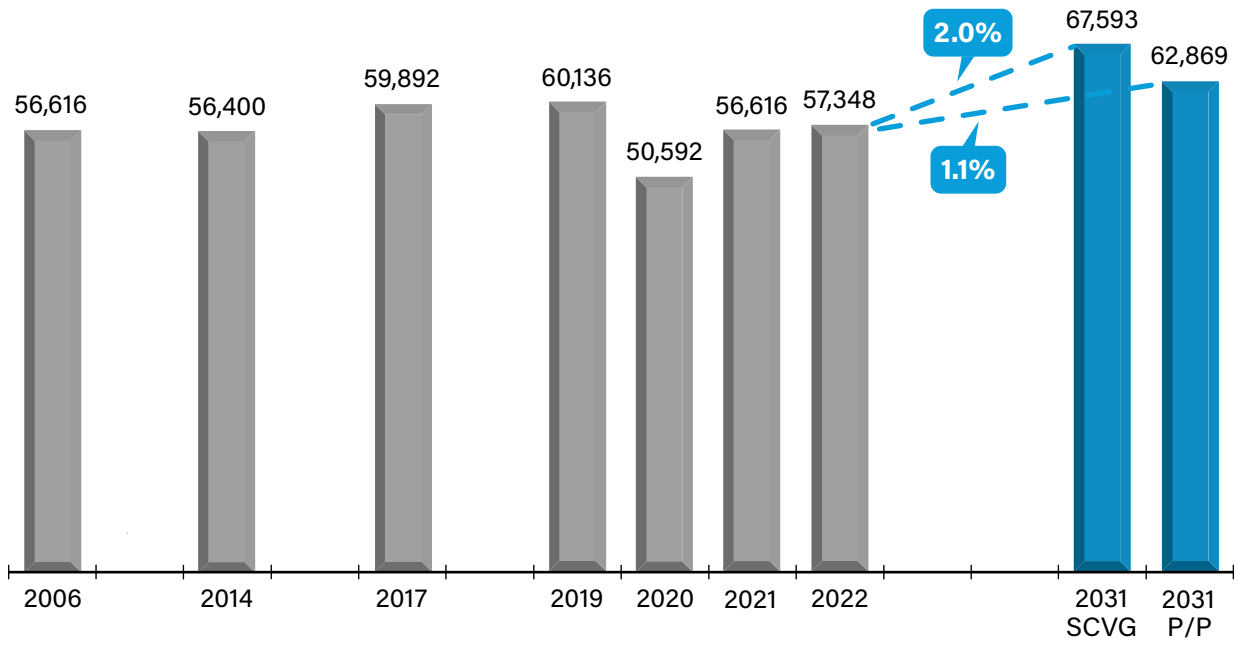
2.4.1 MPO Plans and Programs

In coordination with MDOT, Maryland's MPOs develop federally required metropolitan transportation plans. These plans carefully combine locally driven projections of future land use with stakeholder input on transportation needs to develop a fiscally constrained list of long-term transportation investments over the next 25 years.

The MPO Plans and Programs (P/P) scenario or strategy represents the implementation of the most recently adopted MPO Transportation Improvement Programs (TIP) and fiscally constrained Long Range Transportation Plans (LRTP). The VMT projections of implementing the P/P include MPO planned projects (highway and transit) and future regional demographic projections developed by the jurisdictions in cooperation with the Maryland Department of Planning (MDP).

Maryland is expected to show a decrease of ***4,725 billion VMT*** in 2031 relative to the SCVG VMT forecast. This decrease is the direct result of the implementation of MPO P/P. The average statewide annual growth rate from 2022 through 2031 for the P/P scenario is 1.1% as shown in **Figure 9**. If the plans and programs were not implemented, VMT growth would be expected to be 2.0% based on historic rates. MPO plans and programs yield lower VMT due to multimodal and transportation demand management (TDM) investments.

Figure 9. Maryland VMT Trends, including 2031 MPO Plans and Programs *(in Millions)*



2.4.2 CTP-Funded Strategies

MDOT sets a vision for the transportation system through the MTP, which is then implemented through the six-year budget for transportation projects produced annually as the CTP. These strategies reflect the implementation of the most recent CTP for MDOT that have been implemented with funding from federal agencies (like the Department of Energy, EPA and others) for improving air quality and reducing GHG emissions.

Federal grants and other funding formulas often require state matching funds. Examples include Diesel Emissions Reduction Act funding to replace or repower diesel engines, marine vessels and cargo handling equipment. One such strategy includes the Maryland Port Administration's (MPA) support to replace dray trucks, which results in air quality benefits within the Port of Baltimore area where they operate. SP also estimates the emissions impacts of current diesel transit bus replacement policies toward clean diesel and compressed natural gas for Maryland Transit Administration (MTA), Washington Metropolitan Area Transit Authority (WMATA) and Baltimore Washington International (BWI) Thurgood Marshall Airport shuttle buses. Other CTP-funded strategies focus on mode choice and reducing VMT as opposed to electrification. Transit, bicycle, pedestrian and TDM strategies reduce, shift or combine trips to reduce VMT from carbon-emitting motor vehicles.

Many CTP-funded strategies are defined by or implemented with funding from state agencies or state mandates, like the CSNA, and federal funding sources, like the IIJA. Therefore, several strategies were added since the 2020 MDOT GGRA Plan. One new strategy is the transition to zero-emission school buses due to the CSNA requiring county school boards to begin purchasing zero-emission buses by the end of 2024. Funding from the IIJA also gave Maryland the opportunity to expand its EV charging throughout the state through NEVI, so a new strategy associated with this, labeled as EV Plans and Programs, was identified. The Carbon Reduction Program is another new strategy, which is available to Maryland under the IIJA to reduce emissions from on-road transportation.

2.4.3 Zero-Emission Vehicle Adoption

Three types of federal and state policy tools are accelerating the purchase and adoption of electric and other low- and zero-emission vehicles[4]:

1. Consumer and manufacturer incentives for transitioning to alternatives from conventional internal combustion engine vehicles, most notably ones in the IRA - a $7,500 tax credit for new ZEVs and $4,000 credit for used ZEVs and $2 billion in grants to incentivize domestic production of ZEVs.

2. Investments in charging infrastructure, most notably NEVI programs in the IIJA, which deliver $7.5 billion for this purpose. These investments will support the Biden-Harris Administration's goal of installing 500,000 EV chargers across the country.[5]

3. Regulations that mandate the sale of ZEVs, specifically the adoption of the California Air Resources Board's Regulations[6] by the state of Maryland, which requires that all new passenger cars and light trucks sold in Maryland will be electric by model year 2035. The regulation requires manufacturers to continuously increase the share of EVs sold between 2027 and 2035. According to an MDE analysis, 383,000 fewer new gas-powered vehicles would be sold under the new rule by 2030, rising to 1.68 million fewer conventional vehicles by 2035 when new gasoline-powered automobile sales will be phased out.[7]

State policies will also ensure that the adoption of ZEVs proceeds in an equitable fashion over the next decade. For instance, Maryland developed a NEVI Plan in 2022 that included a goal of equitable charging infrastructure and included many equity considerations including the location of Justice40 areas in relation to the EV-AFCs in the state. Maryland also provides rebates for installation of EV charging infrastructure at multifamily properties through Maryland's Public Conference (PC 44) to ensure that EV charging is more accessible to residents of the state that do not live in single family homes.

