TPB Climate Change Mitigation Study of 2021

Additional Transportation Scenarios Analysis: TPB Survey Identified Scenarios

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Background

The National Capital Region Transportation Planning Board's (TPB) Climate Change Mitigation Study of 2021 (CCMS) analyzed the types of greenhouse gas (GHG) reduction strategies that would be needed to achieve COG's non-sector-specific 2030 and 2050 GHG emissions reduction goals (50% reduction by 2030 and 80% reduction by 2050, compared to 2005 levels). Because there were no transportation-sector-specific GHG reduction goals, the CCMS made the assumption that the on-road, transportation-sector GHG reduction goals would be identical to COG's non-sector-specific GHG reduction goals. The CCMS explored ten scenarios addressing transportation strategies across several pathways – vehicle technology and fuels (VT), mode shift and travel behavior (MS), and transportation systems management and operations (TSMO) – and combinations of these pathways, with various levels of strategy implementation. The results highlighted the need for a broad array of strategies to be implemented, since strategies with a combination of pathways showed the overall highest potential for GHG reduction. The study also highlighted the difficulty of meeting the study's goal levels for on-road transportation sources for 2030, since none of the scenarios were estimated to achieve more than a 43% reduction in GHG emissions in 2030, even under the most optimistic assumptions.

Subsequently, at the January 19, 2022 meeting of the TPB, it was proposed that the TPB should: 1) explicitly adopt GHG reduction goals for the on-road transportation sector; and 2) explicitly endorse a set of multi-pathway strategies to reduce on-road GHG emissions and commit to implementing them in an equitable and expeditious manner. To help in this process, the TPB members received a Climate Change Mitigation Goals and Strategies Questionnaire, and the TPB members were given the opportunity to consider their support for adopting on-road transportation GHG reduction goals and strategies to adopt. The results indicated that most respondents supported formally adopting GHG reduction goals for the on-road transportation sector, but, based on comments in the survey, the preferred levels of the goals, particularly the 2030 goal, were still being debated. Also, a majority or plurality of respondents to the TPB member survey expressed support for adopting seven GHG reduction strategies, but, again, the levels of implementation for some of those strategies were still being debated. The seven GHG reduction strategies that received majority or plurality support are listed below, along with the levels of implementation listed in the survey, even though those levels are still being debated:

1. **Convert vehicles to clean fuels.** In 2030, 100% of new light duty vehicles sold; 50 percent of new medium/heavy duty trucks, and 100% of all buses on the road will be clean fuel vehicles. In 2050, 100% of new light duty vehicles sold, 100% of new medium/heavy duty trucks sold, and 100% of all buses on the road will be clean fuel vehicles.
2. **Develop an electric vehicle charging network** in the region to support an accelerated shift of light-duty passenger cars and trucks to electric vehicles.

3. **Add additional housing units**, above current COG Cooperative Forecasts, (approximately 77,000 by 2030 and 126,000 by 2050) near TPB-identified high-capacity transit stations and in COG's Regional Activity Centers.
4. **Reduce travel times (relative to 2020) on all public transportation bus services**. In 2030, travel times are reduced by 15 percent, and in 2050, travel times are reduced by 30 percent.
5. Implement projects or programs to **provide walk/bike access to all TPB identified high-capacity transit stations**.
6. **Complete the TPB's National Capital Trail Network** to increase walk and bike trips throughout the day.
7. **Implement traffic operational improvement measures** at all eligible locations, including advanced ramp metering, enhanced incident management systems, active signal controls, and transit bus priority treatments.

At the TPB Climate Work Session held on April 20, 2022, the participants expressed a desire to explore what would be the likely impacts of implementing these seven strategies. They also expressed interest in considering possible variations of the assumptions associated with the strategies defined in the survey, particularly for converting vehicles to clean fuels, since the level of clean vehicle fuels (e.g., electric vehicles) assumed in the survey may not have been realistic. This report summarizes the results of that analysis.

Additional Scenarios Analyzed

To support an understanding of the likely effects of implementing the seven strategies, and implications for developing a realistic goal for on-road transportation GHG reduction levels that might be achieved by 2030 and 2050, ICF conducted an analysis of two additional scenarios addressing implementation of the seven strategies:

1. Implementation at the levels defined in the TPB member survey; and
2. Implementation at levels considered more realistic or moderate.

To conduct this analysis, ICF built on the scenario work conducted for the CCMS, and explored two combination scenarios, referred to as COMBO.5 (implementation at levels considered more realistic or moderate, though still ambitious compared to peer agencies)[1] and COMBO.6 (implementation at levels defined in the survey). The naming for these two scenarios was derived from the fact that the original study had four combination scenarios (COMBO.1 to COMBO.4).

The assumptions associated with the two levels of implementation are noted below in Table 1. For most of the strategies, two separate sets of assumptions were used for the two scenarios. However, under both scenarios, the same assumptions were used for two strategies: add additional housing units and complete the TPB's National Capital Trail Network. The strategy to develop an electric vehicle charging network was not modeled separately as it was assumed to be a necessary part of the overall strategy to convert vehicles to clean fuels.

[1] See, for example, Kanti Srikanth et al. to National Capital Region Transportation Planning Board, "Research on Peer MPO On-Road Transportation Greenhouse Gas (GHG) Reduction Targets," Memorandum, April 27, 2022.

Table 1: Strategies and assumptions

Strategy	Assumptions under COMBO.5 ("Modest")	Assumptions under COMBO.6 ("High")
Convert vehicles to clean fuels	**Same as original VT.1 scenario**: Shifts to EVs (50% of new light-duty [LD] vehicle sales are EVs in 2030, with 100% by 2040; 30% of new medium/heavy-duty [M/HD] truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biodiesel/renewable diesel makes up 10% of diesel fuel use in 2030 and 20% in 2050)	**Same as original VT.2 scenario**: 100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biodiesel/renewable diesel makes up 20% of diesel fuel use in 2030 and 30% in 2050
Develop an electric vehicle charging network	Not explicitly analyzed; assumed to be supportive of the conversion of vehicles to clean fuels.	Not explicitly analyzed; assumed to be supportive of the conversion of vehicles to clean fuels.
Add Additional Housing Units	Add additional housing units, above current COG Cooperative Forecasts, (approximately 77,000 by 2030 and 126,000 by 2050) near TPB-identified high-capacity transit stations and in COG's Regional Activity Centers.	
Reduce Travel Times on all Bus Services	**Same as assumptions within original MS.1 scenario:** Reduce travel times (relative to 2020) on all public transportation bus services. In 2030, travel times are reduced by 10 percent, and in 2050, travel times are reduced by 20 percent.	**Same as assumptions within original MS.3 scenario:** Reduce travel times (relative to 2020) on all public transportation bus services. In 2030, travel times are reduced by 15 percent, and in 2050, travel times are reduced by 30 percent.
Provide Walk/Bike Access to all high-capacity transit stations	Implement projects or programs to provide walk/bike access to all TPB identified high-capacity transit stations (lower impact assumption)	Implement projects or programs to provide walk/bike access to all TPB identified high-capacity transit stations (higher impact assumption)
Complete the TPB's National Capital Trail Network	Complete the TPB's National Capital Trail Network to increase walk and bike trips throughout the day.	
Implement traffic operational improvement measures	**Same as original TSMO scenario but without assumption of connected/automated vehicle (CAV) benefits:** Implement traffic operational improvement measures at all eligible locations, including advanced ramp metering, enhanced incident management systems, active signal controls, and transit bus priority treatments	**Same as original TSMO scenario:** Implement traffic operational improvement measures at all eligible locations, including advanced ramp metering, enhanced incident management systems, active signal controls, and transit bus priority treatments; assumed operational benefits from CAVs in 2050.

