Item #6c

Multi-Sector Approach to Reducing Greenhouse Gas Emissions in the Metropolitan Washington Region

Final Technical Report

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Metropolitan Washington Council of Governments

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Background and Purpose

On November 12, 2008, the members of the Metropolitan Washington Council of Governments (COG), representing 22 local governments[1], collaboratively adopted voluntary goals to reduce greenhouse gas (GHG) emissions in pursuit of "a more accessible, sustainable, prosperous, and livable National Capital Region." These goals are ambitious – reducing GHGs by 20% below 2005 levels by 2020 and by 80% below 2005 levels by 2050 – and place the region as a national leader in calling for aggressive action to address climate change.

As a growing region, the National Capital Region is expected to add about 2.3 million people by 2050 to the 4.7 million that lived in the region in 2005. As noted in the *National Capital Region Climate Change Report*, which included the GHG goals, business as usual (BAU) projections of growth in population, housing, employment, and energy use suggested that total GHG emissions in the region would increase by 33% by 2030 and 43% by 2050. Consequently, attaining the GHG reduction goals was recognized to be challenging, and to require significant reductions in emissions across all sectors. Moreover, it was recognized that strategies to meet the goals would require "a coordinated effort involving actions on the part of individuals, businesses, federal and state policy and regulations, academic research and development, and new technologies."

Over the past several years, COG has made progress in understanding the nature of regional emissions through development of a 2005 and 2012 GHG inventory and forecasts, and in identifying opportunities for reductions in various sectors. Many local governments in the Washington region have become national leaders in adopting programs to reduce GHG emissions, including promoting building energy efficiency and transit-oriented development, and many communities have also signed agreements such as Cities for Climate Protection and Cool Counties. In its 2010 and 2013 Climate and Energy Action Plans, COG identified a range of actions and is tracking progress toward these actions. COG also conducted focused analyses of transportation GHG reduction strategies through its "What Would It Take?" Scenario Study, and has explored various scenarios for land use development.

This study represents a focused effort to examine all sectors of the economy to identify potentially viable local, regional, and state actions to significantly reduce GHG emissions in accordance with the voluntarily adopted goals. The purpose of this effort is to:

- Identify potentially viable, implementable, and stretch local, regional, and state strategies for reducing GHG emissions across key sectors (Energy, the Built Environment, Land Use, and Transportation)
- Analyze the potential GHG benefits of these strategies in relation to the adopted goals; and

[1] Charles County became a member in 2012.

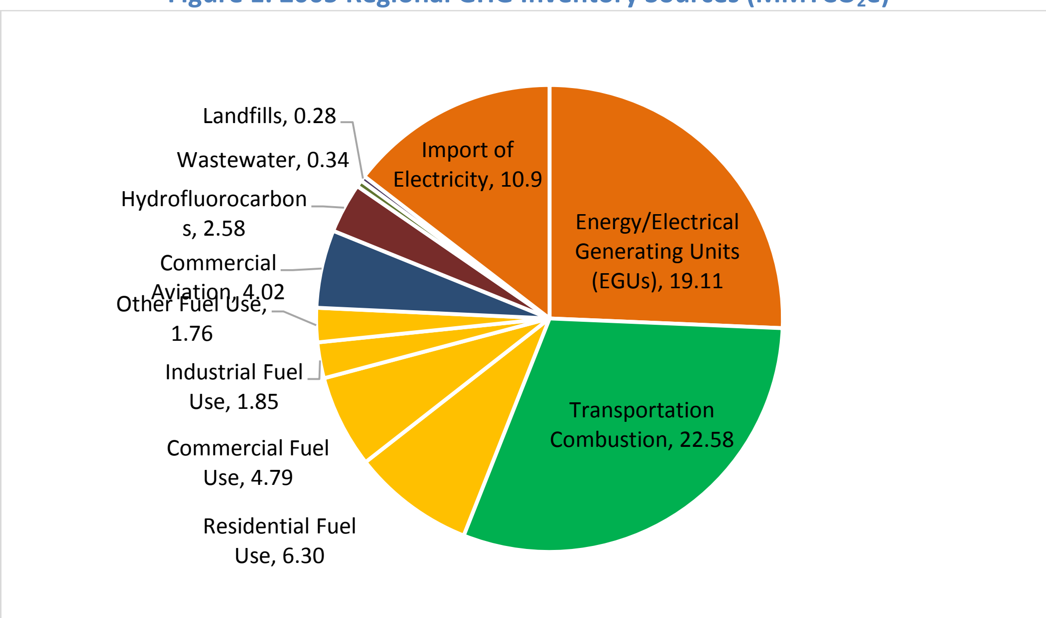
- Identify co-benefits, costs, and implementation timeframes associated with these GHG reduction strategies.

This Interim Technical Report summarizes the findings of this study. It describes the process used to identify feasible strategies, the methods used for analysis, and the results of the strategy analysis. It also provides context for GHG emissions in the metropolitan Washington region and implications for meeting the ambitious regional goals.

Context: A Growing Region, Multiple GHG Sources

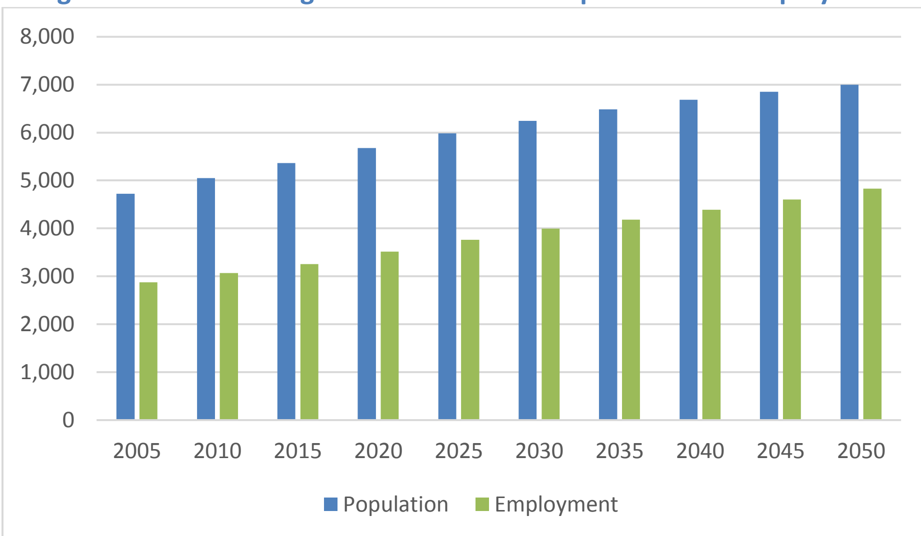
The 2005 regional GHG inventory and baseline forecasts – representing business as usual (BAU) conditions in 2005 – provide a starting basis for the analysis. In the 2005 base year, GHG emissions in the metropolitan Washington region totaled 74.5 million metric tons of carbon dioxide equivalent ($MMTCO_2e$). As shown in Figure 1, the inventory includes emissions from electricity generation; on-road motor vehicle transportation; residential/commercial/industrial and commercial aviation fuel use; and other sources, including hydrofluorocarbons used as refrigerants and solvents, and methane from wastewater treatment plants and landfills. In 2005, electricity contributed about 40% of regional GHG emissions and transportation combustion from motor vehicles contributed about 30% of regional GHG emissions.

Figure 1. 2005 Regional GHG Inventory Sources ($MMTCO_2e$)



Population and employment are projected to grow significantly in the region through 2050, as shown in Figure 2. The residential population is anticipated to grow from approximately 4.72 million in 2005 to its current level of 5.36 million (in 2015) to nearly 7 million in 2050. This is a forecast 48% population increase between 2005 and 2050. Meanwhile, employment is projected to grow even faster, by 68% – from 2.87 million jobs in 2005 to 3.25 million jobs in 2015, to 4.83 million jobs in 2050. Together this growth will create increasing demands for land use development, electricity use, heating and cooling, and travel across the region.

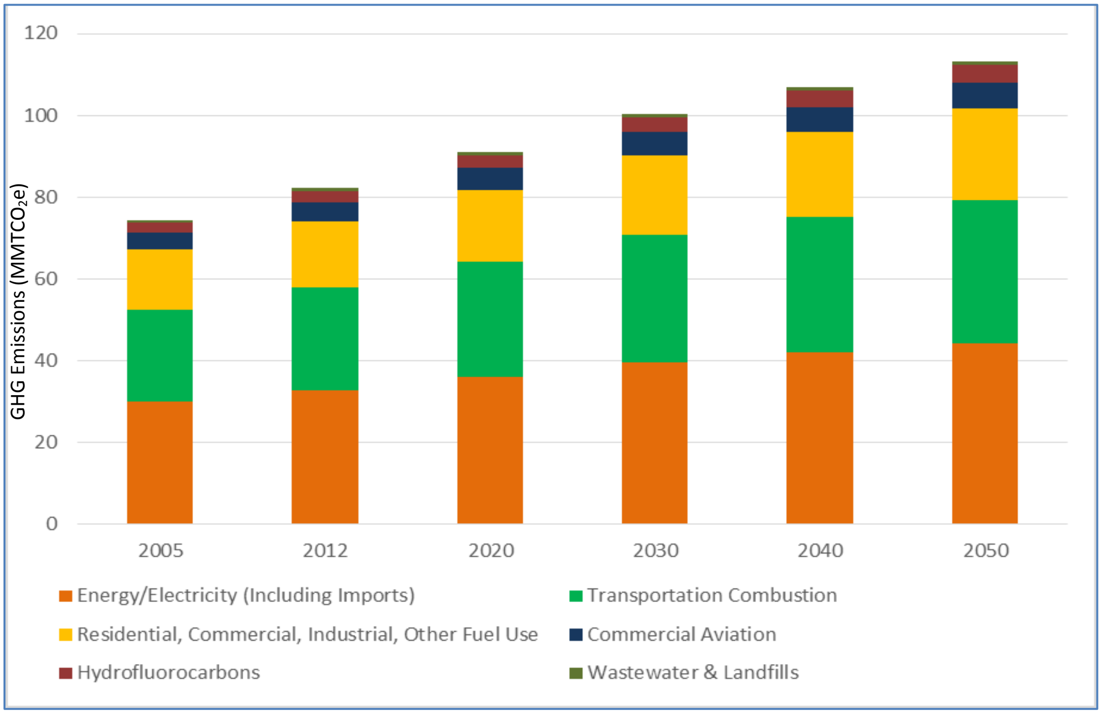
Figure 2. COG Planning Area Forecasts for Population and Employment



Consequently, the 2005 BAU scenario anticipated significant growth in GHG emissions across all key sectors, without further policy actions, as shown in Figure 3 below, from 74.45 $MMTCO_2e$ to 113.35 $MMTCO_2e$. The 2005 BAU scenario projections provided in this report are similar to those in the 2008 National Capital Region Climate Change Report through 2030. For 2040 and 2050, projections were updated based on revised population and employment projections for the region. Population in the COG region was forecast to increase 39 percent in the 2008 report, while updated forecasts project a 48 percent increase. Using the same methodology as the 2008 report, this resulted in a revision for 2050 projected BAU emissions from 106.3 $MMTCO_2e$ to 113.3 $MMTCO_2e$.

Under this 2005 BAU scenario, electricity-related GHG emissions were projected to increase by 48% from 2005 to 2050 (from 29.96 $MMTCO_2e$ to 44.37 $MMTCO_2e$), while transportation combustion-related GHG emissions were projected to increase by 55% (from 22.58 $MMTCO_2e$ to 35.00 $MMTCO_2e$).

