TPB Climate Change Mitigation Study of 2021

Task 4 Technical Memo: Scenarios and Associated Greenhouse Gas Reduction Actions

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Prepared for

National Capital Region Transportation Planning Board

1 Introduction and Purpose

The purpose of this technical memo is to describe a set of scenarios for analysis to determine their ability to meet the region's 2030 and 2050 greenhouse gas (GHG) reduction goals (e.g., 50% below 2005 levels and 80% below 2005 levels, respectively), with a focus on on-road transportation sources. These scenarios were constructed to reflect aggressive but potentially realistic opportunities for GHG emissions reduction, based on past studies[1] conducted for the Metropolitan Washington Council of Governments (COG) and the National Capital Region Transportation Planning Board (TPB), the literature review[2] conducted for this study (Task 2), and previous work on climate action planning in the region.

In developing scenarios for the analysis, the ICF team took various considerations into account:

- **Top-down vs. bottom-up scenarios.** The team explored "top-down" scenarios (those designed specifically to meet the GHG goals by defining, for example, a level of vehicle miles traveled (VMT) or fleet technology adoption required to meet the goals) and "bottom-up" scenarios (identifying a set of strategies and implementation levels to assess what level of GHG reduction might be achieved from implementing these strategies). Some of the top-down scenarios are theoretically feasible but might be unrealistic from a policy or implementation timeline perspective. As a result, while we have conducted some "top-down" analysis to help answer the question of what levels of VMT reduction and technology adoption would be needed to meet the GHG reduction goals, we have focused primarily on defining "bottom-up" scenarios for analysis and to explore potential combinations of strategies that could meet the goals.
- **Ability to analyze impacts of scenarios.** In defining scenarios for analysis, it is important to consider the abilities (and limitations) of models and tools to support analysis of different types of transportation strategies and vehicle emission reductions. The scenarios were selected to be feasible to analyze using primarily sketch planning methods, including the TRIMMS[3] (Trip Reduction Impacts of Mobility Management Strategies) tool, which explores mode shift and travel behavior strategies and has been applied for regional GHG analysis by the U.S. Environmental Protection Agency and utilized in prior analysis for COG's Multisector Work Group (MSWG); the Argonne National Laboratory's VISION[4] model (which allows exploration of alternative vehicle technology and fuels strategies); and spreadsheet-based analysis that utilizes emissions factors from EPA's MOVES[5] (Motor Vehicle Emission Simulator) to estimate emissions for mobile sources. The project team plans to rely primarily upon these sketch planning tools, along with limited analysis using the region's travel demand forecasting model to analyze some mode shift and travel behavior (MSTB) strategies, and feed results from these analyses into

[1] Morrow, Erin, Dusan Vuksan, and Mark S. Moran. "TPB Climate Change Mitigation Study of 2021, Phase 1 Report: Greenhouse Gas Emissions Reductions Strategies: Findings from Past Studies." Metropolitan Washington Council of Governments, National Capital Region Transportation Planning Board, March 2, 2021. https://www.mwcog.org/file.aspx?&A=MiD6Ji82bKyfKHZzxf4NWsf6IDtx%2bOIVznGk7eZoe1E%3d.

[2] ICF. "TPB Climate Change Mitigation Study of 2021: A Review of Climate Action Plans and Literature on Transportation Greenhouse Gas Emissions Reduction Strategies and Their Effectiveness." National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, July 8, 2021. https://www.mwcog.org/events/2021/7/9/tpb-technical-committee/.

[3] Sisinnio, Concas. TRIMMS. Center for Urban Transportation Research, University of South Florida. Accessed August 23, 2021. http://trimms.com/.

[4] "VISION Model: Argonne National Laboratory." VISION Model. Argonne National Laboratory. Accessed August 23, 2021. https://www.anl.gov/es/vision-model.

[5] "MOVES and Other Mobile Source Emissions Models." EPA. Environmental Protection Agency. Accessed August 23, 2021. https://www.epa.gov/moves.

spreadsheet tools developed for this study. Other tools such as VisionEval[6], a strategic planning model that addresses multiple types of transportation GHG reduction strategies, were explored but determined to be too data intensive or time-consuming for use given the timeframe for this study.

- **Considerations related to electricity-associated emissions for EV charging.** Within the context of this climate change mitigation study, we plan to explore transportation emissions accounting both for direct emissions from combustion of fuels (including both tailpipe and evaporative emissions) and emissions associated with electricity used to power electric vehicles (EVs). Strategies that shift the vehicle fleet to EVs and other zero emission vehicles (ZEVs) will not zero out emissions from those vehicles unless the power grid is also zero emissions. Consequently, assumptions about the power sector have an important impact on the ability to meet emissions reduction goals in this analysis. ICF has developed several different assumptions for carbon intensity of electricity emissions to be used in combination with the scenarios (described further in Section 5 below).

2 Pathways for Reducing Transportation GHG Emissions

The ICF team established a set of scenarios covering the three primary pathways for reducing transportation GHG emissions:

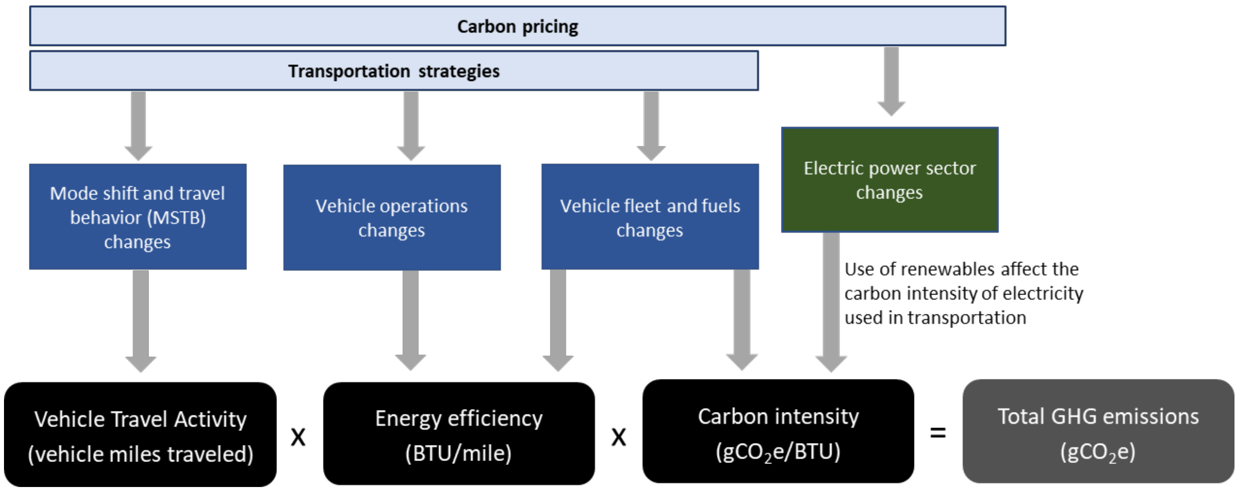
1) **Mode shift and travel behavior (MSTB) changes –** MSTB strategies focus on shifting travel activity to modes that reduce VMT and produce lower emissions; these strategies include land use policies; investments and support for public transit[7], ridesharing, bicycling, walking, telework, and other options; and disincentives for use of private motor vehicles (e.g., road and parking pricing).
2) **Vehicle technology and fuel changes –** Vehicle technology and fuels strategies include interventions that improve the fuel economy of conventional vehicles, shift to fuels with a lower carbon content (e.g., biodiesel, renewable diesel, renewable gas, hydrogen), or replace internal combustion engine (ICE) vehicles with ZEVs, eliminating tailpipe emissions.
3) **Vehicle operations changes** (e.g., changes in vehicle speeds, idling, and smoothness of traffic flow) **–** Transportation systems management and operations (**TSMO**) strategies, such as enhanced traffic signal coordination, incident management, work zone management, as well as idling reduction and eco-driving strategies reduce vehicle delay and affect the flow of traffic and efficiency of travel without changing the vehicles themselves. Connected and automated vehicles (CAVs) also offer the potential to enhance operations through reductions in traffic incidents, enhanced vehicle-to-vehicle and vehicle-to-infrastructure communications to optimize traffic flow, and strategies such as truck platooning that can enhance truck fuel economy.