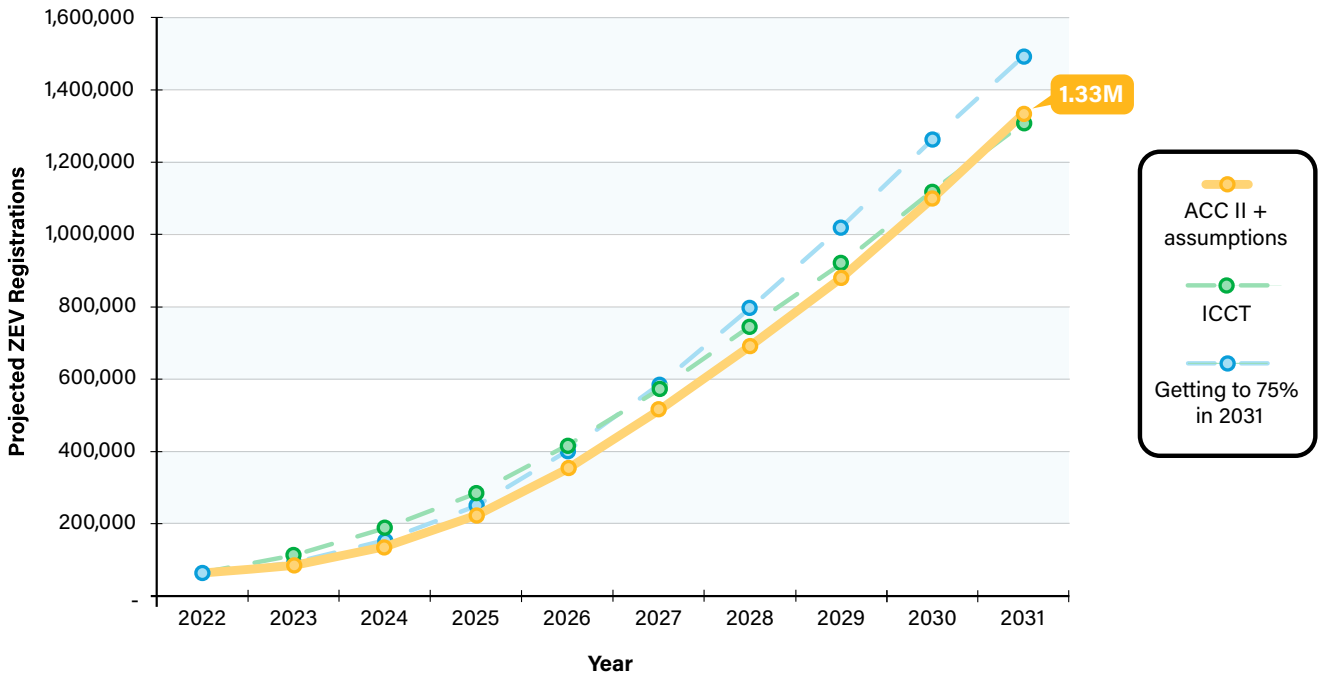
Federal and state policies are expected to result in an increased share of ZEVs among passenger vehicles and light trucks across the state of Maryland between now and 2035. Several different sources were used for vehicle fleet projections after the enactment of the IRA. Specifically, these sources were the national EV sales projections created by the International Council for Clean Transportation (ICCT) in January 2023[8], the Advanced Clean Cars II (ACCII) Regulations plus assumptions made in the years prior to the first-year requirements begin in 2027 and assumptions to achieve the MCCC goal[9] of 75% of new vehicle sales consisting of ZEVs by 2031. The latter source is derived from recommendations from the Mitigation Working Group, which suggested the importance of ensuring that 75% of new vehicle sales consist of ZEVs by 2030. The ACC II scenario is what ultimately became the assumption for new vehicle sales between now and 2031 that is being used for SP and PNI. **Table 2** and **Figure 10** present the projected ZEV deployment curve of all the ZEV sales sources through 2031.

ACC II establishes a roadmap for 100% of new cars and trucks sold in Maryland to be ZEVs and PHEVs by 2035.

Table 2. Projected Total ZEV Registrations in Maryland (Calendar Years)

YEAR	2023	2024	2025	2026	2027	2028	2029	2030	2031
ACC II + Assumptions	84,246	137,494	221,425	352,010	513,051	691,687	879,693	1,099,904	1,334,415
ICCT	110,317	186,743	282,942	415,391	575,437	744,717	921,570	1,117,817	1,309,128
Getting to 75% in 2031	89,621	152,266	249,110	398,349	585,607	795,767	1,018,824	1,261,704	1,493,129

Figure 10. Projected Cumulative ZEV Registrations in Maryland (Calendar Years)



[4] EVs include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

[5] FACT SHEET: The Biden-Harris Electric Vehicle Charging Action Plan, The White House, December 2021 https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/13/fact-sheet-the-biden-harris-electric-vehicle-charging-action-plan/

[6] Advanced Clean Cars II Regulations: All New Passenger Vehicles Sold in California to be Zero Emissions by 2035, California Air Resources Board https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii

[7] Press Release from Office of Governor Wes Moore, March 2023 https://governor.maryland.gov/news/press/pages/Governor-Moore-Announces-Maryland-Adoption-of-the-Advanced-Clean-Cars-II-Rule-to-Combat-the-Effects-of-Climate-Change.aspx

[8] Analyzing the Impact of the Inflation Reduction Act on Electric Vehicle Uptake in the United States, ICCT, January 2023 https://theicct.org/wp-content/uploads/2023/01/ira-impact-evs-us-jan23.pdf

[9] 2022 Annual Report, Maryland Commission on Climate Change, 2023 https://mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/MCCC%20Annual%20Report%202022/2022%20Annual%20Report%20-%20Final.pdf

Electric Buses

MTA's Bus Fleet Management Plan identifies the procurement and replacement schedule for transit buses. The MTA is planning to purchase more battery electric buses (BEB) through 2030, in addition to seven BEBs under a pilot program. The replacement schedule retires diesel buses once they reach 12 years of service life in accordance with their useful life benchmark. By 2031, the MTA transit bus fleet will reach 50% BEBs.

The CSNA requires new school bus purchases and contracts to be electric by 2025. Montgomery County Public Schools leads this effort by contracting to replace 3,326 diesel school buses with electric buses by 2025[10].

Electric Medium- and Heavy-Duty Trucks

The Advanced Clean Truck (ACT) Regulation is part of a holistic approach to accelerate a large-scale transition of zero-emission medium-and heavy-duty vehicles. Starting with model year 2027, the regulation requires a manufacturer ZEV sales requirement by 2035, estimated at 35% for medium-duty trucks and 55% heavy-duty trucks. The ACT program is expected to replace 5,760 medium-duty trucks and 3,163 heavy-duty trucks with zero-emission trucks.