Scenario Results

The estimated on-road transportation GHG reductions associated with implementation of the seven strategies, compared to 2005 levels, are shown in Table 2 below under the three electric grid cases explored in the CCMS. Note that under baseline assumptions, on-road transportation GHGs are estimated to be about 14% below 2005 levels in both 2030 and 2050. These figures account for both tailpipe emissions from motor vehicles and electricity-related emissions associated with use of electric vehicles (not emitted directly from vehicles but by electric utilities).

Table 2: Summary of GHG Reductions Estimated for New Scenarios Under all Electric Grid Cases (% Reductions from 2005 Level)

Scenario	Key Components	2030			2050		
		Ref. Grid	Mod. Grid	Clean Grid	Ref. Grid	Mod. Grid	Clean Grid
COMBO.5	Combination with strategies identified by the TPB survey with lower or more realistic levels	-23%	-23%	-26%	-71%	-77%	-85%
COMBO.6	Combination with strategies and levels identified in the TPB survey	-29%	-30%	-35%	-77%	-84%	-94%

Results of these scenarios in relation to the original scenarios analyzed are displayed in Table 3 and Table 4. The strategy to convert vehicles to clean fuels corresponds with the original VT.1 and VT.2 scenarios and the operational improvements strategy corresponds with the original TSMO scenario. However, the mode shift and travel behavior strategies that received plurality/majority support were only a subset of the original set analyzed. Consequently, ICF developed two separate scenarios, MS.4 and MS.5 to reflect the four mode shift and travel behavior strategies (Add Additional Housing Units, Reduce Travel Times on all Bus Services, Provide Walk/Bike Access to all high-capacity transit stations, and Complete the TPB's National Capital Trail Network) supported in the survey under levels identified in the survey and with lower or more realistic levels. These scenarios were then layered together to yield the COMBO.5 and COMBO.6 results. A comparison of the reductions in GHG emissions from all COMBO scenarios assessed to date is shown in Figure 1.

COMBO.6: Levels of implementation listed in TPB member survey

The COMBO.6 scenario encompasses the identified levels of implementation for the strategies reflected by the TPB member survey. With the reference grid using on-the-books power sector policies, which are, nonetheless, cleaner than the existing electrical grid, the COMBO.6 scenario is projected to reduce CO_2e emissions with respect to 2005 levels by 29% in 2030 and by 77% in 2050. Assuming the clean grid, this scenario is anticipated to reduce CO_2e emissions with respect to 2005 levels by 35% in 2030 and by 94% in 2050.

The bulk of the GHG emissions reductions for this scenario are due to the clean fuels strategy. The mode shift and travel behavior strategies (modeled in isolation as scenario MS.5) are estimated to yield a less than 1% reduction in on-road transportation GHG emissions in 2030 compared to the baseline levels. The operations improvements also have small effects, estimated at about a 1% reduction in 2030. These effects remain small in 2050, with the cleans fuel strategy yielding most of the benefits.

COMBO.5: Lower or more realistic levels of implementation

The COMBO.5 scenario encompasses lower or more realistic but still very ambitious levels of implementation for several of the strategies, compared to the values that were listed in the TPB member survey. With the reference grid using on-the-books power sector policies, the COMBO.5 scenario is projected to reduce CO_2e emissions with respect to 2005 levels by 23% in 2030 and by 71% in 2050. Assuming the clean grid, this scenario is anticipated to reduce CO_2e emissions with respect to 2005 levels by 26% in 2030 and by 85% in 2050.

As with COMBO.6, in COMBO.5, the bulk of the GHG emissions reductions are due to the clean fuels strategy. The mode shift and travel behavior strategies (modeled in isolation as scenario MS.4) are estimated to yield less than 1% reduction in on-road transportation GHG emissions in 2030 compared to the baseline levels, and the operations improvements also have about a 1% reduction impact, and these impacts remain small through 2050.

Figure 1: Comparison of all COMBO scenarios

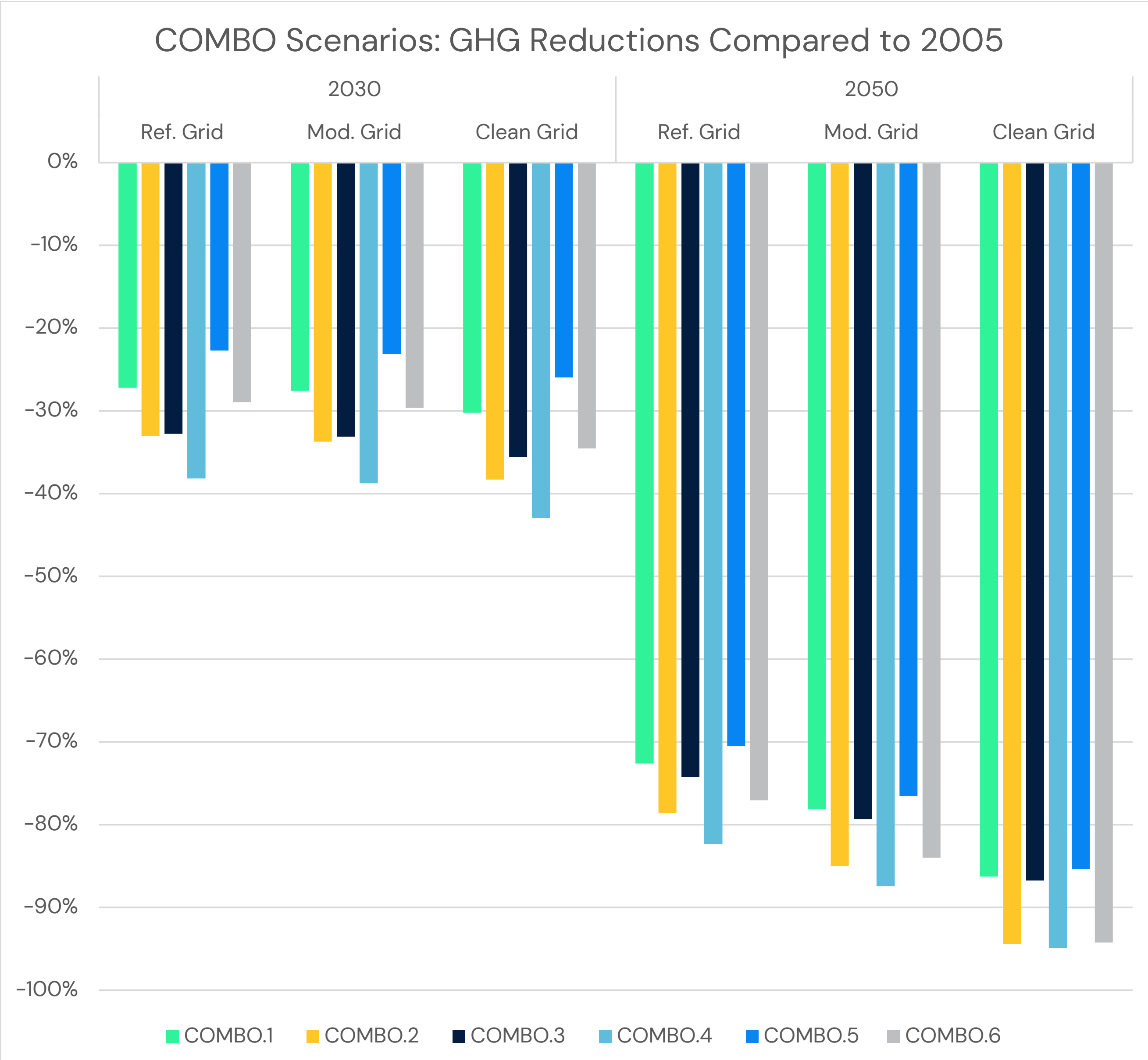

Table 3: Summary of GHG Reductions Estimated for All Transportation Scenarios Under all Electric Grid Cases (% Reductions from 2005 Level)