Figure 3. 2005 Business as Usual (BAU) Regional GHG Inventory and Forecast



Key Findings: Strategies for Reducing GHG Emissions

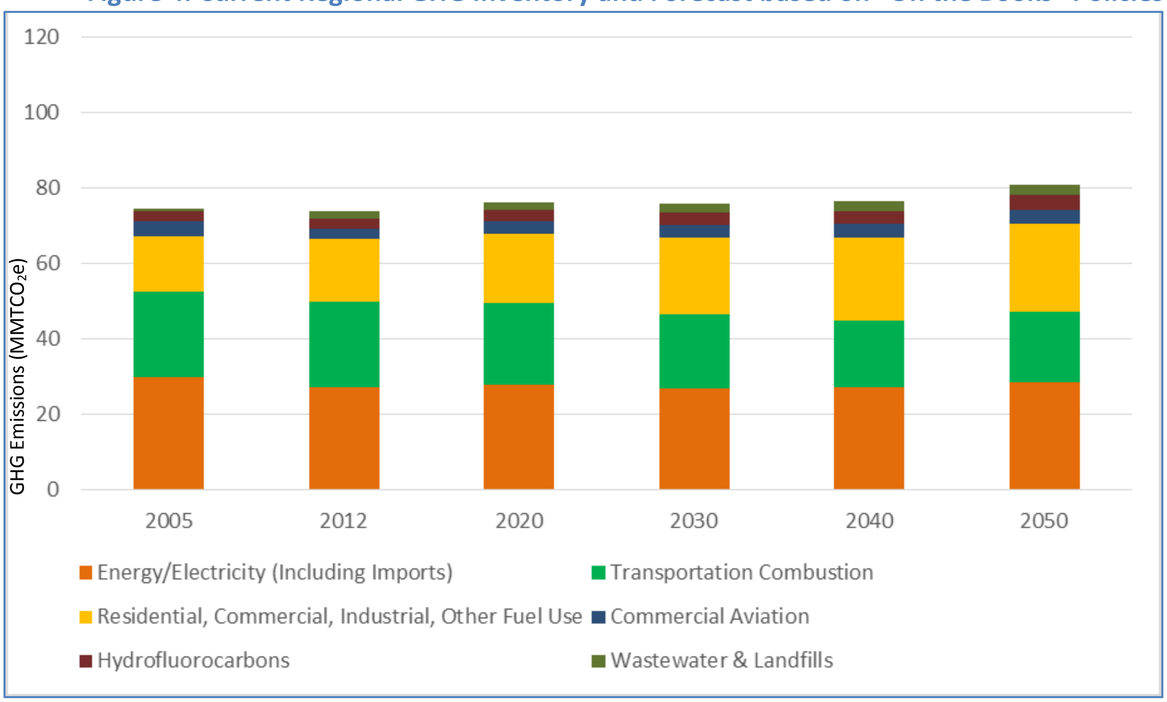
Existing Policies Are Making a Difference

Revised forecasts demonstrate that existing policies implemented at the federal, state, regional, and local levels are already making a significant contribution to reducing GHG emissions in the Washington metropolitan region. A revised "current policies" projection was developed for each emission source category of the regional inventory. These projections were developed to show the effect that current policies are forecast to have on emissions if fully implemented. As shown in Figure 4, existing policies are anticipated to result in 2050 GHG emissions of 80.81 $MMTCO_2e$, a reduction of about 32.53 $MMTCO_2e$, from the 2005 BAU scenario.

The most significant reductions are in emissions from transportation combustion, due to higher federal corporate average fuel economy (CAFE) standards, including light-duty vehicle GHG regulations that phase in for model years 2017-2025 cars and light trucks and heavy-duty engine and vehicle greenhouse gas (GHG) regulations that phase in during model years 2014-2018. In addition, regional land use patterns, transportation investments, and policies in the Constrained Long Range Plan (CLRP) also will reduce the rate of growth of vehicle travel. The transportation combustion "current policies" estimates were developed using outputs from the regional travel demand model and analysis conducted using EPA's MOVES2014 model to 2040, then estimating 2050 emissions based on population growth. Based on these significant improvements in vehicle fuel economy and local policies, GHG emissions from transportation combustion are projected to be 17% lower in 2050 than 2005 levels based on currently implemented policies and plans. This "current policies" scenario shows a reduction in GHG emissions due to transportation combustion-- from 22.6 $MMTCO_2e$ in 2012 to 17.8 $MMTCO_2e$ in 2040; transportation emissions rise to 18.6 $MMTCO_2e$ in 2050, driven by increasing population and VMT without corresponding fuel economy improvements beyond 2040.

Similarly, the electricity sector is forecast to see notable reductions in GHG emissions compared to 2005 BAU projections, with 2050 emissions projected to be 20% above 2005 levels. Power sector projections were anchored to the 2012 COG regional emissions inventory and projected based on the percent change in power sector emissions in the Annual Energy Outlook (AEO) 2015 reference case GHG projections for the PJM[2] region. This reference case takes into account shifts in energy efficiency and generation fuel mix. Layered on top of these projections are assumptions for the permanent locking in of reductions from Maryland's RPS increasing to 20% renewables by 2022 and Washington, D.C.'s RPS increasing to 20% renewables by 2020. Additional emission source categories such as residential fuel use, commercial aviation, and landfills were projected from 2012 levels using regional population and employment projections.

Figure 4. Current Regional GHG Inventory and Forecast based on "On the Books" Policies



[2] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia, an area that includes more than 51 million people.

Additional Regional Strategies Can Reduce GHG Emissions Considerably but Not Achieve the 80% Reduction Goal

COG's Multi-Sector Working Group (MSWG), consisting of technical and policy staff from COG's member jurisdictions, as well as state and regional agencies, who have expertise in one or more of the main sectors from which the region's greenhouse gas emissions come played a key role in identifying strategies for analysis. The MSWG established three subgroups – Energy/Built Environment, Land Use, and Transportation – and following their initial meetings, the Land Use and Transportation Sector Subgroups met jointly, recognizing the strong inter-relationships between strategies in these sectors. Building on an initial set of 75 potential strategy ideas identified by the subgroups, the subgroups refined the list of strategies to those believed to be most promising and worthy of more detailed quantitative analysis. Public comment from agencies, organizations, and individuals also provided input to inform the sets of strategies and policy scenarios considered within this analysis. The result was a refined list of 22 strategies – 9 in the Energy/Built Environment (EBE) Sector and 12 in the Transportation/Land Use (TLU) Sectors, along with one strategy focused on community engagement, which cross-cuts all of the sectors.[3]

Sketch planning methods – relying upon available literature, recent studies, and simple analysis tools – were used to analyze the potential of each strategy for analysis years of 2020, 2040, and 2050. This analysis contained two dimensions: temporal (considering timeframe of implementation) and level of stringency or "stretch" strategies. Based on feedback from the working groups, the analysis presented what were considered generally "viable" strategy assumptions for 2020 and 2040 (strategies that could potentially be implemented in this timeframe) and "stretch" strategy assumptions for 2050 to assess what might be possible under very stringent policy actions. A viable level was one that was generally considered to be consistent with actions proposed by at least some localities across the region and could be implementable by 2040. A stretch level was generally considered going beyond actions that are currently being considered and not to be implementable until after 2040.

In reviewing the results, it is important to keep in mind:

- These results do not account for additional federal policies, which could have a very significant impact on GHG emissions; the focus of this analysis is on strategies that might be applied at the local, regional, or state levels. Some of the strategies explored here might be implemented in part through future federal actions (e.g., increased adoption of electric vehicles can be encouraged regionally but also might occur through additional federal policies that require further increases in average vehicle fuel economy).
- There are high levels of uncertainties associated with future fuel prices, travel demand, technologies, and other factors that will have a significant impact on GHG emissions when

[3] This engagement strategy was initially identified in the EBE sector, but was expanded to cover all sectors, and is referred to as strategy EBE-10 / TLU-0 in this document.

forecasting through 2050. Although this analysis provides single estimates of GHG emissions reductions from strategies, ideally, it would be useful to consider these estimates as point estimates within a feasible range of reductions, based on future circumstances (e.g., fuel prices, economic growth assumptions).

- This study relied on relatively simple sketch planning methods, drawing on existing tools, methodologies, and results of studies from other regions and within the COG region, combined with regional data (and in the case of transportation emissions, the Environmental Protection Agency's MOVES2014 model), to estimate GHG impacts. The study timeframe and budget did not allow for complex modeling that would be useful to assess strategies in more detail. The sketch planning methods address direct impacts of strategies, but do not account for the indirect impacts of most strategies. For instance, the analysis accounts for GHG reductions from transportation and land use strategies that reduce vehicle travel, but does not account for indirect effects due to changes in traffic congestion, which would require more detailed travel modeling to assess.
- While the MSWG members agreed on the list of strategies being evaluated, there were some differences of opinion in regard to the assumptions associated with viable and stretch levels of implementation. While the implementation assumptions were developed based on input and feedback from the MSWG, some members indicated that the stretch levels in the transportation/land use sectors could be implemented sooner and could be more aggressive than those presented in this analysis; others felt that the implementation scenarios were very aggressive and may go beyond what would be acceptable to the public or policy-makers.

In reviewing the results, it is important to note that strategies interact with each other so that **the combined effects of implementing all strategies is less than the sum of GHG reductions from each individual strategy**. For instance, within the transportation and land use sectors, several strategies (e.g., land use strategies, travel demand management) reduce vehicle miles traveled (VMT) from passenger vehicles, while other strategies (e.g., increasing adoption of zero emissions vehicles) improve the average fuel economy of vehicles. While combining these strategies together will maximize overall GHG reduction, each vehicle mile removed from the road will be reducing less emissions (or considered alternatively, the improvement in vehicle fuel economy will be affecting fewer vehicles). Consequently, it is important to look at both the individual impacts of strategies and the combined effectiveness of the full package of strategies implemented together.

Table 1 below presents the estimated overall GHG emission reductions from implementing all considered strategies in combination. It shows that beyond the reductions already anticipated due to existing policies, significant additional reductions might be achieved from Energy/Built Environment (EBE) strategies, as well as Transportation and Land Use (TLU) strategies that could be implemented at the local, regional, or state levels.

Table 1: GHG Reductions from Current Policies and Potential Future Policies

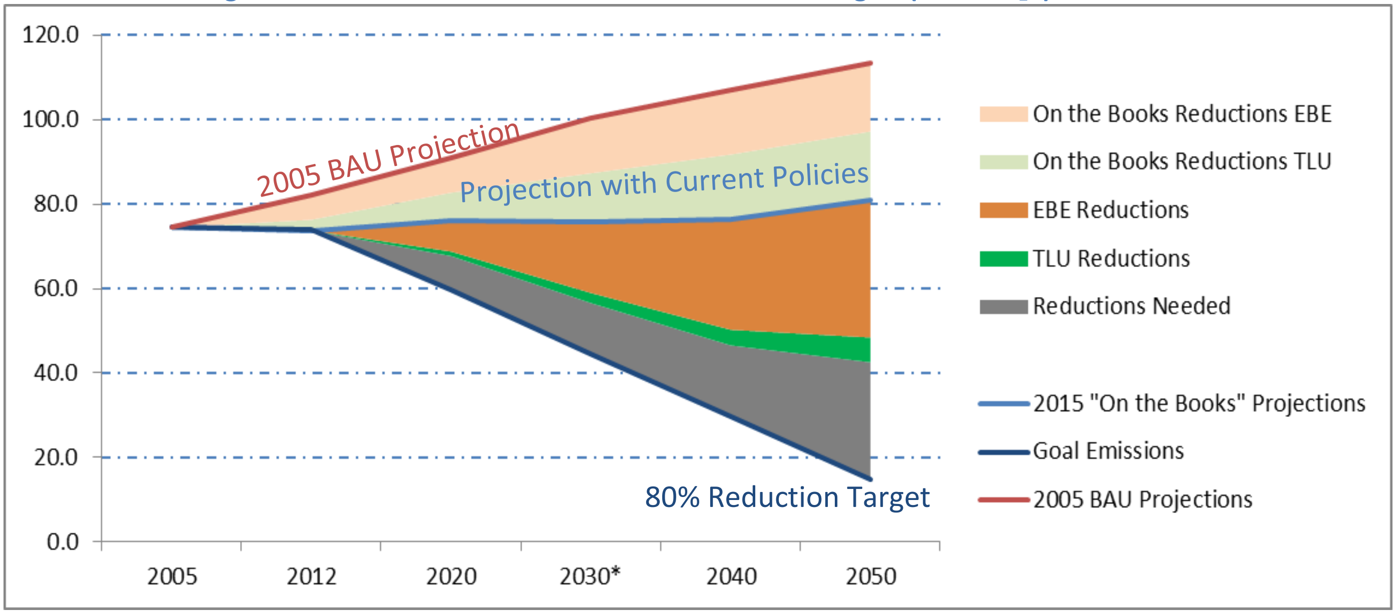
	GHG Emissions ($MMTCO_2e$)				
	2005	**2012**	**2020**	**2040**	**2050**
2005 BAU Projections	**74.5**	**82.3**	**91.3**	**103.3**	**106.3**
Revised 2005 BAU Projections	**74.5**	**82.2**	**91.0**	**106.9**	**113.3**
Reductions from Current Policies	--	8.4	14.9	30.5	32.5
2015 Current Policies Projection	**74.5**	**73.7**	**76.1**	**76.4**	**80.8**
Reductions from additional EBE Strategies	--	--	7.3	26.1	32.4
Reductions from additional Land Use Strategies			0.4	1.5	1.9
Reductions from additional Transportation Strategies	--	--	0.7	2.4	4.2
Total Reductions from New Strategies	--	--	*8.4*	*29.8*	*38.3*
Net Projected Emissions	**74.5**	**73.7**	**67.7**	**46.6**	**42.6**
Goal Emissions*	**74.5**	**74.0**	**59.6**	**29.8**	**14.9**
Further Reductions Needed to Meet Goal	--	-0.2	8.1	16.8	27.7
Projected Reductions from 2005 levels (%)			9%	37%	43%
Projected Reductions from 2005 BAU Projections (%)		10%	26%	56%	62%

*The goal emissions were determined by using the goal of reducing GHGs to 20% below 2005 levels by 2020 and to 80% below 2005 levels by 2050. The interim years were linearly interpolated based on these data points. Carbon sequestration from TLU-1 was not included in the overall reductions.