As shown in Figure 1, transportation strategies typically affect one of three key factors that contribute to GHG emissions, namely vehicle travel activity, the per-mile energy efficiency of travel (often expressed as miles per gallon or miles per gallon equivalent), and the carbon intensity of fuels used. Electric power strategies that support a carbon-free electric grid affect the carbon intensity of electricity used to power ZEVs (as well as to power rail transit), and so also play an important role in total GHG emissions from transportation.

[6] "VisionEval." Collaborative Development of New Strategic Planning Models Pooled Fund. Accessed August 23, 2021. https://visioneval.org/.

[7] In this study, public transit includes buses and rail (heavy-rail, light-rail, commuter rail); as the study is focusing on surface transportation, the scenarios do not explore strategies focused on long-distance travel such as shifting aviation activity to intercity rail.

Figure 1. Strategies and Pathways for Reducing GHG Emissions from Transportation



It is useful to note that while most transportation strategies focus on one individual pathway (e.g., land use and transit strategies focus on MSTB changes, TSMO strategies focus on vehicle operations changes, and EV incentives and charging infrastructure focus on vehicle fleet changes), there are some interactions among effects. For instance, significant reductions in VMT will reduce traffic congestion, leading to changes in traffic flow and vehicle operations; shifts to EVs and more fuel-efficient vehicles that reduce the cost of driving may lead to a "rebound effect" with some increase in VMT. These interactions are complex and difficult to analyze in this type of study, but the proposed analysis approach will attempt to consider these interactions.

It is also important to recognize that carbon pricing is a strategy that supports multiple pathways by providing an economic incentive to drive less, shift to more fuel-efficient vehicles, and shift to lower-carbon fuels. Carbon pricing can occur in the form of a fee on carbon emissions (somewhat similar to a gas tax) or market-based mechanisms such as cap-and-trade or cap-and-invest programs. Carbon pricing is often identified as a very effective mechanism to advance GHG reduction and is one of the tools that may be used by policy makers to support vehicle fleet changes and mode shifts that will be analyzed in the scenarios.

3 Results from Top-Down Analysis

The ICF team conducted a "top-down" analysis to identify what would be required to achieve the 2030 and 2050 GHG reduction goals through two of the three pathways previously described - VMT reduction alone and vehicle technology/fuel changes alone. The TSMO pathway was not analyzed as a stand-alone strategy as part of the "top-down" analysis since the literature review suggested that the levels of GHG reduction required to meet the region's aggressive 2030 and 2050 goals would not be possible through TSMO strategies alone.

The intent of this top-down analysis prior to developing bottom-up scenarios was to help answer questions about what level of VMT reduction would be needed to meet the goals if that were the sole focus of efforts (given current baseline assumptions about the future vehicle fleet), and conversely what level of technology adoption would be needed to meet the goals without additional VMT reduction actions beyond those already in place or in the region's Long-Range Transportation Plan, Visualize 2045.

The analysis was conducted focusing on on-road vehicle emissions (including both direct "tailpipe" emissions and upstream emissions associated with electricity use for EVs).[8]

VMT Reduction Alone

Our analysis suggests that achieving the 50% and 80% GHG reduction goals compared to 2005 levels solely through VMT reduction would require the following:

- In 2030, **passenger VMT would need to be reduced by 57% from the 2018 level.** Total passenger travel in light-duty vehicles (including passenger cars, light-duty trucks, and motorcycles)[9], would need to be held to no more than 16.27 billion vehicle miles annually in 2030, down from an estimated 38.11 billion vehicle miles in 2018. Given that the region's population is forecast to grow from about 5.57 million in 2018 to 6.25 million in 2030 and VMT otherwise is expected to increase, this equates to a 61% reduction in passenger VMT compared to the forecast levels in 2030 (forecast to be 42.23 billion VMT in 2030). Passenger VMT per capita would need to drop from an average of 18.74 vehicle miles daily in 2018 to 7.13 vehicle miles daily in 2030 (compared to a forecast level of 18.52 vehicle miles daily in 2030).
- In 2050, it is **not possible to get to the 80% reduction goal through passenger VMT reduction alone**. Even if all passenger VMT were eliminated, emissions from medium and heavy-duty vehicles, including light-commercial trucks, freight/refuse trucks, and buses, are estimated to exceed the 2050 goal level of emissions of 4.15 million metric tons by 2.24 million metric tons.[10] Because these vehicles perform essential commercial functions, VMT reduction from public and commercial vehicles are not generally expected to occur, and MSTB strategies generally focus on shifting people from driving to transit, ridesharing, walking, bicycling, and other modes, rather than reducing travel from freight/commercial trucks and buses.

Figure 2 shows that while VMT per capita is forecast to decline in the region under existing plans, the level of reduction in passenger VMT per capita needed to meet the goal through VMT reduction alone would be extremely large. Figure 3 shows the total passenger VMT reduction required in the region to meet the 2030 and 2050 goals. These figures demonstrate that it is not possible to meet the 2050 goal through passenger VMT reduction alone.

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[8] The goal level for transportation emissions was calculated based on the 2005 inventory estimate of 20.75 million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.) emissions from on-road sources, yielding a 2030 goal of 10.38 MMT CO_2 Eq. (50% reduction) and a 2050 goal level of 4.15 MMT CO_2 Eq. (80% reduction). Rail emissions, including those from diesel trains (commuter rail, freight) and electricity used for transit, have been estimated but were not accounted for in calculating the goal level of emissions, given further work needed to forecast future rail activity and transit rail electricity consumption for 2030 and 2050. These emissions are approximately 1% of the on-road emissions in 2005.

[9] These figures do not include VMT by light commercial trucks, medium- and heavy-duty trucks (such as those used in freight, refuse collection, and construction), or buses. Note that passenger travel in this analysis includes all travel in light-duty passenger vehicles, including those used by households and for business purposes.

[10] The 2050 figures were calculated using the 2045 forecasts of VMT and on-road emissions from the region's Visualize 2045 plan and extrapolated to 2050 assuming the same rate of VMT growth for each vehicle category from 2040-2045 would occur over the period 2045-2050, with no further improvement in emissions rates.