Scenario	Key Components	2030			2050		
		Ref. Grid	Mod. Grid	Clean Grid	Ref. Grid	Mod. Grid	Clean Grid
Baseline	Base assumptions from Visualize 2045	-14%	-14%	-14%	-14%	-14%	-14%
VT.1	50% of new LD vehicle sales are EVs in 2030, with 100% by 2040; 30% of new M/HD truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biofuels/renewable diesel make up 10% of diesel fuel use in 2030 and 20% in 2050	-21%	-21%	-24%	-69%	-75%	-84%
VT.2	100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biofuels/renewable diesel make up 20% of diesel fuel use in 2030 and 30% in 2050	-28%	-29%	-34%	-76%	-83%	-93%
MS.1	Land use changes, including new housing in the region; transit fares reduced 50% by 2030 and 75% in 2050; all workplace parking in activity centers priced by 2030; 10% reduction in transit travel time by 2030 and 20% by 2050; 25% telework; increased bike/ped/mobility; reduction in vehicle trips to school	-20%	-20%	-20%	-21%	-21%	-22%
MS.2	MS.1 + DC core cordon pricing + VMT-fees of $0.05 per mile in 2030 and $0.10 per mile in 2050	-22%	-22%	-23%	-25%	-25%	-25%
MS.3	MS.2 with amplified strategies, including free transit; all workplace parking priced by 2050 (not just in activity centers), 15% reduction in transit travel time by 2030 and 30% by 2050; 40% telework	-26%	-26%	-26%	-27%	-28%	-28%
MS.4	Includes a revised land use strategy, transit improvements (10% and 20% reductions in transit travel time in 2030 and 2050), increase in bike+transit (25% increase) and walking+transit trips at high capacity transit stations, and the completion of the National Trail Network.	-15%	-15%	-16%	-14%	-15%	-15%
MS.5	Includes a revised land use strategy, amplified transit improvements (15% and 30% reductions in transit travel time in 2030 and 2050), amplified increases in bike+transit (50% increase) and walking+transit trips at high capacity transit stations, and the completion of the National Trail Network.	-15%	-15%	-16%	-14%	-15%	-15%
TSMO	Optimized ITS/TSMO	-16%	-16%	-17%	-15%	-15%	-16%
TSMO + CAV	Optimized ITS/TSMO, with benefits from connected/automated vehicles (CAVs) by 2050	-16%	-16%	-17%	-16%	-17%	-18%
COMBO.1	Combined scenario: VT.1+ MS.1 + TSMO	-27%	-28%	-30%	-73%	-78%	-86%
COMBO.2	Combined scenario with more aggressive technology emphasis: VT.2 + MS.1 + TSMO	-33%	-34%	-38%	-79%	-85%	-94%
COMBO.3	Combined scenario with more aggressive mode shift emphasis: VT.1 + MS.3 + TSMO	-33%	-33%	-36%	-74%	-79%	-87%
COMBO.4	Combined scenario with aggressive actions across all pathways and shared CAV future: VT.2+MS.3+TSMO+CAV+additional sharing	-38%	-39%	-43%	-82%	-87%	-95%
COMBO.5	Combination with strategies identified by the TPB survey with lower or more realistic levels: VT.1 + MS.4 + TSMO	-23%	-23%	-26%	-71%	-77%	-85%
COMBO.6	Combination with strategies and levels identified by the TPB survey: VT.2 + MS.5 + TSMO + CAV	-29%	-30%	-35%	-77%	-84%	-94%

Table 4: Summary of GHG Reductions Estimated for All Transportation Scenarios Under all Electric Grid Cases (% Reductions from Baseline Forecast Level for 2030 and 2050)

Scenario	Key Components	2030			2050		
		Ref. Grid	Mod. Grid	Clean Grid	Ref. Grid	Mod. Grid	Clean Grid
VT.1	50% of new LD vehicle sales are EVs in 2030, with 100% by 2040; 30% of new M/HD truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biofuels/renewable diesel make up 10% of diesel fuel use in 2030 and 20% in 2050	-8%	-8%	-11%	-64%	-71%	-81%
VT.2	100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biofuels/renewable diesel make up 20% of diesel fuel use in 2030 and 30% in 2050	-16%	-17%	-23%	-72%	-81%	-92%
MS.1	Land use changes, including new housing in the region; transit fares reduced 50% by 2030 and 75% in 2050; all workplace parking in activity centers priced by 2030; 10% reduction in transit travel time by 2030 and 20% by 2050; 25% telework; increased bike/ped/mobility; reduction in vehicle trips to school	-6%	-6%	-7%	-9%	-9%	-10%
MS.2	MS.1 + DC core cordon pricing + VMT-fees of $0.05 per mile in 2030 and $0.10 per mile in 2050	-9%	-9%	-10%	-13%	-13%	-14%
MS.3	MS.2 with amplified strategies, including free transit; all workplace parking priced by 2050 (not just in activity centers), 15% reduction in transit travel time by 2030 and 30% by 2050; 40% telework	-13%	-13%	-14%	-16%	-16%	-17%
MS.4	Includes a revised land use strategy, transit improvements (10% and 20% reductions in transit travel time in 2030 and 2050), increase in bike+transit (25% increase) and walking+transit trips at high capacity transit stations, and the completion of the National Trail Network.	0%*	-1%	-2%	-1%	-1%	-2%
MS.5	Includes a revised land use strategy, amplified transit improvements (15% and 30% reductions in transit travel time in 2030 and 2050), amplified increases in bike+transit (50% increase) and walking+transit trips at high capacity transit stations, and the completion of the National Trail Network.	0%*	-1%	-2%	-1%	-1%	-2%
TSMO	Optimized ITS/TSMO	-1%	-2%	-2%	-1%	-2%	-3%
TSMO + CAV	Optimized ITS/TSMO, with benefits from connected/automated vehicles (CAVs) by 2050	-1%	-2%	-2%	-3%	-4%	-5%
COMBO.1	Combined scenario: VT.1+ MS.1 + TSMO + CAV	-15%	-15%	-19%	-68%	-75%	-84%
COMBO.2	Combined scenario with more aggressive technology emphasis: VT.2 + MS.1 + TSMO + CAV	-22%	-23%	-28%	-75%	-83%	-94%
COMBO.3	Combined scenario with more aggressive mode shift emphasis: VT.1 + MS.3 + TSMO + CAV	-21%	-22%	-25%	-70%	-76%	-85%
COMBO.4	Combined scenario with aggressive actions across all pathways and shared CAV future: VT.2+MS.3+TSMO+additional sharing	-28%	-28%	-33%	-80%	-85%	-94%
COMBO.5	Combination with strategies identified by the TPB survey with lower or more realistic levels: VT.1 + MS.4 + TSMO	-10%	-10%	-14%	-66%	-73%	-83%
COMBO.6	Combination with strategies and levels identified by the TPB survey: VT.2 + MS.5 + TSMO + CAV	-17%	-18%	-24%	-73%	-81%	-93%

*Rounded, reflects less than 0.5% reduction from baseline

Conclusion

The seven strategies that received plurality/majority support in the TPB member survey are estimated to reduce on-road transportation GHG emissions by 23% to 29% in 2030, and by 71% to 77% in 2050, compared to 2005 levels, under a reference electric power grid case. They achieve larger reductions with clean grid assumptions, enabling attainment of the 80% reduction goal in 2050 but still well short of the 50% non-sector specific reduction goal in 2030, which was assumed in the CCMS.