These figures are shown in Figure 5 below. The Energy/Built Environment (EBE) strategies address GHG emissions from electricity, as well as residential, commercial, industrial, and other fuel use, which make up 77% of estimated GHG emissions under current policies in 2050. These strategies show significant potential, particularly in the later years, as longer term implementation measures go into effect.

While looking relatively small in the context of total GHG emissions, regional Transportation and Land Use (TLU) strategies are estimated to be able to achieve significant GHG reductions in the near-term by 2020 (approximately 1.2 $MMTCO_2e$, or 5.5% of transportation emissions under the “current policies” scenario) and strategies are forecast to have the potential for significant further reductions in GHGs over the 2040 to 2050 time-horizon (up to 6.8 $MMTCO_2e$ in 2050, or 36% of transportation emissions under the “current policies” scenario). It is important to note that the 2050 strategy assumptions are aggressive stretch goals, which may not be implementable or politically feasible in combination; for instance, the strategies analyzed include significant increases in parking pricing, network-wide road pricing, cordon pricing around downtown Washington, DC, and significant transit fare reductions, all in combination. While each of these individual strategies was considered a feasible “stretch” policy, it is unlikely that all “stretch” strategies would be implemented in combination. Moreover, some of the transportation strategies analyzed (such as fuel economy improvements, and more efficient driving from autonomous or semi-autonomous vehicles in ecodriving mode) can be supported through regional and location actions, but will likely be driven by federal actions.

Figure 5. Total GHG reductions for EBE and TLU strategies (MMTCO_2e)



*2030 reductions are a linear interpolation between 2020 and 2040 for the purposes of this chart. Carbon sequestration from TLU-1 was not included in the overall reductions.

Table 2 presents the estimated results of individual strategies in order of greatest to least reductions (thus, it is important to recognize that the impacts of some strategies will be reduced when combined with others). Some strategies yield significant benefits in the near-term (e.g., operational improvements), while others tend to be longer-term strategies.

Table 2: GHG Reduction strategies in Descending Order of GHG Benefits in 2050[1]

Strategy	Strategy Name	GHG Reductions (MMTCO_2e)		
		2020	2040	2050
EBE-6	Targeted reductions in power sector emissions	1.97	8.05	10.74
EBE-1	Reduce energy and water consumption in existing buildings	2.73	10.55	10.55
EBE-4	Improve new building energy and water efficiency performance	1.03	4.18	6.59
EBE-2	Support existing building-level renewable energy development	1.15	1.86	2.78
TLU-2	Sustainable development patterns & urban design (including enhancements for non-motorized modes)	0.34	1.32	1.67
TLU-6	Low carbon fuel standard	0	1.02	1.29
TLU-1	Increase tree canopy and reduce loss of	0.19	0.82	0.98

Strategy	Strategy Name	GHG Reductions ($MMTCO_2e$)		
	vegetation through sustainable development patterns[2]			
TLU-3	Improve fuel economy of light-duty vehicle fleet[3]	0.09	0.50	0.88
TLU-7	Enhancing system operations	0.34	0.56	0.85
EBE-9	Reduce emissions from non-road engines	0.28	0.85	0.85
TLU-12	Road pricing	0	0.03	0.79
TLU-9	Travel demand management	0.13	0.24	0.54
EBE-3	Encourage development in activity centers	0.02	0.34	0.44
EBE-5	Achieve annual and cumulative reductions in fossil energy use by improving Infrastructure efficiency and increasing renewable energy use	0.05	0.23	0.32
EBE-8	Achieve targeted reduction in municipal solid waste	0.08	0.15	0.27
TLU-11	Transit incentives / fare reductions	0.12	0.10	0.19
EBE-7	Achieve targeted reductions in reduce natural gas pipeline leaks	0.02	0.11	0.11
TLU-4	Increase alternative fuels in public sector fleets	0.007	0.05	0.09
TLU-10	Transit enhancements	0.06	0.06	0.08
TLU-8	Reduce speeding on freeways	0.005	0.006	0.006
TLU-5	Truck stop electrification	<0.001	0.002	0.006

[1] Note that the additive impact of individual strategies does not sum to the combined impact of implementing all strategies. Also note that EBE-10/TLU-0 has not been presented separately in this table because it has been subsumed in other strategies.

[2] Carbon sequestration benefits are not counted against the 80% GHG reduction target; over half of the benefit is the prevention of loss of tree coverage and vegetation due to more compact development.

[3] Net GHG reduction accounts for increase in power sector emissions for electric vehicles; the increase is highly dependent upon other power sector strategies (not accounted for here when analyzing strategies independently). TLU-3 results in a reduction of on-road transportation combustion emissions of 0.22, 1.23, and 2.14 MMT CO_2e in 2020, 2040, and 2050 respectively; these reductions, however, are decreased to some extent by increased electricity consumption from electric vehicles.

Energy and Built Environment Strategies

Emission reductions in the energy sector and the built environment come from a variety of strategies, implemented through many more policy and program actions. The nine strategies assessed in this analysis are summarized in four categories:

- **Energy Efficiency.** Reducing energy use through efficient technology investments and improved facility operations is a proven strategy that has been successfully pursued by federal, state, and local governments for some four decades. In this analysis, efficiency improvements are captured for the existing building stock in EBE-1; the efficiency impacts of smaller residential and commercial spaces associated with buildings in higher-density activity centers are estimated in EBE-3; the effects of building codes and net-zero-energy policies are calculated in EBE-4. EBE-5 focuses on the region's infrastructure institutions, examining efficiency and renewable actions in water/wastewater and transportation institutions.

- **Power Sector and Renewables**. The electricity grid is one of the region's largest emissions sources, even though most of those emissions occur at power plants outside the region. EBE-6 examines the impacts of policy actions that could reduce power sector emissions in the regional grid; though some of these actions can be implemented within the region, some require higher-level policy action. EBE-2 examines renewable energy development in existing buildings, primarily in terms of solar photovoltaic development at the building or facility level. EBE-7 examines targeted reductions in natural gas distribution system leaks and fugitive emissions.
- **Waste Reduction**. The region's solid waste systems produce GHG emissions; while these emissions are not large relative to the building stock and power sector-related emissions, they are largely under area jurisdictions' purview, and so can be a focus for effective action. EBE-8 examines waste reduction actions.
- **Non-Road Engines**. Construction, landscaping, and other off-road equipment generate GHGs as well as criteria pollutant emissions. Higher efficiencies, tailpipe controls, and electric alternatives exist to reduce such emissions. EBE-9 examines this strategy.

Most if not all of these EBE strategies will involve extensive and sustained education and community engagement efforts on the part of COG members. In recognition of that reality, EBE-10/TLU-0 was created to include this important dimension in the analysis.

Because the availability of baseline data, analytical tools, and documented results varies greatly among the EBE strategies, the level of aggressiveness of these strategies also varies. In some cases, the strategies include both reasonable assumptions based on documented results, and "stretch" assumptions that exceed known impacts. For example, in EBE-1, the scenario target assumes a 2% annual/30% cumulative usage reduction for the region's building stock through 2030. Some COG jurisdictions' existing actions have shown that level of impact to be attainable; yet achieving those impacts across the entire building stock, and sustaining those impacts for 15 years and beyond, has yet to be demonstrated. Similarly in EBE-4, the analysis calculated energy savings in new buildings through 2030 using an established energy codes calculator that assumes modest stringency increases in three-year cycles. But from 2030 to 2050, the analysis applied a net-zero-energy assumption that assumes the entire new building stock achieves no net emissions impact by 2050, through a mix of efficiency, onsite renewables, and renewable credit purchases. This second assumption represents a substantial stretch.

The analysis captured interactive effects between scenarios. For example, the emissions impact of reductions in end-use consumption depends in part on the marginal emissions factors that apply in the power sector. The integrated analytic approach performed through this analysis works to capture these effects correctly. The analysis was not able to calculate all such effects, however; for example, in EBE-4 achieving net-zero-energy performance will likely involve some level of renewable credit purchases, which in turn reduces power sector emissions. And electrification of off-road engines would increase power sector emissions; but in neither case was sufficient data available to quantify those effects.

The results of the EBE analysis are shown in Table 3 below.

Table 3: Energy & Built Environment GHG Reduction Benefits

EBE Improvements	GHG Reductions ($MMTCO_2e$)				
	2005	2012	2020	2040	2050
2005 BAU Projections	**51.9**	**57.0**	**62.9**	**73.7**	**78.3**
2015 Current Policies Projections	**51.9**	**51.1**	**54.6**	**58.6**	**62.2**
Energy Efficiency Strategies	--	--	3.8	15.1	17.7
Power Supply Strategies	--	--	3.1	10.0	13.6
Non-Road Engines Strategies	--	--	0.3	0.8	0.8
Waste Strategies	--	--	0.1	0.2	0.3
Total Reductions from Strategies	--	--	7.3	26.1	32.4
Net Projected Emissions	**51.9**	**51.1**	**47.2**	**32.4**	**29.8**
Projected Reductions from 2005 levels (%)			9%	37%	43%
Projected Reductions from 2005 BAU Projections (%)		10%	25%	56%	62%

Figure 6 shows the majority of emission reductions come from the energy efficiency and power supply sectors.

Figure 6. Energy and Built Environment Reductions ($MMTCO_2e$) – 2050

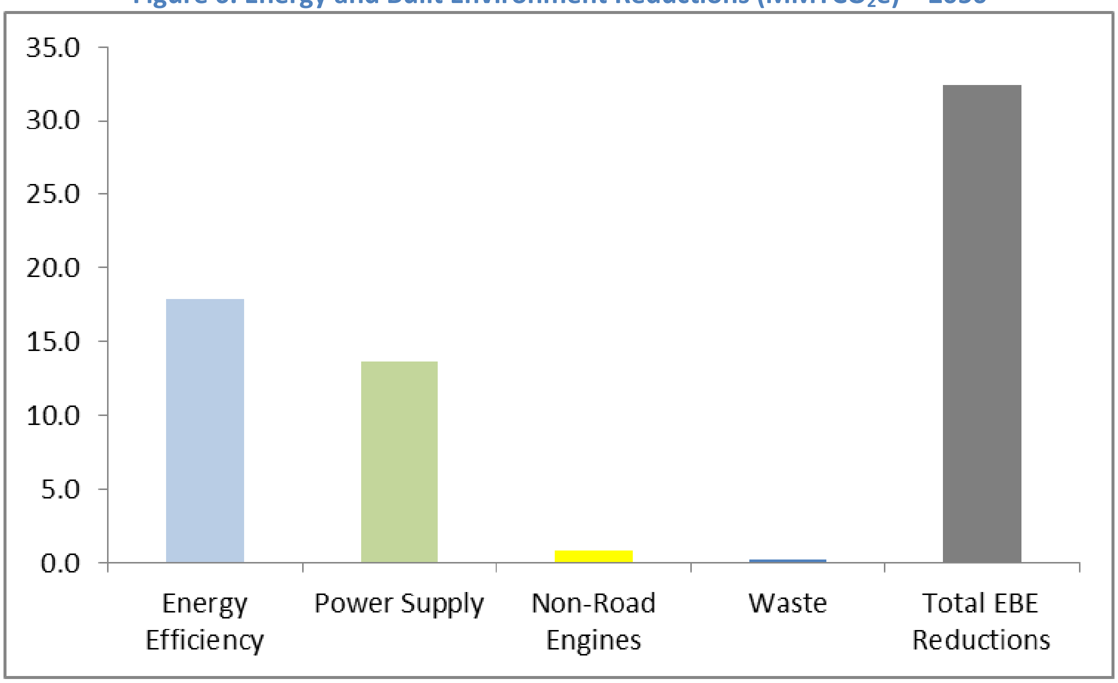
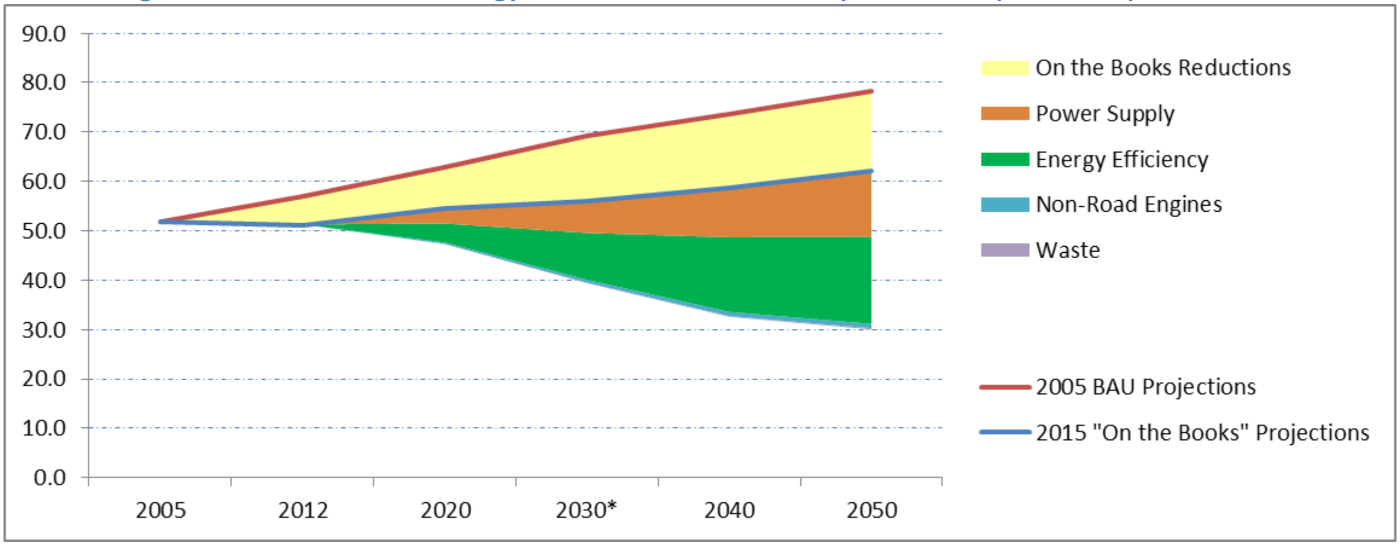


Figure 7 shows that while currently implemented policies will keep emissions from rising significantly, the additional regional strategies targeting the EBE sector analyzed as part of this study may yield significant additional reductions in GHG emissions.