Figure 2: Daily Passenger VMT per Capita Required to Meet GHG Goals through VMT Reduction Alone[11]

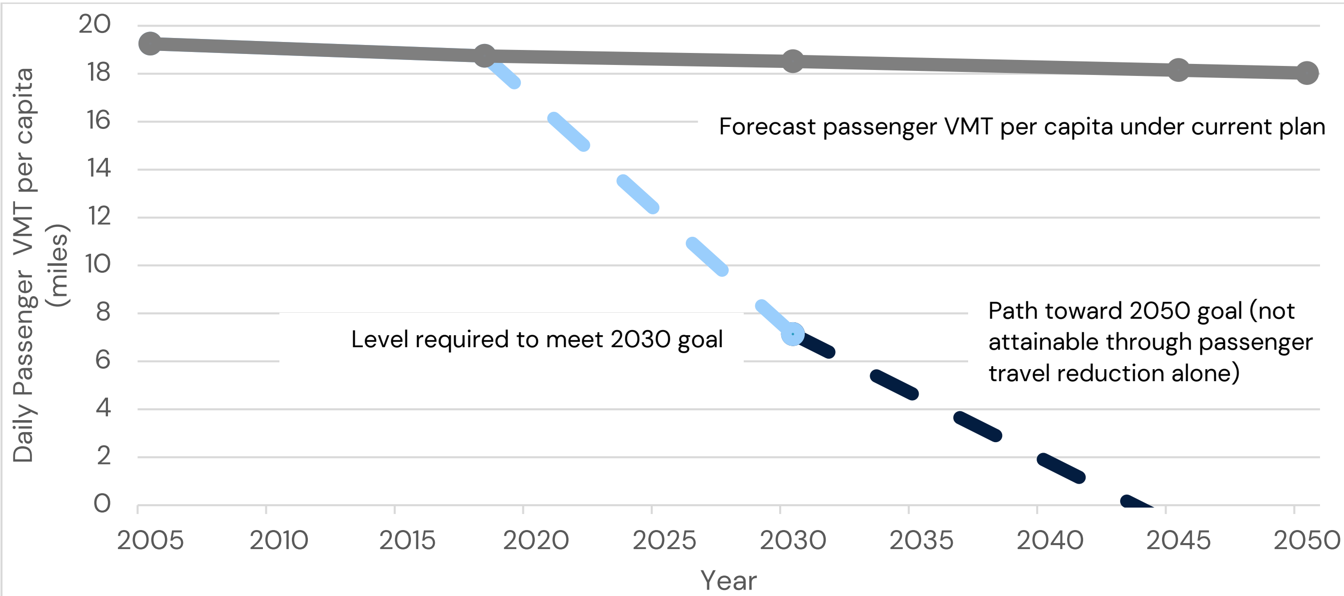
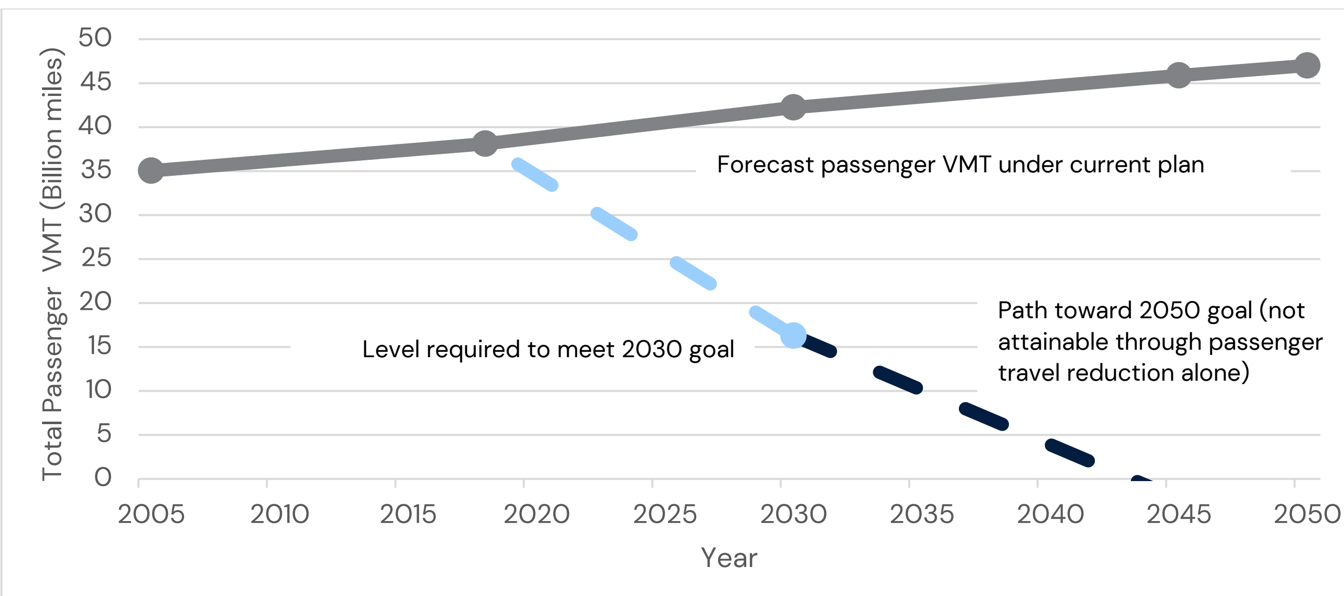


Figure 3: Annual Total Passenger VMT Required to Meet GHG Goals through VMT Reduction Alone



[11] Baseline passenger VMT per capita was calculated based on COG population and VMT projections for passenger cars and passenger trucks. Required per capita VMT was calculated by solving for the passenger VMT level needed to achieve the 50% emissions reduction by 2030 and 80% emissions reduction by 2050 using average passenger vehicle emissions rates in the target year. This VMT was then divided by the projected COG population in the target year.

These results suggest that it would be extremely challenging, if not unrealistic, to meet the 2030 goal with VMT reduction strategies without further vehicle technology improvements. Particularly for 2030, just nine years away, the levels of VMT reduction needed (if that pathway alone were pursued) to achieve the goal would require unprecedented levels of reduction in driving – slightly larger reductions than seen at the peak of pandemic stay at home orders in April 2020, when all schools and businesses but essential workers - were closed or employees told to stay home, and regional traffic volume dropped by about 50% temporarily (by July 2020, while most schools and businesses continued to be on-line/remote-only, traffic volumes had recovered to about 80% of pre-pandemic levels).[12] Sustained traffic reductions at such a level would likely require very high levels of pricing (parking pricing, road pricing, and/or fuel pricing), near complete telework for eligible workers, and/or restrictions on driving. Moreover, the reduction in VMT would need to be occurring over a time when the region's population is forecast to increase by 12% (between 2018 and 2030).

As a point of comparison, California metropolitan planning organizations (MPOs) have VMT reduction goals with targets generally ranging from a 13% to 19% reduction in VMT per capita by 2035 relative to 2005[13], and these MPOs have faced challenges demonstrating how such levels of reductions in VMT per capita could be met. Also note that these are VMT per capita targets for California MPOs, and regional levels of VMT for large MPOs are forecast to increase due to population growth even if the VMT per capita targets are met.