In both cases, the **Convert vehicles to clean fuels** strategy is by far the most impactful when compared to other mode shift and travel behavior or TSMO pathway strategies contained in the package of strategies. (Although the **Develop an electric charging network** strategy was not modeled because the outcomes of this strategy are supportive of the outcomes of the Convert vehicles to clean fuels strategy, an electric charging network is a necessary step to support electrification of the fleet in the region.) It should be noted that the assumptions presented in the survey for the conversion of vehicles to clean fuels (e.g., electric vehicles) are extremely aggressive, and even the more moderate assumptions will require a very large change in the vehicle fleet within a very short window of time through 2030.

Although the mode shift and travel behavior strategies analyzed did not show large impacts in terms of reducing GHG emissions, these strategies have many co-benefits, including potential improvements to physical and social health, equity, and mobility, which are not captured in this analysis. It should be noted that while the strategy to Add Additional Housing Units to the region will yield on-road transportation GHG reduction benefits from the perspective of individual households who now are able to take shorter trips and have more choices for using transit, bicycling, walking, and other non-driving options, this analysis estimated a small overall increase in VMT and on-road transportation GHG emissions within the COG region when adding these additional households. These households reduce long-distance trips into the region but also generate local trips within the COG region that would have occurred outside of the region's boundaries.

The addition of new households to Activity Centers and areas with high-capacity transit stations were estimated to increase the total number of households in the region by 2.50% in 2030 and 3.51% in 2050, while meanwhile yielding about a 1% increase in regional passenger auto VMT in 2030 and 1.35% increase in 2050. As a result, the placement of new housing in the region reduces VMT per capita within the region. While this strategy would likely yield a small increase in VMT and GHG emissions within the region's boundaries, it overall should provide GHG emission benefits when taking into account emissions outside of the region (not counted in this study).

Appendix

Strategies and Assumptions

In this section, the assumptions considered for each of the levels of implementation for the supported strategies as reflected in the TPB member survey are described. These strategies are summarized in Table 5

Table 5. New strategies and their corresponding scenario

Pathway	Scenario	Strategy	Key Components / Assumptions
Vehicle Technology (VT) and Fuels	VT.1	C1: Convert vehicles to clean fuels, lower or more realistic level of implementation	Shifts to EVs (50% of new light-duty [LD] vehicle sales are EVs in 2030, with 100% by 2040; 30% of new medium/heavy-duty [M/HD] truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biodiesel/renewable diesel makes up 10% of diesel fuel use in 2030 and 20% in 2050)
	VT.2	C1: Convert vehicles to clean fuels, levels of implementation selected by TPB in survey	More aggressive shifts to EVs: 100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biodiesel/renewable diesel makes up 20% of diesel fuel use in 2030 and 30% in 2050
Mode Shift and Travel Behavior (MS)	MS.4 & MS.5	C3: Add Additional Housing Units	Add additional housing units, above current COG Cooperative Forecasts, (approximately 77,000 by 2030 and 126,000 by 2050) near TPB-identified high-capacity transit stations and in COG's Regional Activity Centers.
	MS.4	C8: Reduce Travel Times on all Bus Services, lower or more realistic levels of implementation	Reduce travel times (relative to 2020) on all public transportation bus services. In 2030, travel times are reduced by 10 percent, and in 2050, travel times are reduced by 20 percent.
	MS. 5	C8: Reduce Travel Times on all Bus Services, levels of implementation selected by TPB in survey	Reduce travel times (relative to 2020) on all public transportation bus services. In 2030, travel times are reduced by 15 percent, and in 2050, travel times are reduced by 30 percent.
	MS.4	C9: Provide Walk/Bike Access to all high-capacity transit stations, lower or more realistic levels of implementation	Implement projects or programs to provide walk/bike access to all TPB identified high-capacity transit stations (practical impact assumption)
	MS.5	C9: Provide Walk/Bike Access to all high-capacity transit stations, levels of implementation selected by TPB in survey	Implement projects or programs to provide walk/bike access to all TPB identified high-capacity transit stations (aspirational impact assumption)
	MS.4 & MS.5	Complete the TPB's National Capital Trail Network	Complete the TPB's National Capital Trail Network to increase walk and bike trips throughout the day.
Transportation Systems Management & Operations (TSMO)	TSMO:	C14: Implement traffic operational improvement measures, lower or more realistic levels of implementation	Implement traffic operational improvement measures at all eligible locations, including advanced ramp metering, enhanced incident management systems, active signal controls, and transit bus priority treatments
	TSMO + CAV:	C14: Implement traffic operational improvement measures (with CAVs in 2050), levels of implementation selected by TPB in survey	Implement traffic operational improvement measures at all eligible locations, including advanced ramp metering, enhanced incident management systems, active signal controls, and transit bus priority treatments; assumed operational benefits from connected/automated vehicles (CAVs) in 2050.
Combined Pathways	COMBO.5: TPB Defined Combination (Practical)	Lower or more realistic levels of implementation	VT.1 + MS.4 + TSMO
	COMBO.6: TPB Defined Combination (Aspirational	Levels of implementation selected by TPB in survey	VT.2 + MS.5 + TSMO + CAV

C1. Convert vehicles to clean fuels

For this strategy, assumed market shares of clean fuel vehicles are asserted across different vehicle types.

Level of implementation selected in the survey

The assumptions previously used for VT.2 scenario in the Climate Change Mitigation Study of 2021 were applied. This included:

- **100% of new light-duty passenger car and truck sales are EVs by 2030**: These projections align with a Rocky Mountain Institute study[2] focusing on ways to limit cumulative GHG emissions compatible with 1.5-degree Celsius warming and are more aggressive than the 2021 order by California's Governor for the California Air Resources Board to develop regulations that mandate 100% of new passenger cars and trucks sold in the state to be zero-emission by 2035.[3,4]
- **50% of new medium and heavy-duty truck sales are EVs in 2030, ramping up to 100% of new truck sales by 2050**: These projections are consistent with the California Advanced Clean Trucks (ACT) rules, which would require zero-emission vehicle sales for 55% of the new Class 2b-3 trucks, 75% of new Class 4-8 trucks, and 40% of truck tractors by 2035.[5]
- **100% of transit and school buses 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:** For the VT.2 scenario, it was assumed that biofuels and renewable diesel would represent 20% of the residual conventional diesel fuel in 2030, and 30% in 2050.