In addition, the federal proposed rulemaking (April 2023) for the *Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles – Phase 3* requires stronger CO2 standards for model years 2027-2032 heavy-duty vehicles. The rulemaking will require ZEV's new sales adoption rates to support the California Advanced Clean Trucks program.

Equity Considerations of Electric Vehicles

There are many examples of efforts made to ensure that the adoption of EVs occurs equitably for Maryland residents. ZEEVIC continues to prioritize education and outreach. To increase ZEV deployment in underserved populations, ZEEVIC engages Marylanders in their communities at planned events and festivals throughout the state. ZEEVIC also continues to support legislation that will promote EV adoption through incentives and reduce access barriers to EV adoption, especially for those residents living in multi-unit dwellings. Furthermore, Maryland continues to introduce incentives and rebates that support the equitable adoption of EVs within Maryland. Rebates, such as those offered through PC 44 for multi-family properties, reduce the financial cost of installing EV infrastructure and increase access for all communities.

Another pathway to ensure equitable adoption of EVs is to also incorporate the adoption of hybrid electric vehicles (HEVs). While there has been an increase in the number of affordable EVs on the market, most EVs are still more expensive than comparable internal combustion engine vehicles (ICE). This can be a barrier to adoption for disadvantaged communities, thereby to wider and equitable adoption of EVs. HEVs, while not zero-emission, are at or near cost parity with traditional ICE vehicles and would serve as a more affordable low-emission option. In the transition to passenger vehicle electrification, they offer a transitional choice that balances economic viability of "lower" emissions alternatives and low-emissions alternatives. Increasing fuel economy standards are likely to continue increasing the number of HEV choices in the marketplace.

Maryland is committed to ensuring an equitable adoption and deployment of EVs in the state and adhering to this guideline, as evidenced by their NEVI plan. The plan identified seven goals, including equitable charging infrastructure, as well as three principles that will serve to guide Maryland's deployment of EV infrastructure. These principles are

Accessibility – Ensuring all Marylanders and visitors have access to reliable EV charging

Affordability – Creating incentives, innovations and systems that increase the affordability of EV ownership and charging

Communication – Meeting people where they are, listening and educating.

[10] Montgomery County Public Schools, Electric Vehicle Program https://www2.montgomeryschoolsmd.org/departments/facilities/sustainability/Electric-Vehicles#:~:text=The%20school%20district%20is%20on,2027%20and%20100%25%20by%202035

Figure 11. Principles of the Maryland State Plan for NEVI Deployment

Source: Maryland NEVI Plan

MDOT also worked with key planning partners to identify additional state and national data layers to supplement the Justice40 Map to ensure that all disadvantaged communities in Maryland are identified and prioritized for funding. MDOT will continue to plan, invest and implement low-emissions investments and strategies to benefit communities around the state in an equitable manner.

Table 3. Strategies in Progress Summary Table

STRATEGY	2031 Estimate (mmt CO2e)	2031 Total Estimated Costs ($M)	2031 Total Estimated Costs per Reduction ($M per mmt CO2e)
*EV Projections****	3.055	0	*N/A*
2031 P/P Yield Lower Annual VMT Growth	1.53	12,380	8,091
Freight and Freight Rail Programs	0.19	783	4,122
Transportation Demand Management	0.17	80	470
On-Road Technology	0.089	265	2,973
Public Transportation (56% EV Transit Bus Fleet)	0.055	1,170	21,278
Zero-Emission School Buses	0.046	*50**	*N/A*
Carbon Reduction Program	0.038	94	2,483
Bicycle and Pedestrian Strategies	0.033	575	17,409
Pricing Initiatives (Electronic Tolling)	0.015	288	19,227
Public Transportation (New Rail or Bus Capacity or Frequency & Improved Operations)	0.011	3,896	354,191
EV Programs & Policies (NEVI Formula Funding)	*0.007***	*63*	*N/A*
MDOT Fleet Electrification	0.0056	0	*N/A*
Port of Baltimore Drayage Truck Replacements	0.0046	13	2,891
Intercity Transportation Initiatives	0.0033	0	*N/A*
BWI Airport Parking Shuttle Bus Replacements	0.0017	38	22,176
TOTAL:	**5.25**	**19,645**	**3,744**

*Costs not included in total, **GHG reduction estimate not included in total, ***Details can be found in Table 4

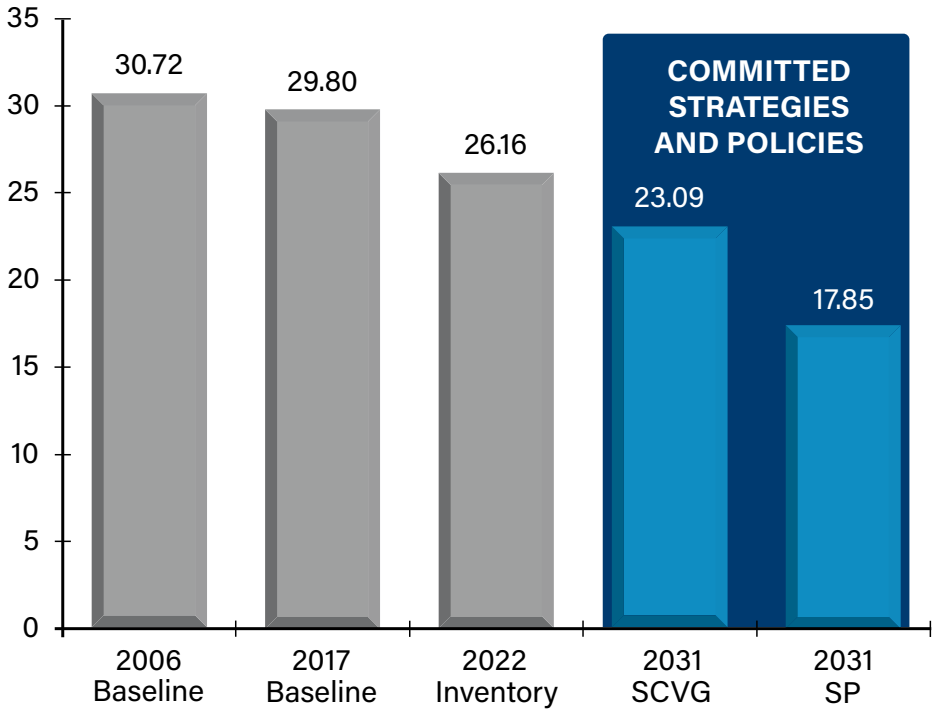
2.5 Strategy, Emissions Outcomes and Cost Summary

Table 3 lists the SP strategies, GHG reduction potential and estimated costs for implementation. The total emission reduction from all of the EV projections and SP strategies is **5.25 mmt CO2e**. The reductions from all of the SP strategies alone is **2.19 mmt CO2e**.