Figure 7: Reductions from Energy and Built Environment Improvements ($MMTCO_2e$)



*2030 reductions are a linear interpolation between 2020 and 2040 for the purposes of this chart.

Transportation and Land Use Strategies

Transportation and land use sector strategies largely affect transportation combustion emissions; strategy TLU-1 is focused on carbon sequestration from increased tree coverage, and the eleven other strategies explored address motor vehicle emissions.

When considering strategies to reduce on-road mobile source combustion emissions, it is important to consider the composition of the regional vehicle fleet, which is comprised of passenger vehicles (cars, SUVs, minivans, pickup trucks, motorcycles) and medium- and heavy-duty vehicles, including buses and trucks of various sizes. Passenger vehicles accounted for 84% of VMT, and 72% of transportation combustion-related GHG emissions in 2012; by 2040, although passenger vehicles are projected to account for nearly the same share of VMT, they will make up only 64% of transportation combustion GHG emissions, due to improved fuel economy of passenger vehicles. Medium and heavy duty vehicles will account for a growing share of emissions, but the range of state, regional, and local strategies available to address these vehicles (which include commercial vehicles, interstate trucking, etc.) is somewhat limited compared to passenger vehicles (which can be more directly affected due to land use, pricing, and transportation options).

In exploring on-road mobile source emissions reduction strategies, there are three primary pathways for reducing emissions:

- **Reduce vehicle miles of travel (VMT)** – Transportation investments, policies, and strategies can encourage shifts from driving alone to options such as transit, ridesharing, biking, walking, and telecommuting. Currently, daily passenger vehicle miles of travel in the region (not including heavy-duty vehicles, such as freight trucks) total more than 100 million miles and, with projected population and employment growth, this number is expected to grow by over 25% by 2040, even with the land use patterns and investments in alternative modes included in the existing CLRTP (based on forecast population growth, passenger miles traveled may be 31% higher in 2050 than today). Beyond the effects of sustainable land use patterns in reducing the growth in VMT, transportation strategies to reduce VMT include policies that promote alternative modes of travel, enhance transit services, reduce the price of transit, manage parking, increase the price of vehicle travel and parking, and other travel demand management measures such as expanding teleworking opportunities.

- **Change vehicle fleet composition and/or fuels** – Further GHG reductions in the region's transportation sector can be achieved by regional actions that would promote improving the fuel economy of the light-duty vehicle fleet, implementation of a low carbon fuel standard, increasing use of lower emission alternative transportation fuels in public sector fleets, and implementation of clean freight technologies such as truck stop electrification to reduce long-haul truck idling. Increases in the share of electric and other zero emissions vehicles (ZEVs) in the passenger vehicle fleet could have a significant impact on reducing GHG emissions from on-road mobile sources, but these reductions would be decreased somewhat by increased emissions from the power sector in generating additional electricity to power these ZEVs. The size of this decrease would depend on the composition of fuels used to generate this electricity and the diurnal pattern of the charging of these ZEVs.
- **Change how vehicles operate (operational efficiency)** – Improving the operating efficiencies of vehicles traveling on the region's roadways holds potential for further reductions in GHG emissions. How vehicles are operated (speeds, acceleration and deceleration patterns) affects their level of fuel economy and how much they emit per mile. "Eco-Driving", which entails driving with less aggressive starts and stops and reduced unnecessary idling can reduce emissions across all vehicles on the region's roadways, and can be furthered through public education and the use of in-vehicle monitoring and feedback. Integrated corridor management on freeways and major arterials, intersection improvements, bottleneck reductions, and reduced speeding on freeways can also improve vehicle operating efficiencies and reduce GHG emissions. In the not-so-distant future, use of semi-autonomous or autonomous vehicles have the potential of greatly improving the operational efficiency of vehicles operating on the region's roadways.

The results of the TLU analysis for 2050 are shown in

Table 4. It is important to note that the 2050 scenario includes very aggressive sets of strategies being implemented in combination, which may not be viable in combination. The estimated benefits of these strategies are considerably larger than previous estimates in the “What Would it Take?” analysis, based on more stringent applications of strategies, in particular in relation to VMT reduction strategies.

Table 4: Transportation and Land Use Strategies GHG Reduction Benefits

Transportation Combustion	GHG Reductions ($MMTCO_2e$)				
	2005	2012	2020	2040	2050
2015 "Current Policies" Projections – On-Road Transportation Combustion	**22.58**	**22.63**	**21.54**	**17.80**	**18.64**
VMT Strategies (including Land Use) – GHG Reduction	-	-	0.64	1.75	3.27
Vehicle/Fuels Strategies – GHG Reduction*	-	-	0.23	2.30	3.53
Operational Efficiency Strategies – GHG Reduction	-	-	0.34	0.57	0.86
Total On-Road GHG Reductions+	-	-	1.19	4.30	6.77
Projected On-Road Transportation Emissions	**22.58**	**22.63**	**20.35**	**13.50**	**11.86**
2005 BAU Projections – On-Road Transportation Combustion	*22.58*	*25.17*	*28.14*	*33.13*	*35.00*
Projected Reductions from 2005 levels (%)			10%	40%	47%
Projected Reductions from 2005 BAU Projections (%)			28%	59%	66%
Off-set from increased electricity consumption*			0.13	0.72	1.26

*Note that an increase in electric vehicles reduces on-road transportation combustion emissions but increases electric utility emissions; the level of increase in electric utility emissions will depend on many factors, including the implementation of EBE strategies.

+The total does not equal the sum of the individual types of strategies due to off-setting effects.

Figure 8 below displays the individual impacts of groupings of strategies based on the three primary pathways, and the cumulative emissions reductions of combining all strategies (which is less than the sum of the three components).

Figure 8. Transportation and Land Use Reductions ($MMTCO_2e$) – 2050

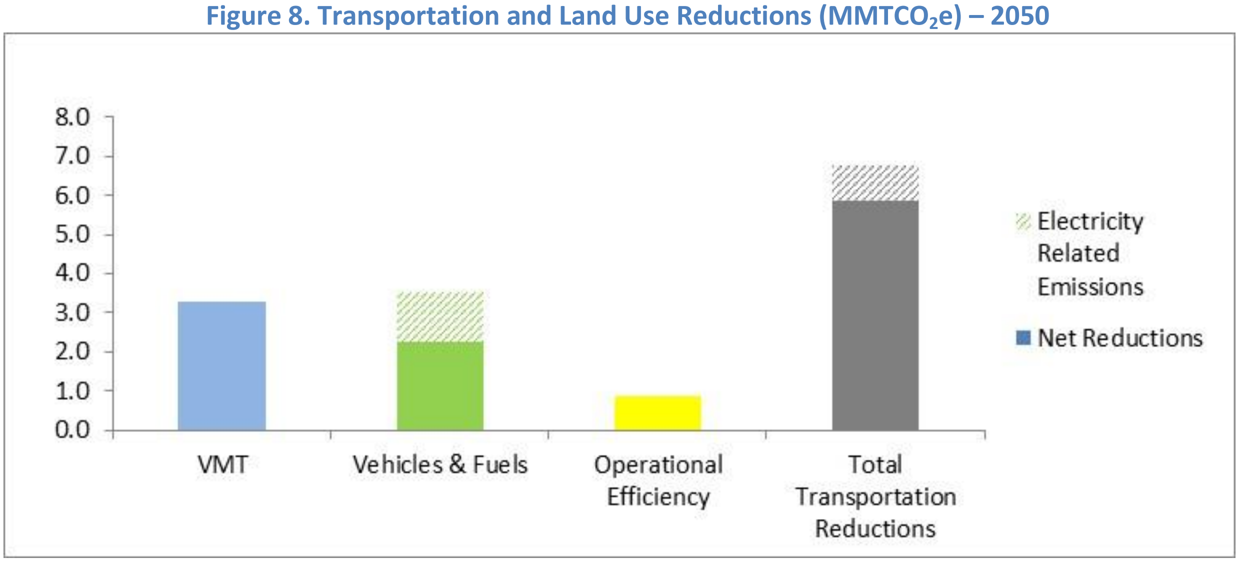
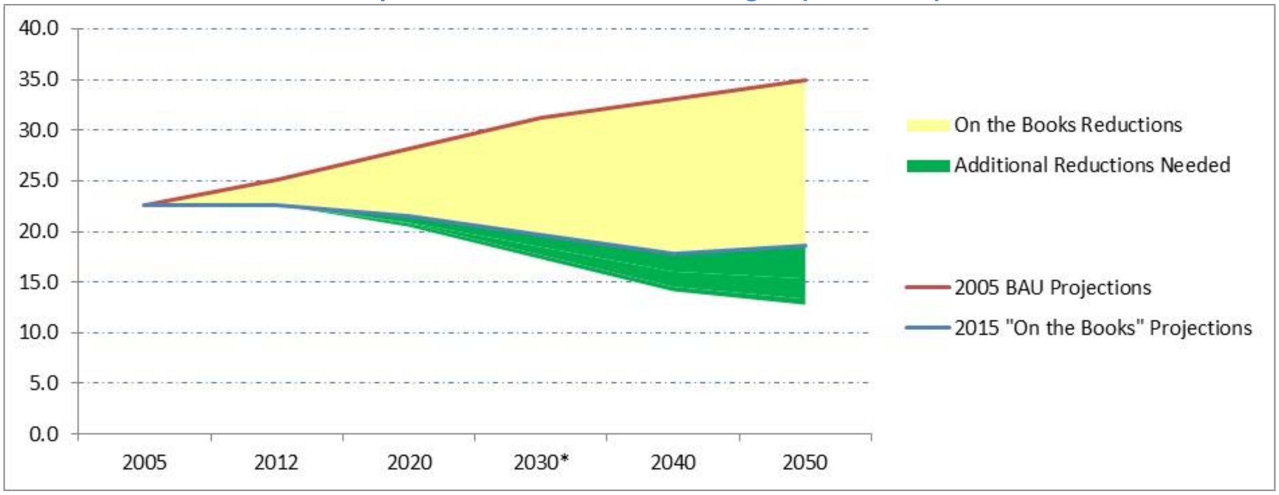


Figure 9 demonstrates that policies currently on the books, including new light-duty and heavy-duty vehicle fuel economy standards, are anticipated to significantly reduce emissions from the 2005 BAU projection. Additional potentially viable and stretch regional strategies targeting the TLU sector analyzed as part of this study may yield significant additional GHG reductions.

Figure 9. On-Road Transportation Combustion Emissions – Forecasts and Reductions from Transportation and Land Use Strategies (MMTCO$_2$e)



*2030 reductions are a linear interpolation between 2020 and 2040 for the purposes of this chart.

Overall, both VMT reduction strategies and vehicle/fuels strategies were estimated to have significant potential to reduce GHG emissions. However, it is important to note that these strategies implemented in combination will cumulatively yield less than the sum of each individual strategy (e.g., a more fuel efficient and lower-carbon vehicle fleet will mean that each mile reduced yields less GHG reduction). Many of the significant VMT and vehicle/fuel strategies also take considerable time to yield impacts (for instance, due to the time it takes for land use policies to make a significant impact and due to the time it takes for the vehicle fleet to turn over). Transportation system operational efficiency strategies, meanwhile, can be implemented relatively quickly for near-term impacts. Key points in regard to strategies are highlighted below.