Lower or more realistic levels of implementation

The assumptions previously used for the VT.1 scenario in the Climate Change Mitigation Study of 2021 were applied. While these levels of implementation are more realistic, they are still very ambitious. This included:

- **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 projections are consistent with President Biden's national goal for new vehicle sales by 2030.[6] Growth in EV sales is assumed to increase linearly over time between asserted sales ratios; however, EV fleet penetration is not linear and depends on the cumulative sales over time.
- **30% of new medium and heavy-duty truck sales are EVs in 2030, ramping up to 100% of new truck sales by 2050**: These projections are consistent with the multi-state Memorandum of Understanding (MOU)[7] signed by Maryland and the District of Columbia committing to achieve at least 30% of all new

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[2] Energy System Transformation for a 1.5 Degree Celsius Future https://rmi.org/insight/1-5-degree-future/

[3] 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.

[4] 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 2030 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.

[5] California Air Resources Board, Advanced Clean Trucks Fact Sheet, June 25, 2020.

[6] 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

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

medium- and heavy-duty vehicle sales to be zero-emission vehicles by 2030, and 100% by 2050 (with sale rates adjusted for different vehicle classes).

- **50% of school and transit buses are EVs in 2030, and 100% are EVs in 2050**: These projections are consistent with a Washington Metropolitan Area Transit Authority (WMATA) plan to move to a fully zero-emission bus fleet by 2045,[8] and with goals set by Montgomery County to transition 300 school buses to electric in the next three years and plans to electrify all 1,422 buses in their fleet by 2035.[9] This scenario assumes that it will take beyond 2030 to get to complete replacement of the bus fleet and deploy the needed EV charging infrastructure.
- **A modest reduction in the carbon intensity of diesel, due to increased use of biodiesel and renewable diesel:** For the VT. 1 scenario, it was assumed that biofuels and renewable diesel would represent 10% of the residual conventional diesel fuel in 2030, and 20% in 2050.

C2. Develop an electric charging network

Because strategy C1 asserts the levels of EV market penetration, no separate analysis was conducted to determine the redundant impacts of the implementation of an electric charging network. It is important to recognize that the implementation of a substantial electric charging network is critical to realizing the assumptions listed in strategy C1.

C3. Add additional housing units

For this strategy, the same assumptions were assumed for both the level of implementation selected in the survey and for the lower or more realistic levels of implementation.

- **Land use changes**: Land use changes were assumed so that 77,000 new households would be added to the region in 2030 and 126,000 new households in 2050 to support a reduction in long-distance commute trips. New households were located near TPB-identified high-capacity transit stations and in COV's Regional Activity Centers.

C8. Reduce travel times on all bus services

For this strategy, assumptions were made about potential improvements in average transit travel times.

Level of implementation selected in the survey

- **Transit enhancements**: Enhancements generally equating to a reduction of transit travel times by about 15% by 2030 and 30% by 2050 throughout the region.

Lower or more realistic levels of implementation

- **Transit enhancements**: Enhancements generally equating to a reduction of transit travel times by about 10% by 2030 and 20% by 2050 throughout the region.

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[8] WMATA, Zero-Emission Bus Update, website.
[9] Steven Mufson and 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/.
9

C9. Provide walk/bike access to all high-capacity transit stations

For this strategy, assumptions were made about increased walk and bike access to high-capacity transit stations and the resulting reductions in passenger auto trips.

Level of implementation selected in the survey

- **Increased bike + transit trips:** The existing number of transit riders accessing transit by bike increases by 50% of current levels, as defined by the TPB's 2017/2018 Regional Travel Survey[10].
- **Increased walk + transit trips**: Transit-oriented development (TOD) improvements surrounding high-capacity transit stations would lead to an overall reduction of 1.20% of regional passenger vehicle trips, as reported by the Maryland State Highway Administration[11] after conducting a simulation analysis using the TPB's Regional Travel Model.

Lower or more realistic levels of implementation

- **Increased bike + transit trips:** The existing number of transit riders accessing transit by bike increases by 25% of current levels, as defined by the TPB's 2017/2018 Regional Travel Survey.
- **Increased walk + transit trips**: It was assumed that the same level of improvements identified in the level of implementation supported by the TPB survey would apply for the lower or more realistic level of implementation.

Complete the TPB's National Capital Trail Network

For this strategy, the same assumptions were assumed for both the level of implementation selected in the survey and for the lower or more realistic levels of implementation.

- **Completion of the TPB's National Capital Trail Network**: According to a report released by the Capital Trails Coalition, the completed National Capital Trail Network[12] could reduce over 49 million passenger vehicle miles per year. When compared with existing auto passenger miles estimates for the region, this equates to 0.13% of the region's passenger auto VMT. It was assumed that the trail network is currently 55% complete, leaving 45% of this 0.13% benefit yet to be realized. A 0.071% reduction in passenger auto VMT was assumed as a result.

C14. Implement traffic operational improvement measures

For this strategy, assumptions were made about improving the flow of vehicular traffic and associated reductions in emissions from improved efficiency.

Level of implementation selected in the survey

The assumptions previously used for TSMO + CAV scenario in the Climate Change Mitigation Study of 2021 were applied. This included:

- Extensive **Intelligent Transportation Systems (ITS)/incident management deployment** to optimize traffic flow.

[10] Metropolitan Washington Council of Governments. "Regional Travel Survey." Accessed May 11, 2022. https://www.mwcog.org/transportation/data-and-tools/household-travel-survey/.
[11] Maryland State Highway Administration. "Development of a Framework for Transit-Oriented Development (TOD)," 2013, 100.
[12] Econsult Solutions, Inc. "The Economic, Health, and Environmental Benefits of Completing the Capital Trails Network." Washington Area Bicyclist Association, Capital Trails Coalition, and Rails-to-Trails Conservancy, May 2021. https://www.capitaltrailscoalition.org/report/.

- Increased **connected/automated vehicles (CAVs)** in 2050, assumed to generate fuel economy effects similar to ecodriving. Analysis was based on literature showing effects of ITS and ecodriving on emissions profiles for vehicles, reflecting maximum ecodriving efficiencies to account for CAVs.

Lower or more realistic levels of implementation

Only the contributions from ITS and incident management system deployment were assessed in this level. Contributions from CAVs in 2050 were not considered.

- Extensive **Intelligent Transportation Systems (ITS)/incident management deployment** to optimize traffic flow.

Method

In this section the method used to conduct the analysis is described. The method is organized by pathway. Within each pathway, the method for relevant strategies to that pathway is discussed.

Vehicle Technology and Fuels Strategies Analysis

The calculations associated with this pathway for strategy **C1: Convert vehicles to clean fuels** follow the same analysis method and assumptions used in the 2021 CCMS.

Mode Shift and Travel Behavior (MSTB) Strategies Analysis

This section discusses the calculations and assumptions used to simulate the impacts of the mode shift and travel behavior (MSTB) strategies, including **C3. Add additional housing units**, **C8. Reduce travel times on all bus services**, **C9. Provide walk/bike access to all high-capacity transit stations**, and **Complete the TPB's National Trail Network**.

C3. Add additional housing units

Baseline VMT

The analysis team began with baseline runs from regional travel demand forecasting model (Gen2/Version 2.3.78) for the years 2030 and 2050. Because no official land use configuration has been adopted for a 2050 model run, extrapolations to the 2045 adopted land use configuration were used to inform a 2050 model run. This is the same configuration used for 2050 in the 2021 CCMS, and the process used to adapt the model to 2050 is specified in an internal memo[13]. Adjustments were made to the baseline, as described in the following sections.