Figure 12 presents the emissions outcomes from the 2031 SP, compared to the 2031 SCVG and the 2006 and 2017 Baselines. With the full implementation of the federal vehicle standards and the SAFE Rule Rollback through 2031, the on-road emissions are reduced by **7.63 mmt CO2e** from the 2006 Baseline. Then, with the implementation of MDOT's vision for the transportation system through the MTP, transportation investments included in the six-year budget for the CTP, and the Maryland MPO's fiscally constrained metropolitan transportation plans, there is an additional 1.53 mmt CO2e reduction for the P/P strategy. These programs incorporate future smart growth land use projections, population and employment growth and

VMT forecast at the county level, which projects 4.725 billion less VMT than the HPMS historic trends. Finally, there is an additional 0.66 mmt CO2e reduction for the rest of the SP strategies minus the EV projections.

Figure 12. Maryland GHG Strategy Reductions, Statewide Emissions Totals, Including SP



Therefore, the total estimated statewide reduction in 2031 is **2.19 mmt CO2e** when including 2031 P/P and SP (excluding the EV projections). Assuming the implementation of ACC II, ACT and the electric transit and school buses under contract, an estimated **3.055 mmt CO2e** reduction is anticipated. The summary of EV projections and potential benefits in the year 2031 is provided in **Table 4**. Since Maryland adopted these standards in 2023, these reductions are included in SP. With these reductions included, the 2031 emissions projections from all committed strategies and policies are **41.9% below 2006 emissions at 17.85 mmt CO2e**.

Table 4. 2031 Maryland Electric Vehicle Projections and Emission Reductions

SCENARIO	Electric Vehicles Total	2031 Emission Benefit (mmt CO2e)
1. ACC II + assumptions	1,334,415	2.461
2. MDOT MTA Buses*	576	0.040
3. School Buses*	326	0.008
4. ACT Medium- /Heavy-Duty Trucks	8,922	0.594
TOTALS:	1,344,239	3.055

*These line items are not included in the total because they are already included in the SP strategies.

2.6 Implementation

Strategies listed as part of SP are funded through the six-year MDOT CTP (FY 23-28), or through federal grants and other funding sources. The total cost of SP is ***$19.9 billion*** in capital investment through 2031. This does not include additional operating costs for expanded transit or other services implemented by 2031. The objective of constructing SP is to group programs and strategies that are completely funded or expected to be funded based on current funding levels and assumptions, and thereby have a high certainty of implementation by 2031.

The challenges for the committed strategies and policies include widely acknowledged concerns such as diminishing fuel tax revenue relative to infrastructure costs, which is a significant funding mechanism for the Maryland Transportation Trust Fund. Funding has been somewhat in flux, with reduced state revenues due to the COVID-19 pandemic and then increased federal funding levels through the passing of the IIJA. MDOT and its partners also need to deliver this program, while at the same time prioritizing funds to support maintaining and operating Maryland's multimodal transportation system. To further leverage investments in the multimodal transportation network, MDOT uses a robust program called Commuter Choice Maryland, which uses TDM strategies and principles to influence travel behavior and shift SOV trips to sustainable modes such as biking, walking, transit, ridesharing and teleworking.

A key part of implementing the committed strategies and policies is equity, particularly environmental justice, which is a focus of the CSNA. The CSNA provides definitions for "underserved" and "overburdened" communities and will be a vital piece to the implementation of the committed strategies and policies.

3.0 Potential New Initiatives (PNI)

PNI strategies are differentiated from SP strategies based on potential funding availability. PNI strategies do not have funding approved in any planning documents by federal, state, local or private agencies. It is also important to note that implementation plans for a number of these strategies are beyond MDOT's direct influence and control. Some of these strategies are driven by market forces where MDOT's role is a facilitator, influencing and supporting policy and regulatory frameworks to realize the strategy. Some other strategies, while still within public authority, are under different jurisdictions, such as local governments or other state agencies. These require strategic coordination and shared goals.

Potential New Initiatives (PNI)

Expanded and accelerated traditional and emerging MDOT programs (unfunded)

New and innovative transportation strategies, partnerships and technologies

PNI envisions implementing two distinct categories of GHG mitigating strategies— emerging and innovative strategies.

3.1 Emerging Strategies

Emerging strategies can be defined as logical next steps for strategies that are currently funded in SP.

Emerging strategies are based on practices that have a demonstrated record of mitigating emissions. However, there is uncertainty due to factors outside MDOT's control, such as the rate of adoption of new technologies by the general public and local land use decisions. Examples of such strategies include adoption of EVs by the public, transition to an electric bus fleet by transit agencies and electrifying trucks by trucking companies.

In PNI, these strategies are expanded in one or more of the following ways:

1. Full implementation of strategies currently constrained by fiscal limits.
2. Expanded scope of a strategy in one of the following ways:
   a. A larger geographic scope of implementation;
   b. Accelerated implementation that would otherwise not be implemented before 2031; and
   c. More aggressive deployment.
3. Strategies that have been implemented in peer states that could work in Maryland.
4. Increased policy impetus and more partnerships for a regional scale strategy application.

3.2 Innovative Strategies

Innovative strategies in PNI comprise strategies that are experiencing rapid technological innovation that has an impact on a significant user base and broad market reach, with the potential to alter the way people exercise their travel choices. However, these strategies are also characterized by large uncertainty in the technological and policy maturity that is required for widespread adoption. Examples of strategies that will require policy or technological maturity are pay-as-you-drive insurance, connected and autonomous vehicles (CAV) technologies and zero emission truck corridors. Some strategies have been implemented on a controlled or limited scale by pioneering jurisdictions—for example, freight consolidation centers and variable speed management corridors. MDOT's role in implementing some of these strategies is as a facilitator and a policy influencer. MDOT can facilitate by providing a safe and conducive environment for Maryland residents and businesses that adopt these new technologies. Challenges to implementing some of these strategies include public funding availability, technological maturity, or time for development to remove weaknesses, MDOT's limited role in strategy facilitation or rolling out an enabling regulatory framework, partnerships with the private sector, transportation safety, and data security, privacy and public acceptance.

3.3 Other Non-Road (Off-Road) Strategies

MDOT's emissions modeling approach is associated with the on-road portion of the emissions inventory. Non-road (off-road) inventory is developed as part of triennial reporting to EPA's NEI and not included in this modeling effort. However, MDOT plans and implements strategies and efforts that extend beyond the on-road scope of emissions to include non-road (off-road) strategies that reduce the transportation sector emissions and overall statewide emissions.

3.3.1 Lead-By-Example

There are many MDOT-led strategies that demonstrate the agency's leadership in using its internal resources and practices to support the transition to a low-emissions pathway.

Building Energy Use

According to MDOT's 2023 Annual Attainment Report[11], electricity use has decreased overall over time due to energy efficiency measures implemented across MDOT. MDOT is committed to further reducing internal energy consumption at its own buildings and facilities. Through comprehensive updates to existing facility, utility and energy asset databases, MDOT assesses overall energy demand and use across the Modal Administrations. Through detailed building energy efficiency audits, MDOT can recommission and customize improvements for its facilities, such as heating, ventilation and air conditioning upgrades and boiler retrofits and updated light-emitting diode (LED) lighting fixtures. These initiatives are driven by innovative funding sources, including private and federal rebate programs, contracts implemented as part of the 2019 "Maryland Leads by Example" energy-savings initiative and funding available through the Maryland Energy Administration.