Vehicle Technology Alone

Based on an analysis of vehicle stock and GHG emissions, we estimated what level of EVs (or other forms of ZEVs such as fuel cells) in the fleet would be necessary to achieve the 50% and 80% GHG reduction goals solely through technology adoption, without any changes in forecast VMT. This analysis used very simplified assumptions (such as assuming proportionate EV adoption across vehicle classes) and no other improvements in low-carbon fuels. Fuel economy improvements for ICE vehicles from the baseline forecast were preserved. More detailed and robust analysis will be conducted as part of the bottom-up scenarios defined in Section 4 below, incorporating different assumptions for EV sales for different vehicle types. The simplified analysis suggests that the following would be required, with results shown in Figure 4 for the reference electricity emissions case (which assumes some improvements in carbon intensity from electricity generation) and Figure 5 for the clean grid electricity emissions case (which assumes a path to net zero emissions from electricity generation by 2035):[14]

- In 2030, the **average emissions rate of all vehicles (**across light-, medium-, and heavy-duty vehicle classes**) would need to be reduced by 56% compared to the 2018 level**, while in the baseline forecast, emissions rates are expected to decline by about 25% over this time period (reflecting policies[15] expected to improve the average fuel economy of the fleet, including increased EV adoption in the baseline forecast). These figures essentially mean that average vehicle fuel economy of vehicles on the road must more than double between 2018 and 2030. To get to these levels, only considering direct mobile source emissions (not accounting for emissions from electricity consumption),

[12] Canan, Tim. "Transportation Impacts of the COVID-19 Pandemic in the National Capital Region." Presented at the January meeting of the National Capital Region Transportation Planning Board, held at the Metropolitan Washington Council of Governments, January 21, 2021. https://www.mwcog.org/events/2021/1/21/transportation-planning-board/.

[13] California Air Resources Board. "SB 375 Regional Plan Climate Targets." https://ww2.arb.ca.gov/our-work/programs/sustainable-communities-program/regional-plan-targets.

[14] This calculation involved estimating the percent of VMT that would be needed from EVs in 2030 and 2050, calculated using estimated net emissions benefits of switching to EVs for each vehicle type weighted by the estimated VMT distribution.

[15] Emissions rates were derived from MOVES2014b outputs for 2005, 2018, and 2030 from the GHG Inventory Study, for 2045 from the 2020 Amendment to Visualize 2045, and for 2050 assumed the same 2045 emissions rates for internal combustion engine vehicles. These reflect the 2012 standards, not the SAFE Vehicles Rule.

approximately 44% of vehicles on the road would need to be EVs in 2030, assuming proportionate reductions across vehicle classes (passenger cars and trucks, buses, medium- and heavy-duty trucks, etc.) and no other improvements in low-carbon fuels or vehicle fuel economy in the rest of the fleet.[16] When accounting for emissions from electricity used to charge electric vehicles, achieving a 50% overall reduction in GHG emissions compared to 2005 levels would require **approximately 75% of the vehicles on the road to be EVs** in 2030,[17] based on ICF's assumed Reference Case for carbon intensity of electricity, which assumes improvements in electricity carbon intensity based on current on-the-books policies. The share of vehicles that need to be EVs would be lower with an even cleaner electric grid. In the Clean Grid Case, achieving a 50% overall reduction in GHG emissions compared to 2005 levels would require approximately 48% of the vehicles on the road to be EVs in 2030.[18] ICF's assumptions for the Reference Case and Clean Grid Case are described further in Section 5.

- In 2050, the **average emissions rate of all vehicles** (across light-, medium-, and heavy-duty vehicle classes) **would need to be reduced by 84% compared to the 2018 level,** while in the baseline forecast, emissions rates are expected to be reduced by about 32% over this time period (as the most significant benefits of existing fuel economy standards have largely already been achieved well before 2050). When accounting for emissions from electricity generation, **achieving the 2050 goal level would not be attainable, based on ICF's assumed Reference Case electricity emissions factors** for the region.[19] In the Clean Grid Case, achieving an 80% reduction in GHG emissions compared to 2005 levels would require approximately 79% of the vehicles on the road to be EVs in 2050. ICF's assumptions for the Reference Case and Clean Grid Case are described further in Section 5.

[16] If only focusing on passenger cars and trucks, about 64% of passenger cars and trucks on the road would need to be EVs, assuming other classes of vehicles follow the baseline forecast, if only accounting for tailpipe emissions.
[17] For purpose of this analysis and the figures reported, we assume that the average mileage driven is similar for EVs and internal combustion engine vehicles. These calculations assume proportional EV deployment across all vehicle types for simplicity of presentation. The scenario study will explore different scenarios regarding the shares of EVs across different types of vehicles (passenger cars and trucks, buses, medium- and heavy-duty trucks, etc.).
[18] Note that VMT is forecast to increase between 2005 and 2030, while emissions rates from internal combustion engine vehicles are anticipated to decline over this period due to improvements in vehicle fuel economy; this clean grid case does not assume an entirely zero emissions electric grid by 2030 but by 2035.
[19] Assumptions are similar to those for 2030.

Figure 4: Forecast VMT by Technology Type Required to Meet GHG Goals through Shifts to EVs Alone, Reference Case for Electricity Carbon Intensity