Land Use Strategies

Development patterns that emphasize compact, mixed-use and walkable urban design focused on activity centers, including enhancement of non-motorized modes of travel, hold potential for GHG reduction through several mechanisms:

- By reducing vehicle travel and corresponding motor vehicle emissions (presented in strategy TLU-2) - Focusing more of the region’s future growth in walkable, mixed use activity centers, complemented by high quality transit and other multimodal transportation investments to support these centers , would be expected to result in fewer vehicle trips, shorter trip lengths, and more trips by transit, walking and biking, thereby reducing GHG emissions from increased daily vehicle miles traveled (VMT) in the region that would result from future population and employment growth.
- By reducing destruction of trees and other natural land cover, which sequester carbon, as well as strategies to increase the tree canopy (presented in strategy TLU-1) - These development patterns are also more efficient in terms of land consumption, commanding less of a footprint

on undeveloped land. So-called greenfield development results in the loss of valuable forest and agricultural/grassland, and along with it the beneficial function of this vegetation in sequestering carbon – a natural mechanism for offsetting GHG emissions. Moreover, expanding the region's tree canopy will also achieve additional carbon sequestration benefits.
- By encouraging denser development (multi-family housing and commercial development), rather than low-density development, which results in lower building energy consumption per dwelling unit (presented in strategy EBE-3).

As a result, even though the impacts of these three strategies is presented separately, it is important to recognize that they are linked. Together, the benefits of land use strategies are significant, and also yield multiple additional co-benefits (e.g., enhanced accessibility, reduced runoff to the Chesapeake Bay from reduced impervious surfaces). Given that the CLRP already assumes a high share of new development in activity centers, this strategy aggressively assumes that all new development will occur in activity centers, with high levels of corresponding accessibility (bicycle/pedestrian infrastructure).

VMT Reduction Strategies

In addition to land use strategies, the analysis included a range of other significant VMT reductions strategies. Based on this analysis, land use strategies reduce VMT by 11.6% in 2040 and 14.1% in the 2050 stretch scenario, but have relatively modest effects in the near term due to the time-frame for development to occur. Other VMT reduction strategies generally reduce VMT by 2 to 4% from 2020 to 2040, but have a much more significant impact in the 2050 stretch scenario (a 13.5% reduction in VMT) due to assumptions of wide-scale implementation of pricing mechanisms, including VMT-based road pricing, parking pricing, and mandated employer-provided commute subsidies. In combination with land use, the analysis suggests nearly a 28% reduction in VMT compared to the "current policies" baseline. While these levels are significantly larger than many studies of VMT reduction strategies suggest, they are comparable to the high scenario estimates developed through a Washington Metropolitan Area Transit Authority (WMATA) study, which involved extensive modeling of alternative land use, pricing, transit, and demand management policies.

The VMT reduction strategies (not accounting for land use) are also associated with a significant increase in transit ridership across the region – approximately a 25% increase beyond the baseline projection for 2040, and nearly 80% increase beyond the baseline projection for the 2050 stretch scenario. Combined with land use strategies, transit ridership would likely more than double compared to the baseline projection.[4]

Viewed comprehensively, these levels of VMT reduction reduce the rate of growth in regional VMT over the analysis period through 2040; the 2050 stretch scenario actually reduces total VMT within the region below 2012 levels, as shown in Table 5. While per capita daily VMT is already forecast to decline, the additional land use and transportation strategies significantly reduce the average per capita daily VMT level, with VMT per capita estimated to drop by nearly one-third by 2050.These significant reductions highlight how aggressive the stretch scenario is, given the expected growth in regional population over this timeframe. These strategies generally have multiple co-benefits, and some pricing mechanisms

[4] Transit mode shift from the land use strategies was not directly estimated, based on the methodology employed.

(road pricing, parking pricing) generate revenues, which may be used to help support other strategies (e.g., electric vehicle incentive programs, transit fare reductions, transit enhancements). There would, however, be significant additional capital and operating costs associated with new transit services that would be needed to accommodate the increased transit demand.

Table 5. VMT Reductions and Average Daily VMT Under Alternative Policy Scenarios

	2012	2020	2040	2050 stretch
VMT Reductions due to Strategies Compared to Baseline with Current Policies				
LU Strategies	-	2.2%	11.6%	14.1%
LU + Other VMT Reduction Strategies	-	4.2%	15.4%	27.6%
Average Daily VMT by Passenger Vehicles (millions)				
VMT with Current Policies	100.81	108.59	126.01	131.91
With LU Strategies		106.18	111.39	113.31
With LU + Other VMT Reduction Strategies		104.00	106.59	95.57
Daily VMT per Capita by Passenger Vehicles				
With Current Policies	19.49	19.13	18.86	18.86
With LU Strategies		18.71	16.67	16.20
With LU + Other VMT Reduction Strategies		18.33	15.95	13.66

Vehicle/Fuel Strategies

Vehicle and fuel strategies yield significant benefits in GHG emissions from on-road combustion, with the most significant reductions coming from strategies to increase the share of zero emissions vehicles (ZEVs) in the passenger vehicle fleet and to adopt a low carbon fuel standard. The direct emissions reductions from on-road mobile sources, however, is somewhat decreased due to increased emissions from electric utilities that are powering ZEVs.

System Operations Strategies

Transportation systems management and operations strategies have potential for moderate reductions in GHG emissions. Although the region already is implementing a wide array of strategies and these strategies are part of the CLRP, there is potential for further applications. In addition, the largest effect of these strategies was estimated to come from "eco-driving", which entails driving with less aggressive starts and stops and reduced unnecessary idling. Eco-driving has a large effect because it can apply to a very large base of vehicles; it can be furthered through public education, as well as in-vehicle systems, and through adoption of semi-autonomous or autonomous vehicles. The 2050 stretch scenario assumes nearly universal application of eco-driving, based in part of new vehicle technologies; consequently, while this strategy can be advanced through public education campaigns and deployment of connected vehicle infrastructure, its full application would likely be associated with federal policies beyond the control of the region.

Many Strategies have Multiple Co-Benefits

While GHG reduction is an important motivator for strategies, most of the strategies also demonstrate multiple co-benefits. In particular, most strategies that reduce GHG emissions also improve air quality by reducing emissions of criteria air pollutants that lead to ozone and fine particulate matter. By reducing energy consumption, many of the strategies also result in overall cost savings for consumers. The land use strategies and VMT-reduction strategies also offer significant additional benefits, including improved accessibility, mobility, and community amenities. Quantitative estimates of air pollutant emissions benefits of transportation and land use strategies were estimated using the MOVES2014 emissions model.

Strategy Costs Vary, but Many Have Net Cost Savings

Some strategies can be advanced through policies or requirements that do not require direct public expenditures, such as many of the strategies focused on the built environment and land use, which can be advanced through zoning, requirements for development approval, and other policy mechanisms. Others will require direct public sector expenditures, such as for new transit services, truck stop electrification, or incentive costs. Parking and road pricing strategies can generate considerable public sector revenues.

It is important to recognize that many of the VMT-reduction strategies will also require investments in transit capacity to accommodate the expected increase in transit demand.

Additional Strategies are Needed to Attain 2050 Goal

Additional strategies beyond those identified by the MSWG will be needed to further reduce the region's GHG emissions to fully achieve COG's GHG reduction goal for 2050.

These additional strategies will likely require significant breakthrough improvements in existing technology and substantially more actions at federal, state, regional and local levels.

Individual Strategy Assessments: Methodology, Assumptions, and Results

This section provides summary documentation of the scenarios analyzed, methodologies, assumptions, GHG impacts, co-benefits, and costs associated with individual strategies. These strategies include:

EBE-1: Reduce energy and water consumption in existing buildings

EBE-2: Support existing building-level renewable energy development

EBE-3: Encourage development in activity centers

EBE-4: Improve new building energy performance and water efficiency performance

EBE-5: Improve infrastructure efficiency and increase renewable energy use

EBE-6: Targeted reductions in power sector emissions

EBE-7: Reduce natural gas pipeline leaks

EBE-8: Targeted reductions in municipal solid waste

EBE-9: Reduce emissions from non-road engines

EBE-10/TLU-0: Educate and motivate public through community engagement

TLU-1: Increase tree canopy and reduce loss of vegetation through sustainable development patterns

TLU-2: Sustainable development patterns and urban design, including bicycle/pedestrian enhancements

TLU-3: Improve fuel economy of light-duty vehicle fleet

TLU-4: Increase alternative fuels in public sector fleets

TLU-5: Truck stop electrification

TLU-6: Low carbon fuel standard

TLU-7: Enhancing system operations

TLU-8: Reduce speeding on freeways

TLU-9: Travel Demand Management

TLU-10: Transit enhancements

TLU-11: Transit incentives/ Fare reductions

TLU-12: Road pricing

EBE-1: Reduce energy and water consumption in existing buildings

This strategy is designed to reduce energy and water consumption in existing buildings. The scenario analyzed assumes achievement of a 2% annual (30% cumulative) reduction in building energy and water use by 2030. This will be accomplished through the following implementation actions.

- Leverage utility ratepayer-funded programs to drive energy performance improvements via incentives and technical assistance
- Adopt Architecture 2030 goal, adapted for existing buildings.
- Extend enforcement of building energy code provisions to better address existing building stock
- Reduce water usage via planning/zoning policies, water utility partnerships
- Drive private building energy and water performance via mandatory benchmarking, and voluntary challenge initiatives
- Expand low-income housing energy and water savings by leveraging federal, state, utility resources.
- Expand financing options for energy and water efficiency and renewable energy.
- Drive public/institutional energy and water savings via performance contracting, especially for public and institutional buildings.

GHG Results

This strategy aligns with existing building goals put in place by COG-member jurisdictions, such as Arlington, the District of Columbia, Greenbelt, Prince George's County, and Montgomery County. These policies have been shown to achieve impacts at or about the 2% annual reductions used in this scenario analysis. For example, a 2012 ENERGY STAR Portfolio Manager Data Trends report indicates that of more than 35,000 buildings for which data entry was completed and ENERGY STAR scores were received (between 2008 and 2011), the average annual savings was 2.4%. Building benchmarking, required for larger commercial buildings in the District of Columbia for the past several years, has shown comparable levels of savings from buildings reporting benchmarking data.

The 2012 Montgomery County Commercial Building Energy Efficiency Policy Study shows that the commercial buildings sector has the technical potential to reduce its energy usage almost 25% over 10 years, even when accounting for new construction; annual savings would average more than 2%. The Maryland Public Service Commission's 2015 order on extending energy savings targets under its authority established in the EmPOWER Maryland legislation now requires affected utilities to achieve annual savings of at least 2% of electricity consumption. The DC Sustainable Energy Utility is pursuing aggressive energy savings programs in the District, and in Virginia, the Governor's Executive Committee on Energy Efficiency is examining options for increasing energy efficiency efforts in the Commonwealth.

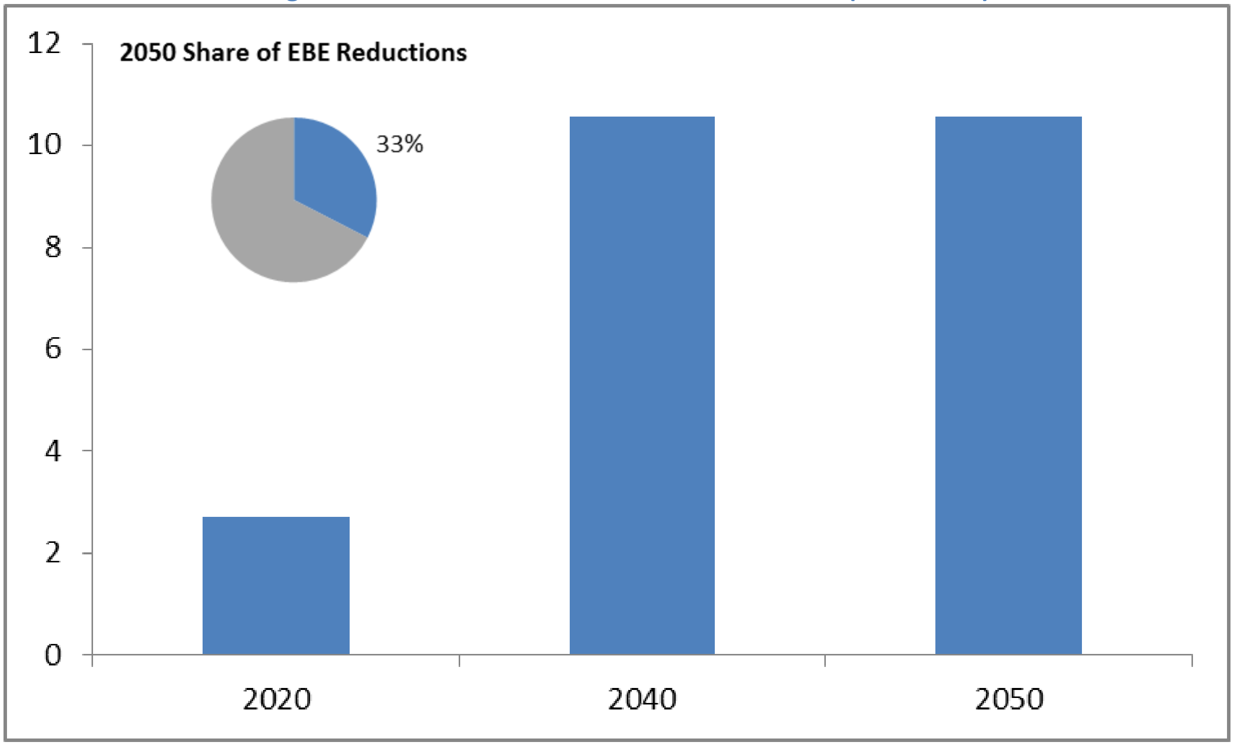
These examples serve to support the attainability of the scenario reduction target; however, it should be pointed out that no jurisdiction has yet shown the ability to sustain 2% or better annual savings across the entire existing building stock, or over the 15-year period that this scenario represents. Therefore, this scenario should be considered relatively aggressive. The policy and program actions detailed in this document, while they have not been modeled individually, would serve as COG members' available levers for reaching the 2% annual and 30% cumulative reductions.