Renewable Energy

Increasing the use of renewable energy, especially solar, to support transportation projects and operations reduces GHG emissions and sustainable, resilient energy. Opportunities exist for the MDOT modal administrations, in partnership with other stakeholders, co-locate with new renewable energy projects. Continued coordination is necessary to ensure the successful deployment of renewable energy projects.

Innovative Pavement

Pavement recycling uses existing degraded surface pavement in resurfacing work. This has the potential to considerably reduce material, energy and associated emissions. If new asphalt is required, innovative low temperature asphalt is being developed, which reduces the temperature required to make asphalt thus reducing costs and emissions. Construction related emissions can be reduced either through innovative materials or construction technologies. MDOT can continue to explore materials with lower-embodied carbon as well light colored pavement to help reduce the urban heat island effect.

3.3.2 Carbon Sequestration

Tree planting and canopy cover enhancement programs can help reduce the impact of climate change by lessening the heat island effect in urban areas, sequestering carbon and enhancing local air quality. MDOT in its capacity has supported the carbon sequestration, tree planting and preservation efforts along the right-of-way and areas owned and managed by the agency.

MDOT's Urban Tree Program incentivizes planting replacement trees beyond mitigation requirements. Other MDOT programs plant trees in communities near transportation assets. In addition, tracking and monitoring its tree planting efforts helps MDOT understand the co-benefits offered by the programs, including carbon sequestration and public health benefits for future GHG emission assessments.

[11] Utility electricity use and renewable energy generation, MDOT Attainment Report, https://www.mdot.maryland.gov/OPCP/ARReport.pdf

3.3.3 Off-Road Transportation

MDOT's scope and involvement in the transportation sector goes beyond on-road transportation. It includes work related to other subsectors, such as ports, airports and rail.

Airport Decarbonization Initiatives

Several initiatives are currently underway at BWI Marshall Airport and Martin State Airport to reduce GHG emissions at its facilities and in operations. The Maryland Aviation Administration (MAA) is developing decarbonization strategies for projects at both facilities. Working with airport partners, including tenants, airlines, logistics service providers and state and federal agencies, can yield projects that improve energy efficiency or alternative fuel usage for airport-related infrastructure, equipment and vehicles. There is also potential to promote alternative energy deployment, such as solar and fuel cell applications at the airports, energy efficiency practices and low-carbon construction methods.

Electrified Locomotives

Replacing MDOT-owned diesel-electric locomotives presents another opportunity for potential emission reductions. In 2022, MDOT was awarded a $11.8 million Consolidated Rail Infrastructure and Safety Improvements Program grant to replace three non-regulated emission diesel-electric locomotives with battery electric locomotives at the Port of Baltimore. Other rail-related assets could follow a similar strategy. There is the potential to electrify a larger fleet and to implement alternate energy sources, including solar, to transition to an entirely sustainable system.

Port Decarbonization Initiatives

The Port of Baltimore has a highly successful record of reducing emissions from trucks and cargo handling equipment at the public marine terminals. However, there are additional opportunities to further reduce GHG emissions associated with cargo movement. MPA can support and advance electrification projects or the use of alternative fuels for port activities in equipment usage, locomotives and dray trucks. The Port can also continue to promote alternative energy sources, such as solar and fuel cell applications, and other energy efficiency practices. There are multiple stakeholders that can potentially be involved, including tenants, shipping lines, truck and rail owners, and operators.

Short Sea Shipping/ Marine Highway

In addition to MPA's efforts, the federal Maritime Administration's Marine Highway Program encourages the efficient use of coastal marine transportation through short-sea shipping for cargo as an alternate mode to landside transportation systems. This reduces congestion, is more energy efficient and provides other indirect benefits. There are currently 31 designated Marine Highway Routes in the United States, including the coastal M-95, which runs parallel to the landside I-95 corridor in Maryland. MPA can explore other opportunities to support the increased use of short-sea shipping options within Maryland's navigable waterways, given water-based transport is an efficient and sustainable alternative to land-based freight modes.

Table 5. Other Non-Road (Off-Road) Strategies

STRATEGY	DESCRIPTION	EXAMPLES
 **Lead-By-Example Strategies**	Strategies MDOT is pursuing to reduce its GHG emissions that other state agencies can also pursue	Reducing energy consumption in buildings, adding on-site solar to properties
 **Carbon Sequestration**	Capturing the carbon from the atmosphere by enhancing tree cover	Tree planting and canopy enhancement at MDOT properties
 **Off-Road Strategies**	Strategies that MDOT can employ that are transportation-related, but do not decrease on-road GHG emissions	Innovative pavement projects, airport and port decarbonization initiatives, electric locomotives for MARC trains

3.4 Strategy, Emissions Outcomes and Cost Summary

Table 6 shows the detailed estimate of modeled GHG reductions between emerging and innovative strategies as well as the estimated costs and costs per reduction presented as ranges. The reason for presenting this information as a range is due to uncertainty in the scope, intensity of implementation and other externalities that determine cost. All numbers are estimated for the year 2031.

Table 6. Potential New Initiatives Summary Table

STRATEGY	2031 Estimate (mmt CO2e)	2031 Total Estimated Costs ($M)	2031 Total Estimated Costs per Reduction ($M per mmt CO2e)
EMERGING STRATEGIES			
Expanded Telework	0.49 to 0.74	981 to 6,077	2,019 to 8,226
Expanded TDM Strategies (Car-Sharing)	0.25 to 0.6	18 to 35	60 to 71
TSMO/Integrated Corridor Management (Arterial System)	0.15 to 0.23	536 to 804	3,454 to 3,661
56% to 75% EV Transit Bus Fleet	0.12 to 0.18	65 to 99	539 to 539
Medium-/Heavy-Duty Vehicle Low-Carbon Fleet/Fueling Incentives and Programs (Non-State Fleets)	0.1 to 0.21	20 to 39	188 to 189

Table 6. Continued

TSMO/Integrated Corridor Management (Limited Access System)	0.08 to 0.15	128 to 180	1,234 to 1,553
Hydrogen Fuel Cell Vehicles (Medium- and Heavy-Duty Vehicles, Non-state Fleet)	0.08 to 0.16	45 to 89	546 to 556
Transit-Oriented Development (TOD) Build-Out	0.05 to 0.1	2 to 2	25 to 49
Expanded Rail Regional Transit (e.g. MARC Growth and Investment Plan, Other Cross-regional Transit)	0.04 to 0.06	2,580 to 2,580	40,528 to 57,892
Eco-Driving	0.04	4 to 6	99 to 164
Lead by Example - Alternative Fuel Usage in State/Local Government Fleet in Medium- and Heavy-Duty Vehicles	0.03 to 0.05	629 to 1,015	19,788 to 20,874
Expanded Bike/Pedestrian System Development	0.02 to 0.04	1,750 to 3,500	79,077 to 79,077
Transit Capacity/Service Expansion (Fiscally Unconstrained)	0.02 to 0.04	3,979 to 4,646	109,475 to 187,539
Truck Stop Electrification	0.02 to 0.03	31 to 53	1,666 to 1,666
Parking Incentives, Pricing, Mins./Maxs.	0.02 to 0.08	*	*
Commercial Vehicle Technologies (Idle Reduction, Low-Carbon Fleet, Dynamic Routing)	0.01 to 0.02	2 to 4	175 to 247
Variable Speeds/Speed Management	0.01 to 0.02	128 to 180	9,700 to 10,683
Intermodal Freight Centers Access Improvement	0.01	2,649 to 3,708	264,880 to 370,832
Red Line Transit	0.005	2,332 to 2,332	494,824 to 494,824
Intercity Bus Service Expansion	0.004 to 0.007	6 to 7	1,126 to 1,486
INNOVATIVE STRATEGIES			
CAV Technologies	0.52 to 0.65	94 to 128	179 to 197
Pay-As-You-Drive Insurance	0.06 to 0.37	**	**
Speed Management on Freeways (Increased Enforcement)	0.04 to 0.09	8 to 17	190 to 190
Freight Villages/Urban Freight Consolidation Centers	0.02 to 0.03	5,737 to 8,405	251,298 to 257,293
Zero-Emission Truck Corridors	0.01 to 0.02	8 to 23	980 to 1,002
TOTAL:	**2.20 to 3.93**	**$21,729 to $33,928**	**$8,624 to $9,874**