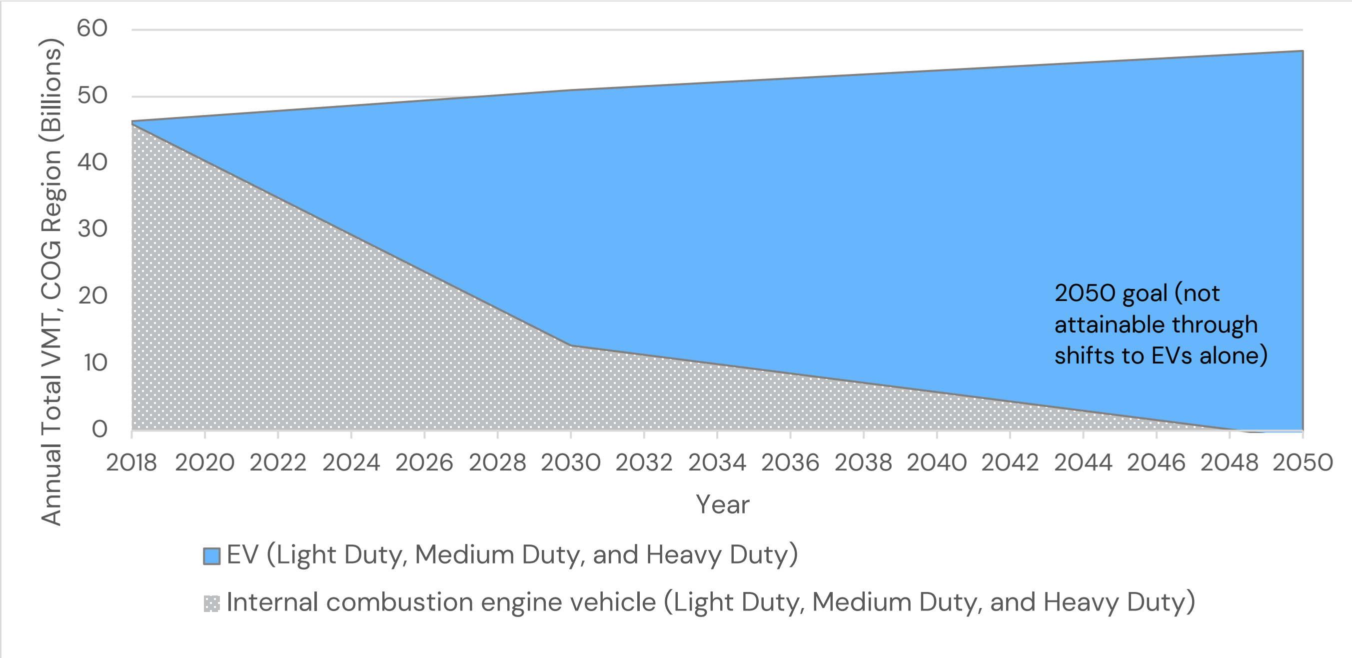
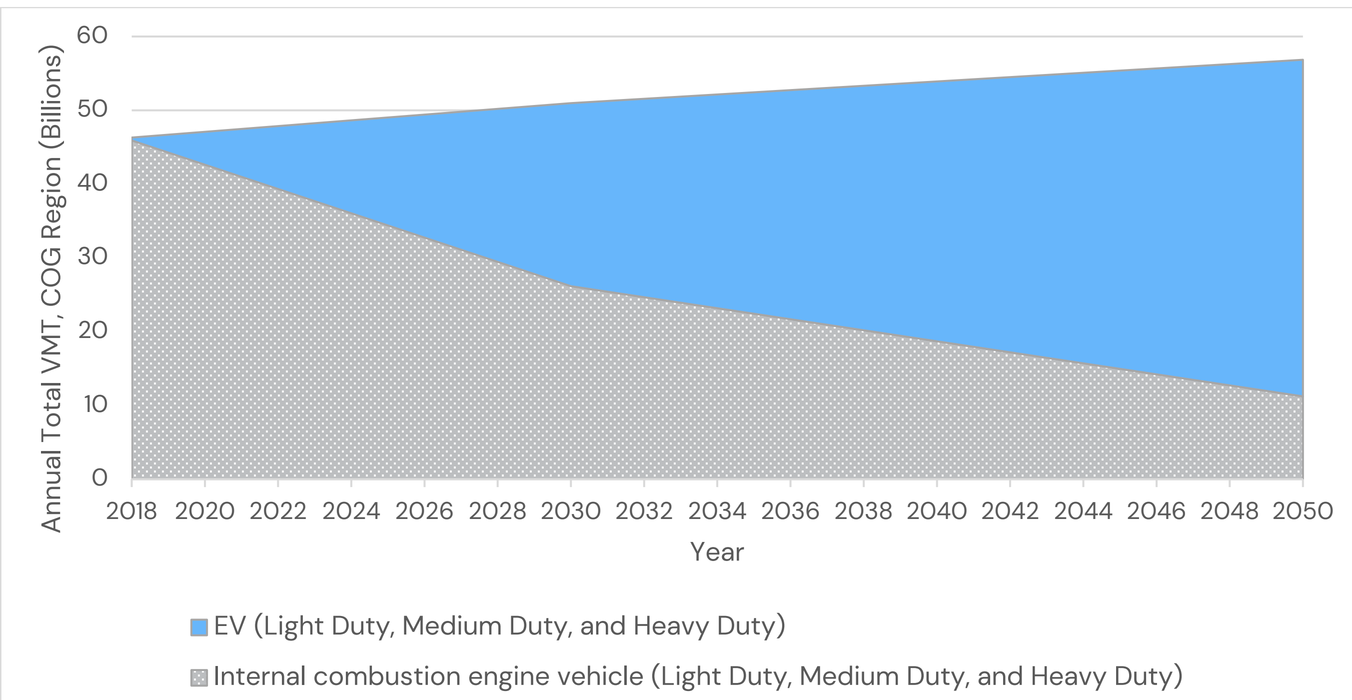


Figure 5: Forecast VMT by Technology Type Required to Meet GHG Goals through Shifts to EVs Alone, Clean Grid Case



Similar to the difficulty associated with VMT reduction needed by 2030, achieving the dramatic changes in the vehicle fleet by 2030 needed to achieve the 2030 GHG goal through shifts to EVs alone appears extremely challenging. The baseline forecast assumes that EVs would make up approximately 6% of VMT in 2030, so increasing that share to 75% is a dramatic change in the fleet. This level of fleet change would be very difficult to achieve by 2030 with the typical timeframes that vehicles are held and rate of turn-over in the fleet. Such an outcome would likely require nearly immediate shifts to having all new vehicles sold as EVs, combined with aggressive consumer incentives including buy-back programs for vehicles to accelerate the rate at which consumers opt for new vehicles, rapid deployment of EV-infrastructure, full public sector fleet conversions to EVs, and/or increases in carbon or fuel pricing to help spur demand. The literature review suggested that even under aggressive scenarios where EV sales ramp up to 100% of new passenger vehicles sold in 2030, EVs may still make up just about a quarter of all vehicles on the road, given the large number of conventional vehicles that would remain in the fleet.

Given the additional twenty years to meet the 80% reduction goal by 2050, it appears that a full-scale shift to EVs could potentially enable attainment of the goal to be met through vehicle technology changes (without new VMT reduction efforts) with assumptions for a clean power grid, through nearly universal shifts to EVs across most classes of vehicles. However, there are risks to meeting the goal with such an approach if the fleet does not turn-over as quickly as anticipated. Moreover, during the transition time period to EVs, reducing vehicle travel through strategies that enhance transit and other options is typically viewed as a "no regrets" approach that can yield multiple benefits. Importantly, given the cumulative nature of GHG emissions in the atmosphere, the level of emissions over the intervening time between now and 2050 is an important consideration, and MSTB strategies can play an important role in reducing emissions over the time period when the fleet is transitioning to EVs and the power grid is decarbonizing.

TSMO Strategies Alone

TSMO strategies were not analyzed for this top-down analysis since these strategies (e.g., eco-driving, better signal control and traffic management) alone cannot achieve the aggressive GHG reduction goals, based on what is known about these strategies from the literature. Studies generally suggest GHG emissions reductions of up to a few percent may be achieved from TSMO strategies on a regional scale. For instance, a meta-analysis conducted for the California Air Resources Board (CARB) identified three studies that estimated GHG impacts of incident management programs, with fuel use or GHG benefits ranging from 0.07% to 4% along the affected roadways.[20] A simulation study addressing multiple operational improvement strategies (ramp metering, incident management, active signal control, and active transportation demand management including lane control, queue warning, junction control, and traveler information) conducted in the San Francisco Bay Area suggested that such strategies could reduce vehicle CO_2 emissions by about 1.6% at a regional scale. [21] Another simulation study investigating the potential emissions impacts that speed smoothing from connected and automated vehicles could achieve estimated that GHGs could be reduced between 3% and 6.6%.[22] TSMO strategies will, however, be analyzed as part of bottom-up analysis, and in combination with other scenarios.

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[20] Avetisyan, H. G., Miller-Hooks, E., Melanta, S., & Qi, B. (2014). Effects of vehicle technologies, traffic volume changes, incidents and work zones on greenhouse gas emissions production. Transportation Research Part D: Transport and Environment, 26, 10-19.
[21] FHWA, "Travel and Emissions Impacts of Highway Operations Strategies," Final Report, dated March 2014, prepared by Cambridge Systematics.
[22] Liu, Jun, Kara M. Kockelman, and Aqshems Nichols. "Anticipating the Emissions Impacts of Smoother Driving by Connected and Autonomous Vehicles, Using the Moves Model." Washington, D.C., 2018. https://www.ce.utexas.edu/prof/kockelman/public_html/TRB17CAVEmissions.pdf.