External travel VMT adjustments

When relocating households from outside of the region to within the TPB region, it follows that there will be adjustments to the internal portion of external, in-commuting travel (known as "X-I" travel), i.e., commute trips with one end outside and one end inside the modeled region, which will result in a reduction of VMT within the region. The analysis team followed a procedure based on the external trip adjustment method developed by Ron Milone[14].

External to Internal Trip Adjustments

The following process was used to calculate trip reductions due to reduced external to internal (X-I) trips.

1. Establish total motorized person trip rates by purpose
2. Convert total motorized person trip rates to vehicular/auto driver trip rates
3. Apply the final auto driver trip rate to 77,000 households in 2030 or 126,000 households in 2050 by purpose
4. Account for the fact that not all external trips will enter the modeled region
5. Subtract the resulting trips from the existing X-I trips

This process provides total remaining X-I trips. An example of the process for the year 2030 is demonstrated in Table 6.

[13] Fehr & Peers. "MWCOG TPB Climate Change Mitigation Strategy – 2050 Base Land Use Assumptions." October 5, 2021.
[14] Milone, Ronald. "LRPTF Study, Initiative #8: Adjustment of 2040 External Crossings." COG/TPB Staff, September 12, 2017.

Table 6: Modified X-I Auto Driver Trips

			Modeled Purpose -->				
	Work step	Calculation / Source:	HBW	HBS	HBO	NHB	Total
(A)	Regional Motorized (Auto, Transit) Person Trip Rates	From 2030 modeled outputs	1.227	0.899	2.177	1.429	5.732
(B)	Regional Transit Pcts.	From Milone 2017 memo, based on 2040 modeled output	22.10%	0.60%	3.20%	2.40%	
(C)	Assumed Auto Occupancy	From '94 Auto External Survey	1.06	1.45	1.63	1.34	
(D)	Auto Driver Trip Rates	(A)*(1.0-(B))/(C)	0.90	0.62	1.29	1.04	3.85
(E)	Total Existing 2030 External (X-I) Auto Driver Travel	From 2030 modeled outputs	351,838	57,542	175,035	81,671	666,086
(F)	Estimated X-I Auto Dr. Travel attributed to 77,000 HHs	77,000 * (D)	69,434	47,447	99,548	80,143	
(G)	Assumed Share of X-I Trips	Asserted	1	0.15	0.15	0.15	
(H)	Revised 2030 External (X-I) Auto Driver Travel (rounded	(E) - ((F)*(G))	282,404	50,425	160,103	69,649	562,582

Internal to External Trip Adjustments

The following process was used to calculate trip additions due to increased internal to external (I-X) trips

1. Calculate the percentage increase that is reflected when 77,000 households in 2030 or 126,000 households in 2050 are added
2. Factor the existing I-X auto trips in like a proportion

An example of the process for the year 2030 is demonstrated in Table 7.

Table 7: Modified I-X Auto Driver Trips

	Work Step	Calculation/Source:	HBW	HBS	HBO	NHB	Total
(A)	Total Existing 2030 External (I-X) Auto Driver Travel	From 2030 modeled inputs	217007	58891	248091	81658	605,647
(B)	Revised 2030 External (I-X) Auto Driver Travel	=(A) * (1 + % increase in HH)	222437	60365	254299	83701	620,803

External to External Trip Adjustments

It was assumed that External to External trips did not change.

Calculate reduction in Regional VMT due to change in external trips

Following the changes in trips, the following process was used to determine the VMT impacts of the reduced external trips.

1. The percent change in external trips (X-I + I-X + X-X) is calculated based on the previous steps
2. The % of regional vehicle trips that are external is calculated
3. The VMT that is due to external trips is calculated
4. A modification is made to remove non-passenger auto VMT
5. The change in external auto VMT is calculated
6. The regional % impact on passenger vehicle VMT is obtained

An example of the process for the year 2030 is demonstrated in Table 8.

Table 8: Determining regional passenger vehicle VMT impact

	Work Step	Calculation/Source	Value
(A)	Percent change in external trips:	Calculated	-6.44%
(B)	Regional Vehicle Trips:	From model	451,271,304
(C)	Baseline external trips:	From model	1,372,471
(D)	% of vehicle trips that are external:	(C) / (B)	0.304%
(E)	Regional VMT:	From model	190,625,074
(F)	"External" VMT:	(D) * (E)	579,756
(G)	% "External" trips from auto:	From Milone memo	89%
(H)	"External" VMT from auto:	(F) * (G)	515,983
(I)	New "External" Auto VMT:	(H) * (1 + (A))	482,768
(J)	Reduction in Auto VMT:	(H) - (I)	33,215
(K)	Percent of regional VMT from auto:	From model	85%
(L)	Regional auto VMT:	(K) * (E)	161,588,464
(M)	Percent reduction in regional Auto VMT:	-1 * (J) / (L)	-0.02%

Internal VMT adjustments

In addition to a reduction in VMT from exogenous trips, an increase in VMT from previously un-modeled trips within the modeling region from additional households can be anticipated. This process is the following:

1. Calculate motorized trips per household from the model
2. Determine the number of those trips that are from passenger automobile travel
3. Determine the average passenger auto trip length in activity center markets (including the DC core and non DC core activity centers)
4. Multiply the average auto trips by the average passenger auto trip length

An example of the process is demonstrated in Table 9.

Table 9: Internal trip and VMT adjustments

	Work Step	Calculation/Source	**2030**	**2050**
(A)	Households added	Asserted	77,000	126,000
(B)	Motorized trips per household	From model	5.73	5.70
(C)	Weighted percent of trips that are auto	From model	82%	80%
(D)	Weighted average auto trip length:	From model	4.46	4.38
(E)	Total VMT added:	(A) * (B) * (C) * (D)	1,621,044	2,500,819
(F)	Percent change in Passenger auto VMT due to added Internal trips (non-attraction trips from DC Core Activity Centers and non-DC Core Activity Centers)	(E) / model output	1.00%	1.38%

Applying the auto VMT change to the baseline VMT figures

The net percent change in auto VMT was determined by adding the reduced exogenous VMT percent change and the increased internal VMT percent change. This amounted to a 0.98% increase in auto VMT in 2030 and a 1.35% increase in 2050. These percent increases were then applied to the baseline MOVES format passenger car and truck VMT outputs only.

C8. Reduce travel times on all bus services

The analysis team used a sketch planning tool, Trip Reduction Impacts of Mobility Management Strategies (TRIMMS),[15] to evaluate transit travel time reductions. To model the strategies more precisely by applying them to only applicable trips, raw regional model outputs were aggregated by origin/destination and trip purpose "markets," as described in the following section, before estimating trip reduction impacts with TRIMMS. The TRIMMS analysis ultimately provided VMT estimates for each of the modeled strategies, which were used to calculate GHG emissions.

Market Aggregation

Market aggregation was conducted in a manner consistent with the original Climate Change Mitigation Study of 2021.

Application of the TRIMMS Model

This section discusses how the TRIMMS tool was applied to model the impacts of various combinations and levels of policy measures. TRIMMS was run once for each market, for each modelled year. The following describes how the tool was configured and calibrated to simulate policy measures.