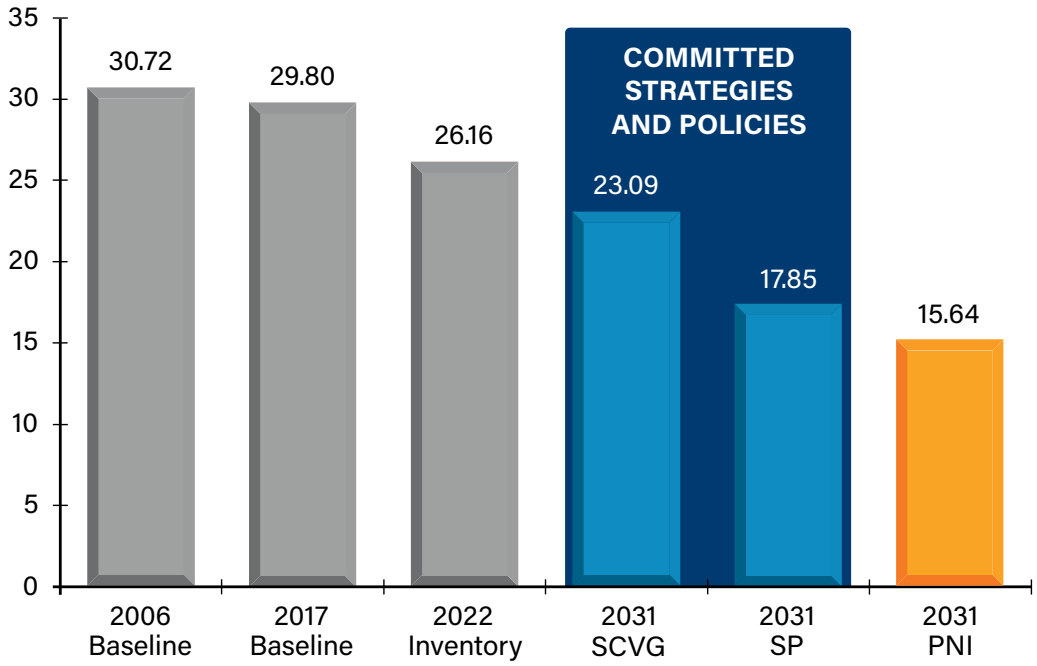
* Policy change with uncertain costs, ** Technology/programs offered by private sector

Figure 13 shows the overall emission outcomes of PNI alongside the 2006 and 2017 baselines, 2022 inventory, 2031 SCVG and the SP reductions after accounting for EV projections.

The total estimated reduction in 2031 as a result of PNI is between **2.201 and 3.934 mmt CO2e**. This brings the 2031 emissions levels to ***15.643 mmt CO2e*** (conservative low range estimate, which is 49.1% below 2006) to ***13.91 mmt CO2e*** (high range estimate, which is 54.7% below 2006). Due to the uncertain nature of PNI strategies, associated emission reductions are conservative. Some strategies could potentially result in greater emission reductions resulting in 13.91 mmtCO2e. However, we consider the conservative estimates for this discussion, and future estimates would be documented in the MDOT State Agency Report.

PNI strategies could reduce VMT by a total of 3.158 billion VMT (conservative low range estimate) in Maryland by 2031, which is lower compared to the reduction from the SP. This is driven by the fact that SP strategies focus more on electrification technologies and system efficiencies, which are implemented more easily and quickly compared to alternate modes or changes in driving behaviors.

Figure 13. Potential New Initiatives Emissions Outcomes



3.5 Implementation

PNI strategies, as mentioned earlier, are not funded within MDOT's CTP or the MPO's metropolitan transportation plans for implementation by 2031. PNI's total estimated cost ranges from $21.73 billion up to $33.93 billion.

Strategies vary in costs per unit of emission reductions. The cost-per-reduction estimates in Table 6 rank strategies based on cost efficiency. Funding such strategies may require substantial shifts in currently programmed and planned investments as well as additional funding.

4.0 Implementation Challenges, Opportunities and Next Steps

With additional funding for PNI strategies and alignment of a range of favorable outcomes, the on-road transportation sector in Maryland could achieve a **49.1%** reduction in CO2e emission by 2031. There are many strategies that MDOT has the autonomy to carry out, such as the transition to a zero-emission bus fleet. Achieving that target requires that MDOT exercise its substantial authority over transportation investments in Maryland. However, some strategies and initiatives are outside MDOT's current direct authority and will require collaboration, coordination and partnering with other agencies, local jurisdictions and the private sector. This is an enormous undertaking. As such, it joins a list of important priorities for the agency in coming years, including maintaining and modernizing infrastructure assets, ensuring the safe and efficient movement of people and goods and providing Marylanders with multimodal access to jobs and services.

4.1 Setting the Context for 2031: Trends and Drivers

Implementation of these strategies is dependent on several trends and drivers that influence travel behavior of Maryland residents and visitors. Opportunities and challenges come hand-in-hand as an increasing number of residents and employers in the state will generate additional revenue, but they will also require transportation services that may necessitate increased spending.

While the impact of electrification has relatively certain GHG reduction benefits, the outlook is less clear for other transportation-related technological changes such as CAVs and the shared mobility economy given insufficient technological maturity and market penetration. Transportation costs outside of MDOT's control, such as gasoline prices before taxes, have varied greatly in recent years, affecting the demand for automobile travel. Finally, land use factors affect where people live, work and shop, which also impacts mobility options for access to these destinations. These four trends and drivers are described in detail in the following sections.

4.1.1 Economic Shifts and Demographics

Economic shifts and changing demographics are key drivers of the demand for travel in Maryland. Changes in the state's overall economy and population greatly impact VMT patterns, distribution and overall trips. For example, a strong job market and economy is generally associated with high trip demand and increased VMT. A global pandemic and associated economic recession (as seen in 2020) significantly decreased the number of trips Marylanders make and can even affect their decisions on where to live and work.