Implications

The simple top-down analysis of what it would take to reach the 2030 or 2050 goals highlights how challenging it would be to reach the goals set, particularly for 2030, through either VMT reduction alone or shifts to EVs alone. This analysis suggests the importance of pursuing multiple pathways to GHG reduction in transportation. Given the benefits of exploring multiple pathways in combination, this study will rely on a bottom-up analysis of different scenarios for each of these pathways and combination of pathways. For practical purposes, the modeling of standalone scenarios will be conducted first, and then scenarios addressing multiple pathways will be combined and layered.

4 Scenarios for Analysis

We plan to analyze the following ten (10) scenarios, which reflect different strategies and implementation levels, as well as combinations of pathways to identify those that could meet the GHG reduction goals for 2030 and 2050. These scenarios have been defined building on analyses conducted for the regional 2030 Climate and Energy Action Plan (CEAP),[23] the previous work of the Multi Sector Work Group (MSWG), and the Long-Range Plan Task Force (LRPTF). Table 1 summarizes the scenarios organized by the pathways.

Table 1: Scenarios to be Analyzed

Pathway	Scenario	Title
Vehicle Technology and Fuels Improvements	VT.1	Vehicle Technology and Fuels Improvement Scenario
	VT.2	Amplified Vehicle Technology and Fuels Improvement Scenario
Mode Shift and Travel Behavior	MS.1	Mode Shift Scenario
	MS.2	Amplified Mode Shift Scenario
	MS.3	Amplified Mode Shift Scenario + Road Pricing
Transportation Systems Management and Operation (TSMO)	TSMO	Transportation System Management and Operations Improvement Scenario
Combined Pathways	COMBO.1	Combined Scenario (VT.1 + MS.1 + TSMO)
	COMBO.2	Combined Scenario with More Aggressive Technology Emphasis (VT.2 + MS.1 + TSMO)
	COMBO.3	Combined Scenario with More Aggressive Mode Shift Emphasis (VT.1 + MS.3 + TSMO)
	COMBO.4	Combined Scenario with Aggressive Actions Across All Pathways and Shared Connected and Automated Vehicle (CAV) Future (VT.2 + MS.3 + shared CAV assumptions)

Several of the scenarios layer others on top of each other to allow an assessment of the combined effects of multiple types of strategies (such as combining MSTB with TSMO and vehicle electrification). These

[23] "Metropolitan Washington 2030 Climate and Energy Action Plan" (Washington, D.C.: Metropolitan Washington Council of Governments, November 18, 2020), https://www.mwcog.org/documents/2020/11/18/metropolitan-washington-2030-climate-and-energy-action-plan/.

combinations of scenarios are anticipated to be the most effective in yielding significant GHG reductions to meet the region's goals.

It should be noted that while carbon pricing is not a specific scenario to be analyzed, carbon pricing is a policy mechanism that could significantly support changes in vehicle technology, as well as mode shifts, that are accounted for in other scenarios. Moreover, the price of fuel is expected to have an important role in vehicle travel and vehicle technology choices, whether adjusted through policy action or exogenous factors. The impacts of the Transportation and Climate Initiative Program (TCI-P), which would set a cap on CO_2 pollution from on-road transportation in participating jurisdictions that declines by 30 percent from 2023 to 2032, have been modeled in other studies, and will be a reference point for considering how such a policy could play a role in achieving the level of vehicle fleet changes and support VMT reductions in the scenarios specified for this study.

The assumptions associated with each scenario are described below.

Vehicle Technology and Fuels Improvement Scenarios

Vehicle technology and fuels improvement scenarios rely on technological advancements including an aggressive expansion of EVs and an increase in use of low carbon fuels. Our proposed scenarios are aggressive and include a mix of alternative variations of vehicle technologies across different classes of vehicles.

Scenario VT.1: Vehicle Technology and Fuels Improvement Scenario

This scenario relies on the adoption of a broad range of strategies to advance the adoption of EVs and low-carbon fuels, including new vehicle fuel economy requirements, incentives for purchases of zero emission vehicles, outreach and education, expansion of EV-charging infrastructure, carbon pricing, and/or implementation of low-carbon fuel standards. The scenario assumes:

- **50% of new light-duty passenger car and truck sales are EVs in 2030, ramping up to 100% of new vehicle sales by 2040**: These figures are consistent with President Biden's recently announced national goals[24] for new vehicle sales by 2030, and consistent with a recent American Lung Association study[25] on electric vehicles. Growth in EV sales percentages are assumed to increase linearly over time.[26]
- **30% of new medium and heavy-duty truck sales are EVs in 2030, ramping up to 100% of new truck sales by 2050**: The focus of this component of the scenario is to be consistent with the multi-jurisdiction Memorandum of Understanding (MOU) signed by Maryland and the District of Columbia committing them to strive to make at least 30% of all new medium- and heavy-duty vehicle sales zero-emission vehicles by 2030, and 100% by 2050 (the MOU has different sales rates for different classes of vehicles, which will be integrated into the analysis).[27] The COG CEAP assumed that by 2030,

[24] Ewing, Jack, "President Biden sets a goal of 50 percent electric vehicle sales by 2030." *The New York Times*. August 5, 2021. https://www.nytimes.com/2021/08/05/business/biden-electric-vehicles.html

[25] "Road to Clean Air - Electric Vehicle Report." American Lung Association, September 2, 2020. https://www.lung.org/clean-air/electric-vehicle-report.

[26] Under this scenario, approximately 18% of total light-duty vehicles on the road are EVs in 2030, which is less than the estimated level of 34% assumed in the region's Climate and Energy Action Plan (CEAP). This assumption for the scenario was selected to reflect an aggressive but realistic assumption, although it is less than included in the CEAP.

[27] NESCAUM, "Multi-State Medium and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding." Note that these goals include buses, which are addressed separately here.

7% of medium-duty and 6% of heavy-duty vehicles on the road will be electric to meet the region's goal for 2030, which may differ somewhat from the results of this analysis but are expected to be in a similar range when analysis is completed.

- **50% of school and transit buses <u>on the road</u> are EVs in 2030, and 100% in 2050**: Local transit agencies across the Washington, D.C. region have deployed electric buses, and WMATA is engaging in zero-emission bus planning to move to a fully zero-emission bus fleet by 2045.[28] Through a partnership with Dominion, Virginia localities including Arlington, Alexandria, Fairfax County, and Prince William County, are deploying electric school buses as part of a plan to move Virginia toward all-electric school bus fleets by 2030. Montgomery County is leveraging a unique leasing and servicing structure to transition 300 school buses to electric in the next three years and plans to replace all 1,422 buses in their fleet by 2035.[29] And other counties in Maryland are deploying electric vehicles as well. This scenario assumes that it will take beyond 2030 to get to complete replacement of the bus fleet and deploy associated EV infrastructure.
- **A modest reduction in the carbon intensity of diesel, due to increased use of biodiesel and renewable diesel,** consistent with what might be achieved with a low-carbon fuel standard policy and supported by carbon pricing. Both have a carbon intensity that is about one-third that of diesel. Biodiesel must be blended with conventional diesel, while renewable diesel is a "drop in" fuel that can be used in any diesel engine.