- **Transit Travel Time Enhancements** – The 2019 State of the Commute Survey[16] reported an average commute time across all modes. The transit mode commute times were averaged, weighted by the number of respondents, resulting in a weighted average transit commute time of 53.6 minutes. This was used as the starting travel time for transit times. Scenario-specific transit travel time improvements

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

[16] https://www.mwcog.org/documents/2020/06/17/state-of-the-commute-survey-report--carsharing-state-of-the-commute-travel-surveys/

were then applied to this value to obtain the new travel time. For example, a 15% reduction in travel time to the 53.6 average travel time resulted in a new travel time of 45.56 minutes.

C9. Provide walk/bike access to all high-capacity transit stations

Additional calculations were performed outside of the TRIMMS tool to account for policies that TRIMMS is not designed to simulate. The process for these is described in this section.

Bike access to high-capacity transit stations

The analysis team used the following process to calculate the VMT impact of increasing bike access to high-capacity transit stations.

1. For baseline data on the number of existing bicycle + transit trips, use the results of the TPB RTS to get percent of transit trips accessed by bike (this is found in the tabulation table T14_TRANSIT_ACCESS_MODE.csv), displayed as Table 10:

Table 10: Transit Access by Mode, TPB RTS 2017/2018

TRANSIT_ACCESS_MODE	Frequency	Weighted Frequency	Standard Deviation of Wgt Freq	Percent
Walking	9586	1537244	18042	88.1433
Bicycle	79	10907	1573	0.6254
Park and ride	830	99649	4450	5.7137
Kiss and ride	360	73185	5987	4.1963
Taxi / Uber / Lyft	45	6522	1260	0.374
Some other mode	154	16522	1638	0.9473
	11054	1744029	18109	100

2. Multiply the 0.6254% by the total number of transit trips (all modes) calculated by the modified regional model estimates to be consistent. So, for the 2030 base run, that is 8,894 transit trips.
3. As part of the new scenario, make an assumption about how many additional bicycle + transit trips would be added. We could assume a 50% increase of bicycle + transit trips – an additional 4,447 transit trips.
4. Not all new bike + transit trips will replace a passenger vehicle. Data from a 2013 LA Metro study[17] of bike + rail riders in LA suggests that 23% of riders would have replaced the trip with either Carpool of Drive Alone.

[17] Los Angeles Metropolitan Transportation Authority. “Bicycle-Rail Trip Analysis and Greenhouse Gas Emissions Reduction Focused Study,” June 2011. https://www.railstotrails.org/resource-library/resources/bicycle-rail-trip-analysis-and-greenhouse-gas-emissions-reduction-focused-study/?collection=Trail+Management.

Table 11: LA Metro survey: If you didn't have your bike and couldn't take a train, how would you get from your origin to your destination?

Mode to Which Respondents Would Switch	Number	Percent
Bus	305	40%
Drive Alone	137	18%
Walk	135	18%
Carpool	37	5%
Drop off	33	4%
Other	14	2%
Train/Subway/Light Rail	10	1%
Would not make the trip	97	13%
Total	**768**	

Respondents could choose more than one answer.

Multiply the summed percentages of drive alone and carpool (18% + 5% = 23%) by the increase in transit trips (4,447 * 23%) to get the total new transit trips that replace auto trips (1,022).

5. 1,022 Auto trips is about 0.005% of the existing 20,435,596 drive alone or shared rides from the 2030 year base model.
6. Apply this .005% reduction in trips, which results in a .005% reduction in VMT and passenger vehicle GHG emissions assuming the reduction in trips is spread evenly across different trip markets.

Walking access to high-capacity transit stations

The analysis team referenced a 2013 report by the Maryland State Highway Administration[18] to determine the change in region wide VMT. The Maryland State Highway Administration used the MWCOG regional model to assess the impact of adding transit oriented development (TOD) zones throughout the region. They found that compared to the baseline scenario, the TOD scenario resulted in a reduction in 1.2% of auto trips. The present analysis team applied this 1.2% reduction of auto trips to model the impact of increased walking access.

Complete the TPB's National Capital Trail Network

The analysis team used the following process to calculate the VMT impact of completing the TPB National Capital Trail Network.

1. A 2021 Capital Trails Coalition report[19] detailing the environmental benefits of completing the National Capital Trail Network stated that the completed network could reduce annual VMT by 49.1 million annually.

[18] Maryland State Highway Administration. "Development of a Framework for Transit-Oriented Development (TOD)," 2013, 100.
[19] Econsult Solutions, Inc. "The Economic, Health, and Environmental Benefits of Completing the Capital Trails Network." Washington Area Bicyclist Association, Capital Trails Coalition, and Rails-to-Trails Conservancy, May 2021. https://www.capitaltrailscoalition.org/report/.

2. The MWCOG published MOVES format total annual VMT from passenger vehicles in 2018 was 38.1 billion.
3. From correspondence with COG staff[20], it is generally accepted that 55% of the trail network is left to be built out.
4. Multiplying steps 1-3 yields an additional projected 0.071% reduction in VMT once the trail network is completed.

Excel Layering

The various analysis techniques were layered in a structured approach using Excel. This approach is summarized in Figure 2 and is described in detail below.