Maryland's economic growth relative to its surrounding states will affect the migration of the working age population. The working age population contributes a substantial share of the state's VMT. The median age in Maryland is 39.7[12] years, slightly above the national average of 39 years. Over the next decade, a gradually

aging population will affect where people live and work. An aging population will shift transportation needs of the state, particularly if a larger percent of the population can no longer drive themselves. This will likely cause an increased demand in accessible and user-friendly transportation options, such as public transit in denser areas or on-demand transportation and ride-sharing in less dense areas. This will be crucial to ensuring mobility and quality of life for seniors. Additionally, changing demographic distributions are influential because in areas of the state with high population density, residents tend to rely more on mass transit and non-motorized transportation modes, while those living in rural, ex-urban and less populated areas rely on motor vehicles for connectivity and access. Long term investments will need to factor in changing demographics and economic development to focus on the parts of the state with the potential for highest emission reductions.

4.1.2 Transportation Technology and Options

Maryland's adoption of ACC II and ACT have placed it on a trajectory to turnover much of the passenger vehicle and truck fleet to ZEVs, placing it on a path expected to have well over a million ZEVs by 2031.

Other transportation technologies have the potential to significantly alter transportation GHG emissions in future years. Emerging mobility and accessibility trends toward a "sharing economy" with an increased focus towards "mobility on demand" or "mobility as a service" in transportation. One form of the sharing economy applied to transportation that could significantly decrease transportation emissions is the availability of car-sharing, which is associated with decreased vehicle ownership and subsequently VMT. The nature of CAV technology is still developing, and the impacts of widespread deployment have the potential to impact logistics and supply chain patterns across the transportation system.

4.1.3 Transportation Costs

The cost of transportation varies significantly by mode and affects transportation decisions. Though traveling by car is currently often the fastest and easiest transportation option for many trips, motor vehicle transportation has many layers of costs including car or light truck ownership or leasing, taxes, fuel, maintenance, tolls and insurance. The cost of owning or leasing an automobile and of ICE fuel (e.g., gasoline) has become unpredictable and/or expensive in recent years due to complex global geopolitical and economic reasons. Historically high inflation post-pandemic and high interest rates add to this unpredictability. Insurance is another component of automobile costs. Increased availability of "pay-as-you-drive" insurance could help alleviate the burden of high monthly premiums for some automobile drivers in the state.

Despite this unpredictability, some elements of the cost of automobile ownership are within MDOT's influence. Vehicle registration and other fees and road tolls are all significant portions of travel costs. Maryland policies supplementing federal incentives and investments also decrease the cost of EVs. The Maryland Excise Tax Credit provides up to a maximum of $3,000 for qualifying zero-emission PHEVs or BEVs. Maryland also offers a rebate of 40% of the cost of Electric Vehicle Charging Equipment and Installation. The rebate is up to $700 for individuals; $4,000 for businesses; and $5,000 for retail service stations.

However, MDOT's own spending capabilities are also affected post-pandemic. The cost of labor, material and equipment have all risen due to inflation, irrespective of change in revenues. Access to capital to mitigate this gap is increasingly difficult with higher interest rates.

[12] Maryland - Census Bureau Profile

4.1.4 Land Use and Accessibility Factors

Reducing transportation GHG emissions is also dependent on land use and accessibility factors such as residential and job density and distribution throughout the state. Local municipalities like cities and towns, ultimately determine the availability of housing and jobs and other destinations within their jurisdictions. These changes occur too slowly to have much impact on 2031 emissions.

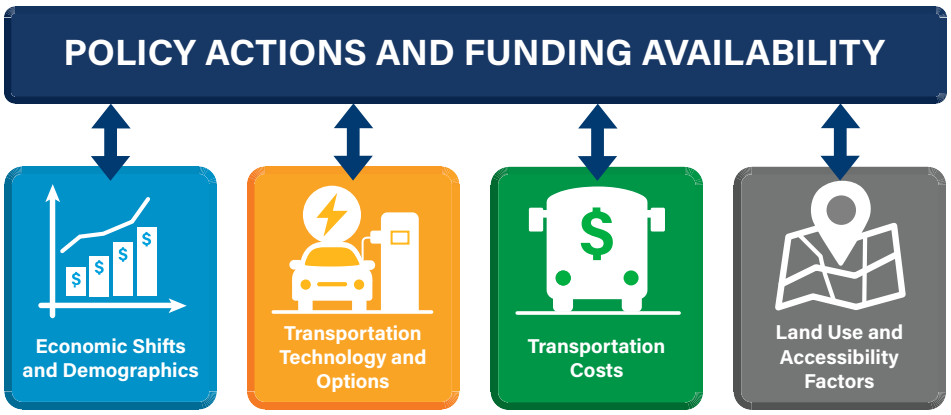
However, near-term changes to roadway design and walkability of MDOT-maintained roads are possible. Similarly, proximity to transit service is also adjustable over the next decade (given sufficient funding and other resources). In addition to owning land suitable for Transit-Oriented Development (TOD) around its stations, MDOT provides resources to help coordinate between agencies in planning, design and investment for TOD, including through a dedicated Office of Real Estate and Economic Development. TOD can help Maryland leverage transportation infrastructure investments, promote active and engaged communities, protect environmental and land resources and support growth without adding traffic congestion. In addition, MDOT has developed a Context Driven Guide that considers factors such as safety, land use, environmental issues, culture and community livability to plan, design, construct and operate facilities that are safe for pedestrians and bicyclists ranging from rural to urban core landscapes.

4.1.5 Policy & Funding

Across all of these challenges, the most significant factor affecting the implementation of all the carbon reduction strategies for on-road emissions is the ability of Maryland to implement policies that provide the funding and other resources necessary for MDOT, partner agencies and other organizations to carry out these strategies. Maryland is currently addressing fiscal uncertainty associated with the transportation-funding picture through 2031 because needs outweigh available resources and revenues. In addition, a key traditional revenue source - state motor fuel taxes - are projected to decline as less fuel is consumed due to improved fuel efficiency and the increase in ZEVs. These funding trends make it difficult for any policy to obtain the necessary funding to become a state action.

MDOT will work with agency partners and local jurisdictions to strive for implementation of the strategies described in **Appendix B**, and coordinate with private sector organizations.

Figure 14. Trends and Drivers



4.2 Public Health and Equity Co-Benefits

Environmental stewardship is one of the goals of the 2050 MTP. The goal focuses on strategies to deliver sustainable transportation infrastructure improvements that protect and reduce impacts on Maryland's environmental resources. Transportation-related control measures and improvements to vehicle technologies that reduce ozone and PM2.5 have been included in State Implementation Plans and transportation conformity determinations. These measures are major contributors to meeting the state's air quality goals and have proven to be effective in attaining the National Ambient Air Quality Standards for ozone and fine particulates.

The strategies presented as part of this plan will reduce VMT and increase fuel-efficiency in the transportation sector. This will deliver cascading benefits beyond emission reductions.