Scenario VT.2: Amplified Vehicle Technology Improvement

This scenario relies on an even more aggressive set of strategies to advance the adoption of EVs and low-carbon fuels. This scenario assumes:

- **100% of <u>new</u> light-duty passenger car and truck sales are EVs by 2030**: These figures are consistent with figures used in the Rocky Mountain Institute study focusing on ways to limit cumulative GHG emissions compatible with 1.5-degree Celsius warming, and are even more aggressive than the recent order by California's governor for the California Air Resources Board to develop regulations that mandate that 100% of new passenger cars and trucks sold in the state would be zero-emission by 2035.[30] [31] This scenario would also assume vehicle incentives and buy-backs to advance the rate of fleet turnover to achieve the EV levels assumed in COG's CEAP, which is that 34% of light-duty vehicles on the road would be EVs by 2030.
- **50% of <u>new</u> medium and heavy-duty truck sales are EVs in 2030, ramping up to 100% of new truck sales by 2040**: These figures go beyond the assumptions in the VT.1 scenario and are quite aggressive, while being generally consistent with the California Advanced Clean Trucks (ACT) rules,

[28] WMATA, Zero-Emission Bus Update, website.
[29] Steven Mufson and Sarah Kaplan, "Montgomery County School Board Seals Deal to Get 300 of the Buses," *The Washington Post*, February 24, 2021, sec. Climate Solutions, https://www.washingtonpost.com/climate-solutions/2021/02/24/climate-solutions-electric-schoolbuses/.
[30] Office of Governor Gavin Newsom, "Governor Newsom Announces California Will Phase Out Gasoline-Powered Cars & Drastically Reduce Demand for Fossil Fuel in California's Fight Against Climate Change", September 23, 2020.
[31] The extent to which the overall light-duty fleet is converted to EVs will depend on the rate at which EV sales ramp up. According to the Rocky Mountain Institute Study, 100% of new light-duty vehicle sales at EVs in 2030 would likely equate to about 20% of light-duty vehicles on the road as EVs in 2030 and nearly 100% in 2050. To be consistent with COG's CEAP, we assume that 34% of light-duty vehicles on the road would be EVs in 2030, which would reflect a significantly higher level of vehicle turn-over than under typical conditions. This assumption seems very aggressive but is not as aggressive as the Montgomery County Climate Action Plan, which assumes 100% electrification of transportation options by 2035.

which would require zero-emission truck sales to be 55% of Class 2b-3 truck sales, 75% of Class 4-8 truck sales, and 40% of truck tractor sales by 2035.[32] Different sales rate assumptions for different vehicle classes will be integrated into the analysis.

- **100% of transit and school buses on the road are EVs by 2030**: Under this scenario, bus fleet conversion is accelerated more quickly than in the VT.1 scenario.
- **A more substantial increase in use of biofuels,** consistent with what might be achieved with a more aggressive low-carbon fuel standard policy, mandates, and potentially supported by carbon pricing.

Mode Shift and Travel Behavior Scenarios

The MSTB scenarios each assume a combination of strategies being implemented together to yield reductions in VMT. These scenarios build on assumptions used in past TPB and COG studies (COG's 2030 CEAP, MSWG, and LRPTF). The analysis for the MSTB scenarios will differ from past studies, which generally analyzed MSTB strategies individually, by considering how MSTB strategies can impact each other.

Scenario MS.1: Mode Shift Scenario

This scenario draws heavily from MSTB strategies included in past COG and TPB studies including the MSWG, LRPTF, and 2030 CEAP. Assumptions for this scenario include:

- **Land use changes and bicycle/pedestrian/micro-mobility enhancements**: Land use changes will be assumed so that incremental growth after 2025 (for 2030 and 2050) outside of Activity Centers would be shifted to Activity Centers and areas with high-capacity transit stations within the jurisdiction, with a focus on improving jobs-housing balance, similar to the LRPTF aspirational land use initiative.[33] This analysis will rely largely upon the previous LRPTF assumptions/results, for modeling, as well as additional assumptions about mode shift to bicycle/ped/micro-mobility for short trips.
- **Transit fare reductions**: Transit fares reduced 50% by 2030 and 75% by 2050. This assumption is more aggressive than what was analyzed in the MSWG where transit fares were reduced regionally by 25% in 2040 and 40% in 2050. These fare reductions could be in the form of overall system-wide price reductions and/or subsidies provided by employers.
- **Travel demand management strategies**: 25% telework assumption on an average day (equates to about 50% telework for "office" employees, which make up about half of the workforce; this could be in the form of a hybrid work arrangement where employees on average work from home 2-3 days per week); all workplace parking in Activity Centers is priced by 2030 (more aggressive than MSWG assumptions). These assumptions are generally consistent with, but somewhat more aggressive than those assumed in the LRPTF study.
- **Transit enhancements**: Enhancements generally equating to a reduction of transit travel times by about 10% by 2030 and 20% by 2050 (due to increased transit frequencies, improved transfer connections, and expanded bus rapid transit (BRT) networks), throughout the region.

[32] California Air Resources Board, Advanced Clean Trucks Fact Sheet, June 25, 2020.
[33] Note: this analysis will be conducted for 2045 using the COG's Cooperative Land Use Forecast, and scaled to 2050.

Scenario MS.2: Amplified Mode Shift Scenario

This scenario extends upon the strategies listed above and is more aggressive in application.

- **Land use changes and bicycle/pedestrian enhancements**: All incremental growth between 2025 and 2030/2050 outside of Activity Centers would be shifted to Activity Centers and high-capacity transit station areas across the region, with a more aggressive focus on improving jobs-housing balance across the region and additional shifts to bicycle/pedestrian modes beyond those in scenario MS.1.[34]
- **Free transit**.
- **Travel demand management strategies**: About 40% telework assumption (equates to about 80% telework for "office" employees on an average day, or just coming into office 1 day per week on average under a hybrid work arrangement); all worksite parking in all locations (not just Activity Centers) is priced by 2050.
- **Transit enhancements**: Enhancements generally equating to a reduction of transit travel times by 15% by 2030 and 30% by 2050, reflecting even more extensive implementation of BRT and other transit enhancement strategies.

Scenario MS.3: Amplified Mode Shift Scenario + Road Pricing

This scenario layers on top of the strategies from the MS.2 scenario a road charge averaging of $0.05 per mile in 2030 and $0.10 per mile in 2050 (in comparison to current year prices), and an estimated cordon price for downtown DC of $5 per trip by 2030, continuing beyond. This analysis would be conducted using TRIMMS to layer onto the results from the previous analyses.

This analysis is intended to focus on VMT fees that are designed to support a reduction in driving, as opposed to replacing existing fuel tax charges. For simplicity, the analysis will assume that the fee is applied to all drivers, although various forms of fees could be designed to be more targeted to specific policy goals, such as fees that differ for conventional vehicles and EVs, for different times of day, or for more congested parts of the region. The modeling will essentially assume the fee is an increase in the cost of driving per mile and reflect assumptions about additional costs on drivers beyond current/expected average driving costs. The cordon price for entering downtown would be structured similar to analysis for the MSWG.