The following results were estimated for EBE-1. Since the implementation actions within the strategy are slated to begin in 2015 and end in 2030, the savings phase-in more quickly than for other strategies. An energy intensity growth rate, calculated from 2005-2012 data, was applied to derive a starting 2015 data point, marking the beginning of the analysis timeframe.

Table 6. Greenhouse Gas Reductions for EBE-1

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	2.73	10.55	10.55
Electricity Reductions (MWh)	2,406,764	14,671,915	14,671,915
Natural Gas Reductions (MMBtu)	15,843,725	44,920,334	44,920,334
Water Reductions (Gallons)	23,943	82,642	91,484

Figure 10. EBE-1: GHG reductions – stand-alone (MMTCO_2e)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

MWCOG provided the following data that were used in the analysis for EBE-1:

- 2005 and 2012 electric and natural gas usage by sector;
- 2012 water consumption for COG region;
- Round 8.3 commercial and residential sector square footage and household growth forecasts through 2050; and
- Round 8.3 population forecasts through 2050.

Assumptions

- The analysis assumed a 2005 baseline, and used 2012 data to develop energy intensity and average annual improvement numbers for interpolating data points. This leads to a slightly incongruous drop from 2015 – 2016 as the 2% improvement is phased in, which continues through 2030. A 2012 baseline was assumed for the water reduction in accordance with the historical data provided.

Potential Co-Benefits

In addition to saving energy and GHG emissions, building energy efficiency comes with a variety of co-benefits provided in Table 7 below.

Table 7. Co-Benefit Results for EBE-1

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Energy efficiency lessens the demand for electricity and natural gas, resulting in fewer emissions from buildings and power plants.
Local Job Growth	Efficiency investments are typically more labor-intensive than energy supply investments, creating more jobs per dollar invested. Jobs in engineering and architecture, building trades, and the supply chain tend to increase, with most new jobs developing locally. Energy supply jobs tend to be generated outside the region.
Improved Occupant Comfort, Health, and Safety	Buildings that perform efficiently are often more comfortable, healthier, and safer for workers and visitors.

Costs

While there are costs associated with energy efficiency policy and program actions, they have generally been found to be very cost-effective as individual investments, and to generate net economic benefits for local economies.

Table 8. Costs for EBE-1

Level	Public Sector Costs	Private Sector/Other Costs
Low to Medium	Utility incentive programs to stimulate energy efficiency Public efficiency programs for multifamily and affordable housing	Mandatory building benchmarking Private sector portion of efficiency investments Compliance with building code policies
Cost Savings Efficiency encompasses very cost-effective measures that typically would yield positive net present value over the study period. Numerous analyses typically show a range of efficiency measures costing less than available energy supply options.		

- Utility incentive programs come at a relatively small cost to ratepayers, whose average energy bills are lower over the long term, even after program costs are recovered in rates. These programs help manage demand so that total costs to the electric grid are minimized over the course of the planning period.

- Energy efficiency programs can also provide benefits for housing affordability, by targeting low-income housing, including multifamily buildings. Low-income programs help families stay in their homes, reduce their housing cost burden, and improve the quality and value of the affordable housing stock.
- Mandatory building benchmarking and compliance with building code policies place a nominal cost and time burden on the private sector. However, businesses also stand to benefit financially from better information with which to pursue energy management and associated offerings that result, like performance contracting arrangements and utility incentives.

Implementation Issues

EBE-1 encompasses a wide range of policy and program actions, some of which can be directly implemented by MWCOG members and some of which require policy actions at higher levels. Direct actions can include commercial building benchmarking policies, extending building code administration to more actively focus on additions, alterations, or renovations of existing buildings, enabling financing options such as PACE, and creating voluntary energy savings challenges for organizations and citizens.

Higher-level action is needed to affect policies such as state-regulated utility ratepayer-funded efficiency programs, federal appliance efficiency standards, and federal tax incentives for energy efficiency. For such higher-level policy and program actions, MWCOG members can take constituent action to express support for increased energy efficiency with the appropriate state and federal entities.

EBE-2: Support existing building-level renewable energy development

This strategy is designed to increase renewable energy deployment in and for existing buildings, separate from utility-developed renewables (shown separately in EBE-6). The goal for this strategy is to driving net energy and GHG reductions via distributed deployment of renewables including solar PV, wind and other technologies that may become viable within the forecasting window through 2050.

Shown below are the potential actions that have been evaluated and forecast. These are complementary and could be pursued either individually or in aggregate.

- EBE2.0 Baseline Solar/Wind deployment across all sectors
- EBE2.1 Support cooperative/community renewable energy purchasing for residential sector
- EBE2.2 Support cooperative/aggregated renewable energy purchasing for commercial sector.
- EBE2.3 Support cooperative/aggregated renewable energy purchasing for government sector
- EBE2.4 Provide incentives for building-level renewable technologies
- EBE2.5 Adopt solar access ordinances and similar regulations to support renewable development.

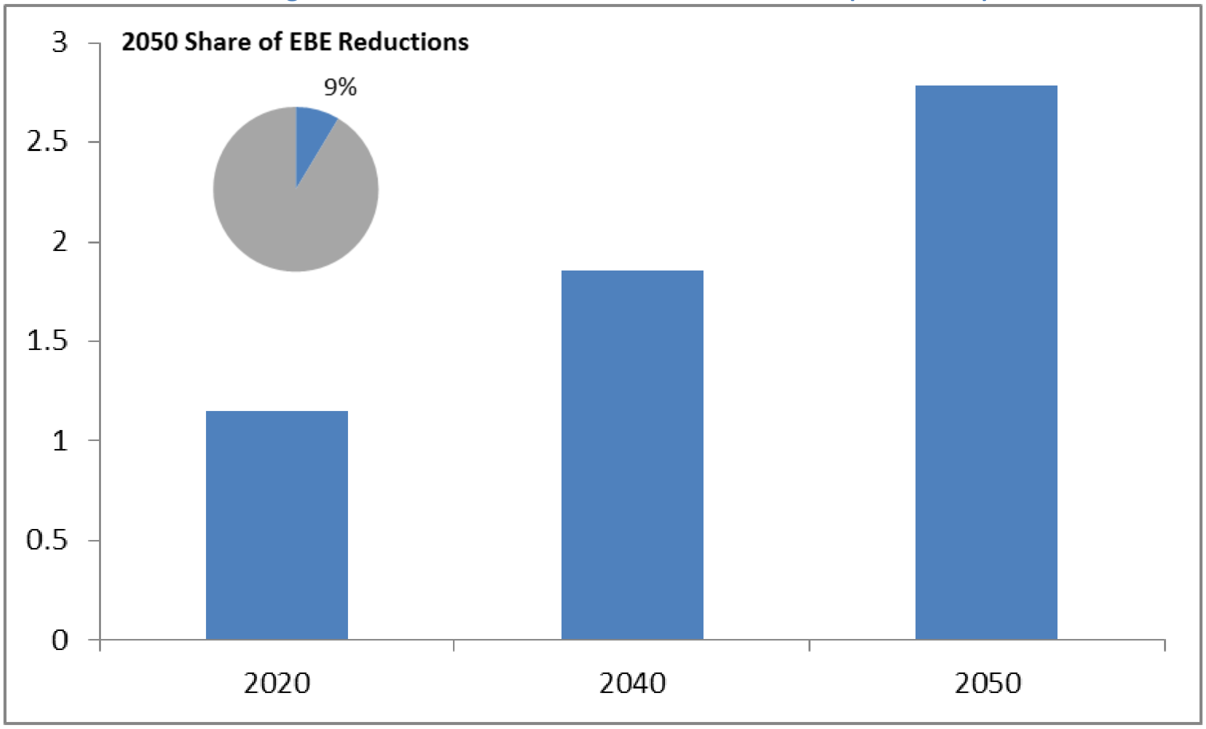
GHG Results

As shown in Table 9, the total impact from the actions within EBE-2 could reduce 2050 GHG emissions by almost 3 million metric tons, and can also drive broad awareness and support for regional GHG reduction plans and strategies. In energy terms, the 5.5 million MWH in projected 2050 savings represents the output of almost one million typical residential PV systems; compared to a 2014 base of 69,000 installed kW, which equates to less than 15,000 typical systems, this analysis indicates massive growth in solar PV. This PV capacity would occur through a mix of residential and commercial systems, so the actual number of systems would likely be low. Other renewables, such as solar thermal, could also develop substantially, though they were not the focus of this analysis.

Table 9. Greenhouse Gas Reductions for EBE-2

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO_2e)	1.15	1.86	2.78
Electricity Reductions (MWh)	1,582,167	3,654,453	5,468,655

Figure 11. EBE-2: GHG reductions – stand-alone ($MMTCO_2e$)



Following are the total forecast impact with further descriptions for each specific action below.

EBE2.0 – Baseline Distributed Renewables Growth (BAU)

In certain jurisdictions in Maryland and Washington DC there has been rapid growth in deployment of distributed renewables, primarily solar PV and limited wind power or solar hot water. In Virginia jurisdictions, growth to date has been slower on average due to a number of factors. During the forecasting process, the continued growth curve as a baseline indicates that 10% to 13% of the total impact from EBE-2 can be achieved through organic adoption regionally. Ongoing support for existing policies and programs from MWCOG and its members is critical to realizing this ongoing benefit.

EBE2.1 – Aggregated Residential Programs

Using national examples for successful aggregated residential programs (also known as community or collaborative programs), this forecast assumes a 3-year program that drives deployment regionally by leveraging existing organizations to implement established best practices on a widespread basis. The impact from this effort is forecast to more than double the BAU baseline over the forecast period due to the acceleration of deployment and synergistic effects from broader awareness and adoption in the residential sector. In total, the analysis forecasted approximately 40,000 homes may participate in this kind of program when fully deployed regionally. An important consideration is the use of "community/shared" projects that enable residents with non-optimal housing site characteristics to participate. This model is currently available in limited forms in Maryland and DC and can be a "game changer" if made readily available to all consumers.

EBE2.2 – Aggregated Commercial Programs

The commercial sector is largely un-tapped for renewable energy deployment but encouraging opportunities are available regionally. By pursuing programs, outreach and also shared/remote solar and/or wind purchases, this aggregated effort could yield significant results for GHG reduction. Forecasting only 2.5% net decrease from on-site and off-site renewables within a 5-year program period yields nearly 50% of the total impact from the EBE-2 actions in total.

EBE2.3 – Aggregated Government Programs

Local, state and federal government agencies have been leading the way in renewable energy deployment and still have the potential for expanding deployment regionally using both on-site and remote solar and wind purchasing options. The forecasts for this action include group efforts to purchase cost-effective renewable power and accelerate achievement of individual jurisdictional clean power goals. Replacing just 10% of current government power with regional clean power can nearly double the BAU baseline growth as well. However, due to the aggressive government purchasing of renewable energy from Washington DC and others, this forecast reflects that some of the potential has already been realized and is included in BAU. This strategy thus reflects incremental emission reductions beyond BAU baseline reductions.

EBE2.4 – Renewable Energy Incentive Programs

The contemplated incentive programs within this action (property tax abatements, density allowances, and permit fee reductions) are forecast to support overall BAU growth across the region, although they are not considered transformative. Depending on the incentive levels and marketing of these benefits over an extended period, the total contribution of this action could reach 5% of the overall impact of EBE-2.

EBE2.5 – Improve Solar Ordinances and Permitting

National studies on improvements to local ordinances and permit process yield limited benefits in markets where solar power is already being deployed. Therefore, the forecasted impact from this action is fairly muted and reflects a nominal increase to the BAU growth curve by enabling slightly faster and simpler installation processes.