Lower on-road GHG emissions will improve public health directly by also reducing particulate matter emissions. These health benefits are enhanced particularly in urban areas, where most pollution exposure is from the transportation sector. If accompanied by safe and complete street design improvements and investments, reduction in VMT can reduce road crashes and save lives. Strategies such as CAVs and speed management have the potential to reduce fatalities and serious injuries due to roadway crashes. From a demographic perspective, some of these strategies will particularly benefit communities that have historically been overburdened with the negative impacts of transportation-related pollution. Strategies involving some form of transit investment can also benefit low income communities by providing access to other resources such as jobs, education and health care.

The strategies presented as part of this plan will deliver multiple benefits beyond emission reductions. For example, investments in transit, bicycle and pedestrian infrastructure reduce VMT while also improving public health, increasing access to jobs and other necessities, and reducing pedestrian and bicyclist injuries and deaths. Such benefits are especially important and valuable for historically overburdened communities.

4.3 Cost Savings

The need for system preservation is often the largest capital cost in the transportation sector. Reduction in VMT directly translates to reduced deterioration of road surfaces, thus reducing highway management and expansion costs for the state. Transit service expansion has the potential to reduce car ownership needs in dense land use areas, thereby reducing the end users' individual transportation costs. Congestion mitigation and other driving efficiency strategies reduce the time costs of transportation. This is particularly significant for the truck freight sector, which is often time-sensitive.

5.0 Pathways to Net-Zero Emissions by 2045

"Net-zero" GHG emissions refers to the balance between the amount of GHG emissions produced economy-wide and those offset by removing an equivalent amount of emissions by either storing them in natural sinks or using technology to remove them from the atmosphere. The implementation and potential enhancement of the strategies discussed in this document illustrate MDOT's dedication to decarbonizing the transportation sector and contributing to the achievement of net-zero GHG emissions statewide by 2045. The following discussion outlines potential GHG reduction opportunities, challenges and uncertainties that are linked to the future of the transportation sector and potential emission reductions.

5.1 Opportunities

Continued Turnover of the Light-, Medium- and Heavy-Duty Fleets. With the passage of ACC II, Maryland is projected to achieve adoption of approximately 1.34 million light-duty ZEVs by 2031, representing approximately 26% of projected registered light-duty vehicles. Beginning in 2035, 100% of all new car sales in Maryland will be ZEV. Furthermore, ACT is projected to lead to the adoption of 8,922 medium- and heavy-duty ZEVs by 2031. Also, under Advanced Clean Fleets (ACF), covered fleets would need to purchase 100% ZEVs after 2035, which will further increase ZEV adoption in medium- and heavy-duty vehicles.

Sequestration. In total, Maryland's Climate Pathway includes 20.0 mmt CO2e of negative emissions in 2045 — 8.8 mmt CO2e from natural sinks and 11.2 mmt CO2e from technological removals. MDOT is contributing to these initiatives through innovative programs, like participation in Maryland's Five Million Trees Initiative and the administration of the MDOT Urban Tree Grant Program in partnership with the Maryland Urban and Community Forestry Committee.

VMT Reduction. MDOT has set ambitious goals of reducing VMT per capita by 20% by 2050. This reduction is tracked through MDOT's Annual Attainment Report and can be achieved through strategies such as investment in transit, TDM programs (e.g., Commuter Choice Maryland) and the IncenTrip mobile application, which raise awareness of transportation options. These strategies executed by MDOT help Marylanders take more trips via transit, biking and walking and influence travel behavior.

5.2 Challenges

Through Traffic. Through traffic refers to trips that originate and/or terminate outside of Maryland. It is difficult to capture the true nature of this travel and it is difficult for MDOT to influence the technology of the vehicles that are not purchased here and the amount of travel they do in the state.

Medium- and Heavy-Duty Vehicles. Many of these vehicles, particularly fleet vehicles and long-haul trucks, are purchased and registered outside of Maryland. This makes it difficult to influence the vehicle technology choices of the owners.

Local Land Use Decisions. Transportation has a deep connection to land use and housing policy. Since land use decisions are enacted at the local and municipal level, it is difficult to coordinate statewide or regional transportation investments with local land use policy. MDP provides

technical assistance to localities in their municipal planning and coordinates with MDOT to help ensure communication and synchrony between local land use and transportation planning.

5.3 Uncertainties

Funding Constraints. Transportation programs and projects in Maryland are primarily funded from sources including a motor fuel tax, rental car sales tax, titling tax, corporate income tax, operating revenues, federal aid, motor vehicle taxes and fees and bond sales. The distribution of revenue is subject to a number of federal and state laws that constrain how and for what system revenues can be assigned. Another uncertainty associated with funding is diminishing fuel tax revenue that leads to decreasing returns relative to federal sources.

Travel Behavior. The evolution of personal travel behavior has been a key uncertainty as a result of generational shifts in location preferences, vehicle ownership choices and the emergence of mobility as a service and other options. These shifts and changes over time will have a profound impact on decarbonization pathways and transition to low-emissions development.

Technological Maturity and Cost Parity. Thanks in part to generous state and federal consumer incentives, cost parity is appearing in some segments of the auto sector for electric passenger vehicles, which are expected to reach a wider scale in the next few years. However, for the medium- and heavy-duty vehicles, which are contributing an increased share of on-road transportation emissions, parity is expected by 2030 and 2035 respectively[13]. The timing around technological maturity of medium- and heavy-duty EVs, forthcoming federal and state policy supporting these changes and their parity with their ICE equivalents, is a source of uncertainty towards adoption of those vehicles.

Shifting Supply Chain Patterns. As post-pandemic supply chain reconfigurations have shown, global sourcing and logistical shifts, as well as finding new efficiencies, could have a significant impact on freight movement through Maryland's and nearby ports and through traffic.

Climate Impacts and System Resiliency. Rising sea levels, extreme weather and other climate variability is expected to have impacts on coastal communities' infrastructure and travel patterns. People living in these vulnerable areas rely on infrastructure that is increasingly going to be at risk of disruption and damage. The extent to which it is projected to happen by 2045 is still uncertain, but MDOT is planning and preparing to enhance the state transportation infrastructure's resilience.

Figure 15 outlines some of the opportunities, challenges and uncertainties in the transportation sector.

Figure 15. Pathways to Net-Zero Emissions by 2045

OPPORTUNITIES	CHALLENGES	UNCERTAINTIES
Trends and drivers that present inherent opportunities to decrease GHG emissions from the transportation sector	*Trends and drivers that present inherent challenges to mitigating GHG emissions in the transportation sector*	*Trends and drivers where there are too many uncertainties in transportation sector impacts or extent of relevance through 2031*
▪ Federal GHG Emission Standards ▪ Projected ZEV market growth ▪ Transition to an electric transit fleet	▪ Projected population and VMT growth ▪ System delay and reliability ▪ Transportation costs	▪ Autonomous and connected vehicles ▪ Mobility as a service ▪ Change in freight logistics patterns ▪ Climate impacts and system resiliency ▪ Local land use decisions

[13] Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis, Catherine Ledna, Matteo Muratori, Arthur Yip, Paige Jadun, and Chris Hoehne, March 2022 https://www.nrel.gov/docs/fy22osti/82081.pdf

2023 CLIMATE POLLUTION REDUCTION PLAN