Transportation System Management and Operations (TSMO) Scenario

One scenario would be analyzed to address TSMO strategies:

Scenario TSMO: Transportation System Management and Operations (TSMO) Improvement

This scenario assumes extensive Intelligent Transportation Systems (ITS)/incident management deployment to optimize traffic flow, and increased connected/automated vehicles (CAVs) in 2050. Analysis will be conducted using sketch analysis, based on levels of traffic congestion forecast and literature showing effects of ITS and ecodriving on emissions profiles for vehicles, building on results from the LRPTF and with 2050 results reflecting maximum eco-driving efficiencies to account for CAVs.

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[34] The modeling will primarily rely on the same land use assumptions as under MS.1, but incorporate off-model adjustments to account for increased bicycle/pedestrian activity and shorter trip lengths due to a better jobs-housing balance.

Combined Scenarios

Scenario COMBO.1: Combined Scenario (VT.1 + MS.1 + TSMO)

This scenario combines the strategies/policies under scenarios (VT.1 + MS.1 + TSMO), and layers these together yielding reductions in emissions rates and VMT.

Scenario COMBO.2: Combined Scenario with More Aggressive Technology Emphasis (VT.2 + MS.1 + TSMO)

This scenario combines the strategies/policies under the more aggressive technology adoption assumptions (VT.2) with the effects of mode shift and system management strategies (MS.1 + TSMO), and layers these together yielding reductions in emissions rates and VMT.

Scenario COMBO.3: Combined Scenario with More Aggressive Mode Shift Emphasis (VT.1 + MS.3 + TSMO)

This scenario combines the strategies/policies under the more aggressive mode shift assumptions (MS.3) with the effects of vehicle technology and system management strategies (VT.1 + TSMO), and layers these together yielding reductions in emissions rates and VMT.

Scenario COMBO.4: Combined Scenario with Aggressive Actions Across All Pathways and Shared CAV Future (VT.2 + MS.3 + TSMO + additional sharing)

This scenario combines the most aggressive set of strategies and implementation levels across each of the pathways from the other scenarios (VT.2 + MS.3 + TSMO), and layers these together yielding reductions in emissions rates and VMT. In addition, this scenario includes further assumptions about a shared CAV future for 2050 that includes high levels of ridesharing using optimized networks of automated vehicles. This analysis will build on early results from the U.S. Department of Energy's Vehicle Technology Office SMART Mobility Consortium research. The SMART effort has generated various tools to model GHG reductions from CAV infrastructure and automated vehicles (in sharing and non-sharing mode) to explore operational efficiencies in mobility.[35] These analyses suggest the potential for optimized networks that could both significantly reduce VMT through on-call shared vehicles and optimize energy efficiency through connected vehicle technologies.

5 Electricity Grid Sensitivity Analysis

The business as usual (BAU) assumption for the carbon intensity of electricity used in the MWCOG 2030 Climate and Energy Action Plan was calculated by weighting the total electricity use from each jurisdiction with the eGRID factor[36] associated with electricity use. The value was held constant over time in the BAU scenario for that analysis.

The vehicle technology scenarios to be analyzed in this study incorporate the GHG emissions associated with the electric grid to present "fuel cycle" emissions for EVs. Given the important effects of the electric grid on total emissions, we plan to conduct a sensitivity analysis to show the effects of grid decarbonization on GHG emissions from EVs using three different assumptions for electricity carbon intensities:

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[35] U.S. Department of Energy, Energy Efficient Mobility Systems website. https://www.energy.gov/eere/vehicles/energy-efficient-mobility-systems

[36] eGRID: U.S. Environmental Protection Agency (EPA) eGRID Subregion Output Emission Rates – Greenhouse Gases. Subregions RFC East (RFCE) and SERV Virginia/Carolina (SRVC) total output emission rates of CO_2 (lb/MWh), CH_4 (lb/GWh), and N_2O (lb/GWh).

1. **Reference Case for Electricity Carbon Intensity –** The Reference Emissions Factor represents the emissions factor based on current on-the-books policies. The value has been calculated by ICF by weighting the total VMT from each state's EV population in 2018 to influence regional grid factor projections from present to 2050. The grid factor projections are from ICF's proprietary power sector model, the Integrated Planning Model (IPM). IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. It provides forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies while meeting energy demand, environmental, transmission, dispatch, and reliability constraints. Each state's emissions factor accounts for electricity decarbonization policies such as Virginia's Clean Economic Act (100% clean power by 2045, assuming Dominion as the dominant utility), Maryland's Renewable Portfolio Standard (50% renewable energy by 2030) and DC's Renewable Portfolio Standard (100% renewable energy by 2032). IPM's grid factor projections include not only the impact of state renewable portfolio standard (RPS) policies, but also the changes in fossil fuel emission intensity over time as coal retires and is replaced by natural gas or clean renewables. The grid factor projections also factor in the emission intensity of imports to the states based on each state's imports in 2019 (from U.S. Energy Information Administration [EIA] data). As a starting point for this analysis, ICF used 2019 eGRID values for Virginia and Maryland, and 2019 RFCEast values for Washington, DC.
2. **Modified Reference Case for Electricity Carbon Intensity** – The Modified Reference Case emissions factor has been calculated to represent a slightly more aggressive Reference Case. In this scenario, ICF assumes a more aggressive policy for Maryland: a zero-carbon grid by 2040. This assumption aligns with Governor Hogan's legislative proposal. In this scenario, ICF assumes that the 100% by 2040 requirement would have to be met in-state, as opposed to the current policy where eligible sources can be located anywhere in the PJM Interconnection, a regional transmission organization in the U.S. and part of the Eastern Interconnection grid operating an electric transmission system.
3. **Clean Grid Case –** The Clean Grid Case emissions factor represents the Biden Administration's plan for a 100% clean grid by 2035. This policy would be applied nationally, so the emission intensity of imports by 2035 is assumed to be zero. At present time, there have been multiple reports of a grid that is 80% decarbonized by 2030 and zero carbon by 2035.

6 Next Steps and Approach to Analysis

The ICF team is moving forward expeditiously to conduct the analysis of the ten scenarios. Given the aggressive schedule for the study and substantial work required, we do not anticipate having the ability to add additional scenarios or change the proposed analysis approach significantly. However, we are pleased to take feedback from the TPB Technical Committee regarding the scenario assumptions, and we will consider adjustments to the assumptions about levels of implementation of the GHG reduction strategies in response to that feedback.

ICF is building a spreadsheet tool, such as the one developed for the MSWG, to support integration of the analysis findings from individual scenarios into a comprehensive analysis tool that will support layering of scenarios together to determine those combinations that could meet the 50% and 80% reduction goals. The layering approach typically will start with vehicle fleet and fuels strategies, and then layer on top MSTB strategies and TSMO strategies to show combined results. We anticipate that some of the combined scenarios will meet the goal levels, but to the extent that the analysis finds the goals are not achieved by some scenarios, we can present adjustments to assumptions (such as vehicle fleets and technologies, or mode shifts) that would meet the goals. We will also describe expected equity implications of the strategies associated with the scenarios (e.g., costs associated with EV adoption for low- and moderate-income segments, ability to telework), uncertainties associated with the analysis results, and factors that may affect results (e.g., fuel prices, behavioral aspects).