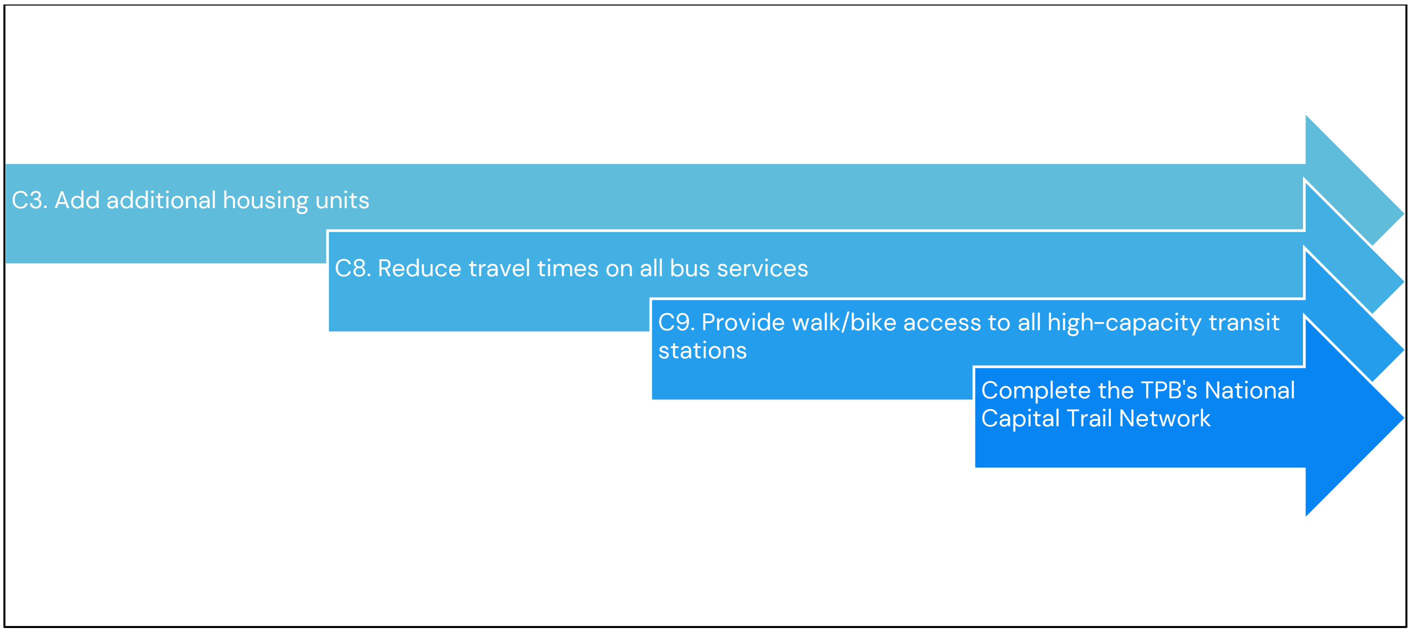

Figure 2: Layering Approach

1. **C3. Add additional housing units** – The regionwide total link VMT, or the VMT by vehicle type distributed across the regional roadway network generated by the regional model, was obtained for the baseline land use specification runs for 2030 and 2050. The percent changes in passenger auto VMT was calculated, as described in the **C3 Add additional housing units** strategy on page 12, and applied to the HV2, HV3, and SOV mode link VMT. The total link VMT was aggregated by MOVES class, and percent link VMT change by class was calculated. (Airport vehicle VMT was not considered). The results of this process are summarized in Table 12. Passenger Cars and Passenger Truck VMT from the baseline annual MOVES format VMT was recalculated from the link VMT percent changes, to be adjusted again after the mode shift and travel behavior policy simulation in the following steps. Commercial vehicle and truck VMT remained unchanged from the baseline run.

[20] Email correspondence with Mark Moran, COG, 4/28/22

Table 12: Baseline and Revised Land Use Regional Model Link VMT

Baseline Model VMT	MOVES Class	2030	2050
APX	NA	1,882,836	2,565,608
CV	Light Duty Comm. Trucks	16,143,516	18,782,622
HV2	Pass. Cars, Pass. Trucks	33,785,505	38,303,842
HV3	Pass. Cars, Pass. Trucks	15,845,350	19,157,080
SOV	Pass. Cars, Pass. Trucks	125,805,501	139,167,053
TRK	Heavy Duty Trucks, Combination Trucks	13,498,653	15,665,755
Total:		206,961,360	233,641,960
Revised Model VMT	**MOVES Class**	**2030**	**2050**
APX	NA	1,882,836	2,565,608
CV	Light Duty Comm. Trucks	16,143,516	18,782,622
HV2	Pass. Cars, Pass. Trucks	34,117,494	38,820,860
HV3	Pass. Cars, Pass. Trucks	16,001,052	19,415,658
SOV	Pass. Cars, Pass. Trucks	127,041,714	141,045,504
TRK	Heavy Duty Trucks, Combination Trucks	13,498,653	15,665,755
Total:		208,685,264	236,296,008
% Change, Baseline to Revised	**MOVES Class**	**2030**	**2050**
CV	Light Duty Comm. Trucks	0%	0%
HV2, HV3, SOV	Pass. Cars, Pass. Trucks	0.98%	1.35%
TRK	Heavy Duty Trucks, Combination Trucks	0%	0%

2. **C8. Reduce travel times on all bus services** – This mode shift policy was simulated using TRIMMS. Baseline trips and mode share provided to TRIMMS were calculated using the Market Aggregation method. When TRIMMS estimates the impact of mode shift policies, it does not preserve the initial number of trips, and assumes some induced or avoided trips. As a result, the results were interpreted differently for HBW and non-HBW markets.
   For HBW market trips, a percent change in vehicle trips was calculated using the following formula, as it was assumed that the total number of trips would not change:
   $$Trip\ Adjustment = 1 - \frac{(new\ drive\ alone\ mode\ share + new\ rideshare\ mode\ share) * baseline\ oneway\ trips}{baseline\ drive\ alone\ trips + baseline\ rideshare\ trips}$$
   For non-HBW market trips, a percent change in vehicle trips was calculated using the following formula, as it was assumed that the total number of trips could change:
   $$Trip\ Adjustment = \frac{\Delta\ drive\ alone\ trips + \Delta\ rideshare\ trips}{baseline\ drive\ alone\ trips + baseline\ rideshare\ trips}$$
   To calculate the impact on vehicle travel, the starting person trips for the private passenger vehicle mode was discounted by the Trip Adjustment factor calculated in this step. The resulting reduced number of private passenger trips then multiplied by the average VMT/trip calculated for that market

and summed to determine the new resulting VMT due to reductions in trips. This process was repeated for each market for each year, based on that market and year's TRIMMS results.

3. **C9. Provide walk/bike access to all high-capacity transit stations**
    a. Determine trips replaced by cycling + transit trips due to increased bike access at all high capacity transit stations
    b. Determine trips replaced by walking + transit trips due to increased bike access at all high capacity transit stations
4. **Complete the TPB's National Capital Trail Network -** Determine trips replaced by walking + transit trips due to completion of the trail network
5. **Apply Passenger VMT changes** – The percent change in VMT due to the mode shift and travel behavior policies above was again applied to the revised VMT calculated in step 1 after accounting for the land use adjustments. In effect, this stacked both the land use and mode shift and travel behavior changes on passenger vehicles only.
6. **Adjust Transit VMT due to increased transit ridership** – Due to the need for increased transit service to support higher transit ridership and decreased transit travel times, an increase in transit VMT of 5% in 2030 and 10% in 2050 were assumed.
7. **Calculate resulting emissions** – The final VMT results were multiplied by the appropriate baseline emissions rates for ICE and EV vehicles, assuming the same vehicle technology penetrations assumed in the baseline scenario. The resulting emissions were summed to produce the total emissions projected for 2030 and 2050.

Transportation System Management and Operations (TSMO)

The key components of the strategy **C14: Implement traffic operational improvement measures** are consistent with the original TSMO scenario. The TSMO + CAV implementation scenario corresponds to the level indicated by the TPB survey implementation of the C1 strategy, and the TSMO scenario corresponds to the lower or more realistic implementation of the C1 strategy.

Combination Scenarios

This section discusses how the previously defined scenarios were layered to create the combination scenario results:

1. **Calculate share of VMT by propulsion type (ICE, BEV, PHEV) based on results of the VT scenarios** – the share of VMT by ICE, BEV, and PHEV resulting from the VT scenarios was applied.
2. **Calculate VMT by vehicle type based on results of the MS scenarios** – Because the total VMT was modified in the MS scenarios, this total VMT was used.
3. **Apply adjusted emissions factors for diesel vehicles to take credit for use of biodiesel/renewable diesel** – The VT scenarios adjusted the emissions factors of buses, mid-duty trucks, and heavy-duty trucks to account for the increased use of biodiesel and renewable diesel. These adjusted emissions factors are then applied to the diesel vehicles.
4. **Apply TSMO benefits to reduce emissions factors for ICE vehicles**– The VMT at this stage is distributed by roadway functional class, as described in the TSMO calculation method, and the estimated improvement in GHG emissions rate was applied to ICE vehicles.

5. **Calculate total GHG emissions** – Emissions are calculated for all vehicle classes, propulsion types, and ICE adjusted emissions rates, weighted by the percent VMT of that vehicle class on a specific functional class group. Emissions from electricity used for EVs are then calculated by multiplying the estimated VMT by EVs by the associated energy economy for each vehicle type and multiplied by the electricity grid emissions factor for the appropriate grid assumptions.

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