Table 10. Greenhouse Gas Reductions for EBE-2

Summary Metric	**2020**	**2040**	**2050**
Electricity Produced/Offset (mWh)			
EBE2.0	74,044	404,797	738,619
EBE2.1	206,731	548,519	893,479
EBE2.2	489,503	1,565,436	2,549,931
EBE2.3	606,832	769,705	769,705
EBE2.4	58,367	177,167	288,587
EBE2.5	20,679	62,816	102,321
EBE2 TOTAL	**1,582,167**	**3,654,453**	**5,468,655**

Overview of Methods and Key Assumptions

Data, Models, and other tools used

Excel modeling and PVWatts were utilized to carry out the methodology for EBE-2. MWCOG provided the following data that were used in the analysis for EBE-2:

- 2005 and 2012 energy usage by sector and jurisdiction;
- 2009 to 2014 renewable energy deployment by jurisdiction; and
- 2005 and 2012 population by jurisdiction with forecasts through 2050.

To calculate the individual and total GHG impact, the analysis utilized the energy production forecasts for each action multiplied by the marginal GHG intensity (within PJM territory) to create a close approximation of the expected GHG mass reduction potential from the EBE-2 scenario.

Assumptions

EBE2.0: Baseline

For the baseline growth in solar and renewables regionally, the analysis assumed "business as usual" trends for Maryland and DC based on 2014 growth rates for renewables as supplied by MWCOG with a cap at 20% growth per year. MWCOG data indicates that solar PV installations totaled more than 7,000 individual building-level systems, with a total installed capacity of about 69,000 kW. After the first five years, and for the remaining analysis period, the analysis assumed this decreased to 5% annual growth. For modeling of solar production in kWh from the installed capacity, the following sites were used as representatives from each state: Baltimore, MD (solar yield 1,326kWh/kW); DCA Airport (solar yield 1,294kWh/kW); and Manassas, VA (solar yield 1,493kWh/kW).

EBE2.1: Support cooperative/aggregated renewable energy purchasing for residential sector

Based on successful "solarize" type programs in Massachusetts, the analysis estimated that up to 1% of residences may participate in on-site and remote renewable energy programs per year with an average purchase of 6,000 kWh per year, with some variations based on population density and policy framework. The forecasted impact considers a 3-year program for aggregated purchasing and then only nominal BAU growth beyond that point (without further program support.)

EBE2.2: Support cooperative/aggregated renewable energy purchasing for commercial sector

Based on emerging growth and captive potential within the commercial sector, the analysis estimated that up to 5% of total C&I energy usage could be targeted with 50% decrease on average, using a 5-year program period for both on-site and remote renewable energy purchases. Beyond the 5-year period, only nominal BAU growth going forward.

EBE2.3: Support cooperative/aggregated renewable energy purchasing for government sector

Based on emerging growth and captive potential within the government sector, along with demonstrated impact from collaborative procurement, the analysis estimated that a regional effort could reach up to a 10% total energy decrease from public sector energy usage. This was forecast over a 5-year period looking at both on-site and remote purchases of renewable energy.

EBE2.4: Provide incentives for building-level renewable technologies

Based on documented impact from Property Tax Abatements, Density Allowances, and Permit Fee Reductions, we estimated the potential for +5% increase in BAU growth in Maryland and DC, and +10% increase in BAU growth in Virginia for targeted sectors (Residential & C&I) over an incentive period of 10 years.

EBE2.5: Adopt solar access ordinances and similar regulations to support renewable development

Based on national Department of Energy programs, incremental improvements to permitting and planning ordinances have a nominal impact on market growth, unless current policies are highly restrictive. The analysis estimated a potential for +2% increase in BAU growth for Maryland and DC, and +5% in Virginia.

Potential Co-Benefits

Adoption of the strategies and actions in EBE-2 create a number of beneficial impacts to the regional and individual communities beyond GHG reductions. These include the creation of new jobs and related economic growth; new investment in the region and electricity grid infrastructure; building awareness and support of renewable energy programs; and reduction of ongoing operational costs for participants. Identified major co-benefits are listed in Table 11 below.

Table 11. Co-Benefit Results for EBE-2

Co-Benefit	Description of Co-Benefit
Air quality benefits	Developing renewable technology applications in existing buildings and facilities can reduce direct criteria air pollutant emissions from site fuel combustion. PV and other electricity-generation renewables also displace grid power emissions of criteria air pollutants.
Generate new employment opportunities	Distributed renewables create new local jobs in a variety of organizations from construction and supplies to design and finance. Supporting broader adoption of these technologies enables faster economic growth in the clean energy sector.

Costs

EBE-2 costs would be in the low to medium range. MWCOG member costs would likely be on the low side, focusing mainly on enabling private sector business models to drive investment. Private sector costs could range widely: some “true green” facility owners/individuals may be willing to make large investments to become net-zero at their sites, with cost considerations secondary. The majority of the market, however, would be more likely to take on moderate-cost investments as part of larger portfolios of sustainable/clean energy commitments.

Table 12. Costs for EBE-2

Level	Public Sector Costs	Private Sector/Other Costs
Low to Medium	Public sector program costs would be relatively low, assuming MWCOG member focus is on enabling supportive business models, federal incentives continue and private sector drives investments.	Private sector costs could run into medium-level expenditures, depending on building/facility owners' commitment to "green." Some individuals and organizations may commit to "off the grid" level installations, which can be substantial investments, while others may opt for most modest and cost-effective projects.
Cost Savings Renewable installations at the building level would reduce purchased energy bills. Depending on the business model used by installers, some facilities may enjoy neutral or positive cash flow as lease or power purchase payments are no greater than prevailing energy prices.		

EBE-3: Encourage development in activity centers

This strategy focuses on the incremental reductions in energy use in buildings (residential, commercial, etc.) associated with shifting development to activity centers. It assumes that energy usage is 20% lower for buildings located in activity centers, due to reductions in average dwelling unit sizes and square footage of commercial spaces, as well as efficiencies associated with denser, multi-unit and multi-use buildings. The energy savings and GHG emissions reductions for this strategy depend upon implementation of strategy TLU-2 (Sustainable Development Patterns and Urban Design), which directs more of the region's anticipated growth and redevelopment in compact, walkable, mixed use activity centers served by premium transit. Consequently, the benefits of this strategy may be considered a co-benefit of the TLU-2.

The strategy will be implemented through the following actions:

- Update comprehensive plans to include energy and transportation efficiencies as a factor in public facility siting decisions.
- Plan and construct transportation systems to enable and support development within and connecting activity centers, including improved transit, pedestrian, and bicycle infrastructure.
- Tie development review to GHG performance; e.g. locating new development in activity centers could be linked to a GHG credit or bonus.
- Encourage activity-center residential density to reduce average housing unit size and energy demand.
- Locate development at sites and in densities that can be served by efficient and renewable district energy systems.

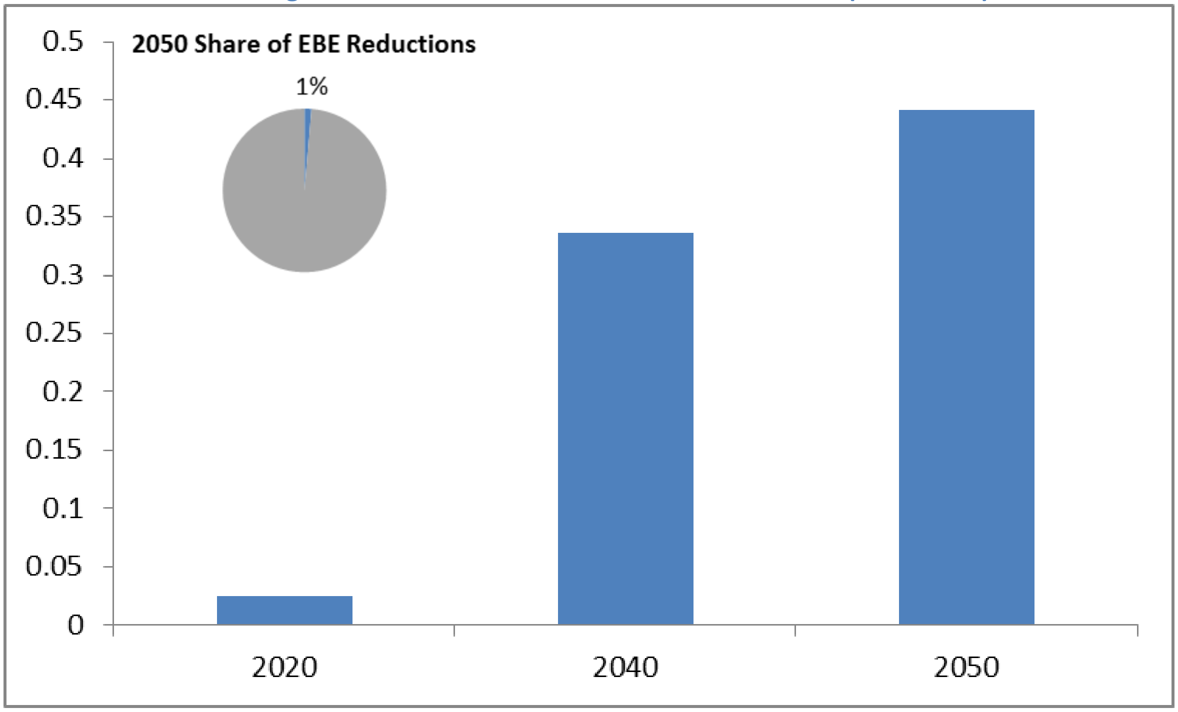
GHG Results

Results from EBE-3 are linked to the land use scenarios developed under TLU-2.

Table 12. Greenhouse Gas Reductions for EBE-3

Summary Metric	2020	2040	2050
GHG Reductions - layered with EBE-4 ($MMTCO_2e$)	0.01	0.16	0.19
GHG Reductions ($MMTCO_2e$) – strategy alone	0.02	0.34	0.44
Electricity Reductions (MWh)	24,627	404,648	537,373
Natural Gas Reductions (MMBtu)	109,004	2,185,250	3,401,663

Figure 12. EBE-3: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

- Multimodal accessibility tool, developed for Arlington VA under NCHRP study 08-78[6] with COG data/support, subsequently applied in Montgomery County for MDOT, expanded in this study to include all TAZs in the MWCOG region.
- TPB's CLRP growth forecasts by TAZ for 2012, 2020 and 2040

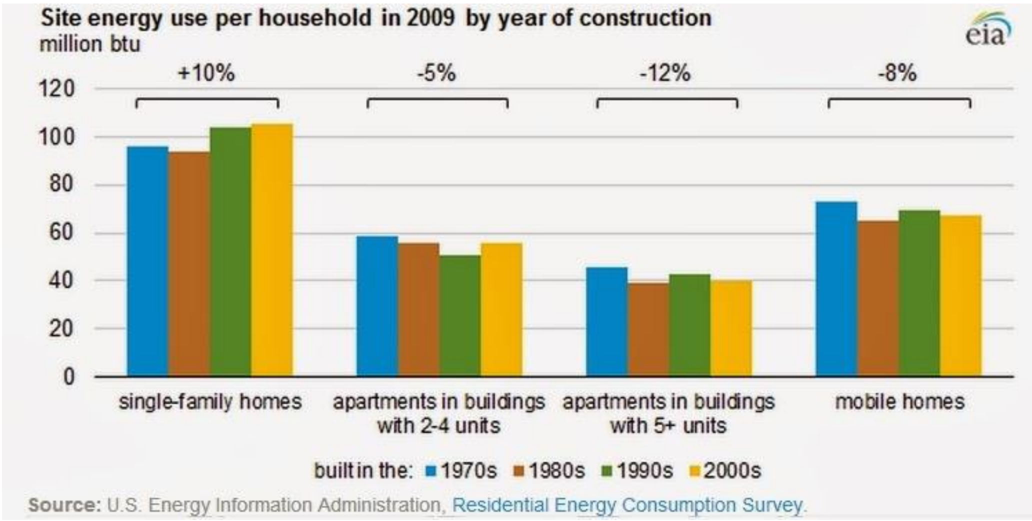
Assumptions

- The analysis assumed a 20% reduction in energy usage for residential and commercial spaces located in activity centers. National data suggests that substituting apartments for single-family dwelling units could reduce energy usage by as much as half (see Figure 17). However, this analysis did not have data available on expected distribution of dwelling units or other buildings by type. It was therefore assumed a mix of single-family and multifamily dwelling units that yields a nominal 20% reduction in energy use, and applied this to nonresidential buildings as well. A more detailed analysis, and a stronger shift of housing units from single-family to

[6] NCHRP Report 770: Estimating Bicycle and Pedestrian Demand for Planning and Project Development. Renaissance Planning, et al., for National Cooperative Highway Research Program, National Academy of Sciences (August 2014).

multifamily, could produce greater energy and emissions savings associated with Activity Center policies.

Figure 13. Energy Usage by Dwelling Unit Type



- See TLU-2 for more assumptions that were made in modeling development in activity centers.

Potential Co-Benefits

By reducing the physical footprint of households and business establishments, EBE-3 reduces energy usage and emissions, providing co-benefits similar to those shown for EBE-1. In addition, the transportation-related co-benefits (shown also in TLU-2) are summarized in Table 13.

Table 13. Co-Benefit Results for EBE-3

Co-Benefit	Description of Co-Benefit
Congestion Reduction	Significant reductions in VMT should lead to reductions in congestion levels and travel time delay; better running speeds should provide lower GHG emissions rates.
Reliability	Lower congestion should mean fewer breakdowns of level of service and greater predictability of travel time.
Criteria Air Pollutants	Fewer vehicle trips, reduced VMT and more stable speeds should be helpful in reducing other criteria pollutants.
Alternative mode use	Higher rates of transit use, walking and biking.
Reduced infrastructure costs	Less VMT demand means less need for new highway capacity and lower rates of maintenance and repair.
Reduced public service costs	Infill and mixed use should lead to lower public services costs for schools, water and sewer, public safety, etc.
Reduced land consumption	Redirecting growth to infill or compact mixed-use/transit settings results in smaller development footprints and preserves forest and undeveloped lands (see TLU-1).
Accessibility	Accessibility is improved because of shorter distances and greater viability of modes other than auto.

Co-Benefit	Description of Co-Benefit
Chesapeake Bay/ Storm water	Fewer highways and developed impervious surface implies less storm water runoff.

Costs

Generally speaking, it is expected that EBE-3 would reduce costs in several ways: lower construction costs for smaller residential and commercial spaces associated with buildings (and lower total amount of building square footage), lower energy costs, and reduced infrastructure development costs by making better use of activity-center infrastructure and reducing Greenfield development costs. To the extent that Activity Center development supports development of distributed energy systems, such as district heating or cooling and/or distributed renewable energy systems, there could be some public and private infrastructure costs to support such systems. Such costs would be expected to be decreased in full or in part by greater system efficiencies and lower costs of energy services.

Table 14. Costs for EBE-3

Level	Public Sector Costs	Private Sector/Other Costs
Unknown	Investment in transit and urban public and shared infrastructure, counterbalanced against reduced cost for highway expansion and maintenance. Other public costs could include public and shared infrastructure for distributed energy systems.	Potentially higher costs for building in infill and higher density areas, but counterbalanced by higher sales prices. If distributed energy systems are developed, private sector costs may be involved. Employers should see reduced costs for employee travel
Cost Savings Denser development in Activity Centers could reduce costs for public infrastructure such as roads, water and sewer, and energy utility infrastructure. It would reduce energy costs by reducing average building and dwelling unit sizes, and reduce transportation costs by lessening travel times and distances. Distributed energy systems could also potentially reduce customer costs for delivered energy services.		

Implementation Issues

EBE-3 implementation will be driven primarily by MWCOG member land use and transportation actions that support regional goals for focusing development in Activity Centers. Those actions are described in the Transportation and Land Use strategy section. On the Energy and Built Environment side, implementation issues could include enabling the legal and financial structures needed for distributed and/or renewable energy systems, enabling fuel supply infrastructure, modifying building codes and planning policies to accommodate distributed energy, and other measures.

EBE-4: Improve new building energy performance and water efficiency performance

This strategy is designed to reduce energy and water consumption in new buildings. The scenario analyzed assumes:

- 100% compliance with most stringent ICC (including IGCC) or ASHRAE building code/energy performance standards by 2020
- 100% of new buildings use WaterSense fixtures by 2030 to reduce energy needs of water and wastewater)
- 50% of new buildings designed to be net zero energy by 2040
- 100% new buildings designed to be net zero energy by 2050.

This will be accomplished through the following implementation actions:

- Updating planning/zoning/building code policies and provisions
- Increasing building code compliance efforts, including-related utility programs

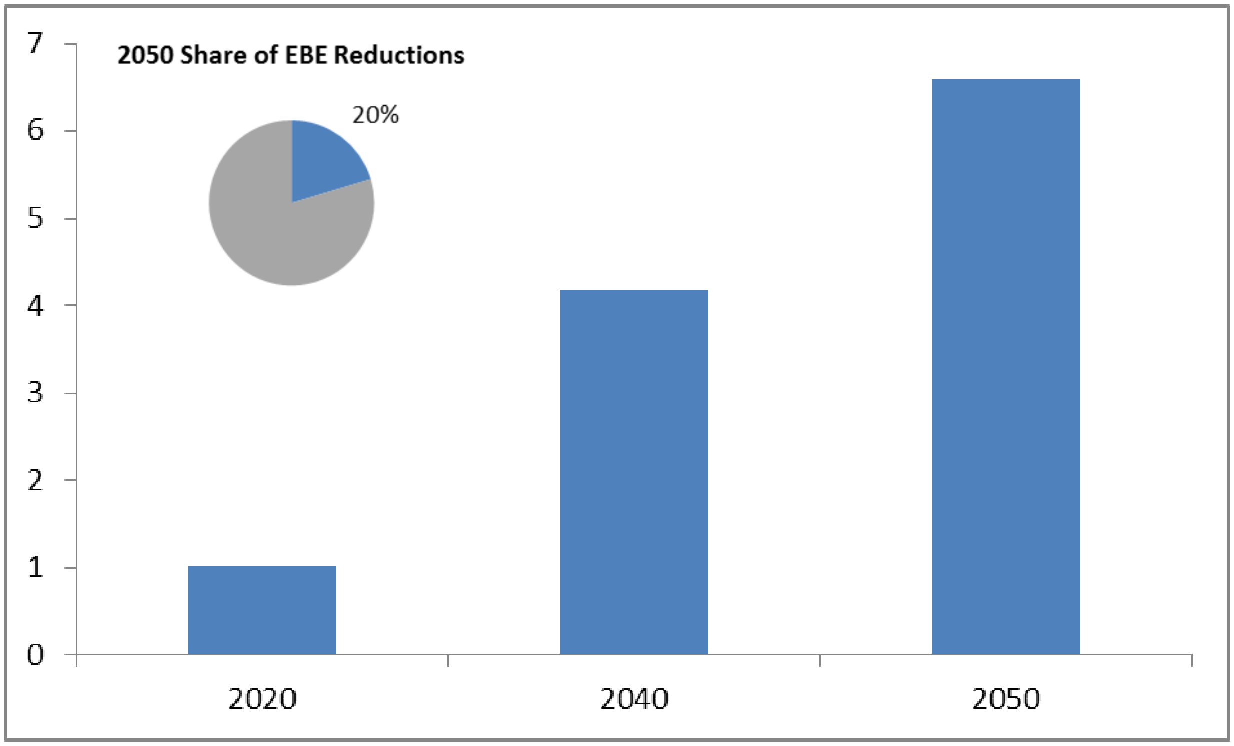
GHG Results

The results below were estimated for EBE-4. Since the strategy only focuses on new construction, the analysis did not establish a calendar year baseline and instead compared emissions against a BAU calculation. Incremental savings are achieved from 2015 -2025 through ASHRAE and IECC code enforcement, which are responsible for over 2 billion kWh of electric savings and almost 250 thousand therms through 2030. The projected code updates in ICF's codes calculator tool only run until 2025 and 2027, after which the net zero building and Water Sense policies are applied. However, because of the long-term impacts of building energy codes, energy savings from these actions are assumed to persist through the study period.

Table 15. Greenhouse Gas Reductions for EBE-4

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO_2e)	1.03	4.18	6.59
Electricity Reductions (MWh)	754,305	3,290,694	5,069,696
Natural Gas Reductions (MMBtu)	8,258,484	44,607,606	71,577,122
Water Reductions (Gallons)	0	196,932,718	323,257,485

Figure 14. EBE-4: GHG reductions – stand-alone (MMTCO_2e)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

Data supplied by MWCOG: 2005 and 2012 electric and natural gas usage by sector; 2012 water consumption for COG region; Round 8.3 commercial and residential sector square footage and household growth forecasts through 2050; Round 8.3 population forecasts through 2050

Tools: ICF's Clean Power Plan Emissions Code Calculator, MS Excel

Assumptions

- **BAU Projection**: Residential and commercial/industrial growth have been adjusted via energy intensity trends calculated from household growth and commercial square footage growth, using 2005 and 2012 as historical data points. Commercial and industrial space have been grouped together due to data forecasts, which is likely inflating commercial kWh and therms savings.
- Water consumption has been adjusted by population growth, and the analysis assumed an average 20% savings per Water Sense fixture over conventional new appliances based on a sampling of Water Sense certified appliances. Since the strategy only looks at new construction, and since 100% Water Sense appliances are not phased in until 2030, the analysis applied a flat 20% water savings beginning in 2030.
- The net zero building policies have also been applied all at once during their target years, rather than phased in. Since this strategy deals with all new construction, this seemed appropriate. It is not unlikely that there will be some lag on both sides of the target date for early adopters and laggards, so the analysis assumes this levels out.

- The ICF Code Calculator projects future code stringency increases through the 2025 (IECC) and 2027 (ASHRAE) and applies a standard increase every three years. The savings from these projected codes have been estimated by codes advocates as nominal and reasonable, and implement a consistent 7% improvement in stringency for each new code cycle. This assumption has the effect of projecting slightly more than 2% improvement in new building efficiency on an average annual basis, consistent with the savings target used in EBE-1.
- From 2030 on, the analysis applied a set of assumptions on Zero Energy Building (ZEB) and Water Sense policy impacts. A Zero Energy Building is defined as an energy-efficient building where energy efficiency performance is maximized, and any remaining onsite energy consumption is provided either directly by onsite renewable energy, or indirectly by renewable energy credit purchases. The net effect modeled is essentially to show zero net emissions impacts at the building site level by 2050; the analysis assumed a straight-line reduction path from 2030-2050 to reach that target. The analysis notes that any renewable credit purchases would have the effect of increasing renewable energy in the power sector generation mix. However, because the analysis did not have specific data from which to project the actual amounts of renewable credits purchased by year, the analysis did not model this effect.
- The 2012 Montgomery County Commercial Building Energy Efficiency Policy Study shows that commercial energy codes could become 15-45% more stringent over 10 years. The calculator tool used in this analysis projects codes to become 25-30% more stringent than the 2015 IECC over 15 years, which falls in the middle of this range.

Potential Co-Benefits

Energy and water efficiency have a number of co-benefits in addition to saving energy and greenhouse gas emissions.

Table 16. Co-Benefit Results for EBE-4

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Energy efficiency lessens the demand for electricity and natural gas, resulting in fewer emission from power plants.
Local Job Growth	Engineers, tradesmen, architects, and construction workers are essential to building energy efficiency improvements. Many of the jobs require local staff to perform on-site work.
Improved Occupant Comfort	Buildings that perform efficiently are often more comfortable for workers and visitors.

Costs

Efficiency measures are generally more cost-effective when designed into new buildings than when retrofitted into existing buildings. This means that the efficiency measures embedded in building energy codes tend to be even more cost-effective than those associated with existing building policy and program actions.

Table 17. Costs for EBE-4

Level	Public Sector Costs	Private Sector/Other Costs
Low	Building code administration and compliance costs	Incremental material, equipment, and construction costs
Cost Savings Efficiency is an investment that can realize substantial cost savings. Energy improvement are consistently more financially viable than supply-side solutions to reducing pollution and GHG emissions.		

- Mandatory building benchmarking and compliance with building code policies place a cost and time burden on the private sector. However, businesses also stand to gain financially from energy savings, and many businesses are built to help assist organizations take advantage of opportunities, including energy service companies and demand response utility programs.
- Net Zero Building and Water Sense do come with some costs, though the timeline is delayed enough that the costs are likely to decline, technologies are likely to improve, and energy costs are likely to rise to make these policies financially viable.

EBE-5: Improve infrastructure efficiency and increase renewable energy use

This strategy is designed to reduce fossil fuel energy use through efficiency improvements and expanded renewables options in the COG region's infrastructure institutions, including water and wastewater systems, WMATA, and airports. The scenario assumes a 1% annual reduction in fossil energy use, 35% cumulative by 2050 will be accomplished through the following implementation actions.

- Reduce energy use by water and wastewater systems by reducing leaks, increasing onsite generation, increasing system efficiency, and fostering process improvements, by working through institutional and utility programs.
- Implement outdoor lighting and other end-use efficiency technologies, working through institutional and utility programs.
- Install on-site renewable power systems at facility and transit sites by working through institutional and utility programs.

GHG Results

While this scenario analysis uses a simple, top-down reduction approach, it is recognized that many of the region's infrastructure institutions are moving aggressively on energy efficiency, renewable energy, and other sustainability initiatives. Many water authorities and wastewater treatment facilities have projects underway or planned for producing power on-site. UOSA and Alex Renew have biogas plants operational, and DC Water has opened the first of two biodigesters at Blue Plains in 2015. WSSC is planning for denitration and deammonification facilities by 2021. WMATA plans to receive 30% of their electricity from renewables by 2025 through on and off-site projects. WSSC entered into a solar PPA at 2 water treatment plants, and began operation in fall of 2013 to generate 6.6 million kWh, 17% of electricity required to operate the 2 plants, saving $3.5 million over 20 years. WMATA is active in building energy efficiency, where they have completed construction of a net zero facility in Largo. The organization has also identified lighting upgrades in parking garages as an opportunity for use of energy savings performance contracting.

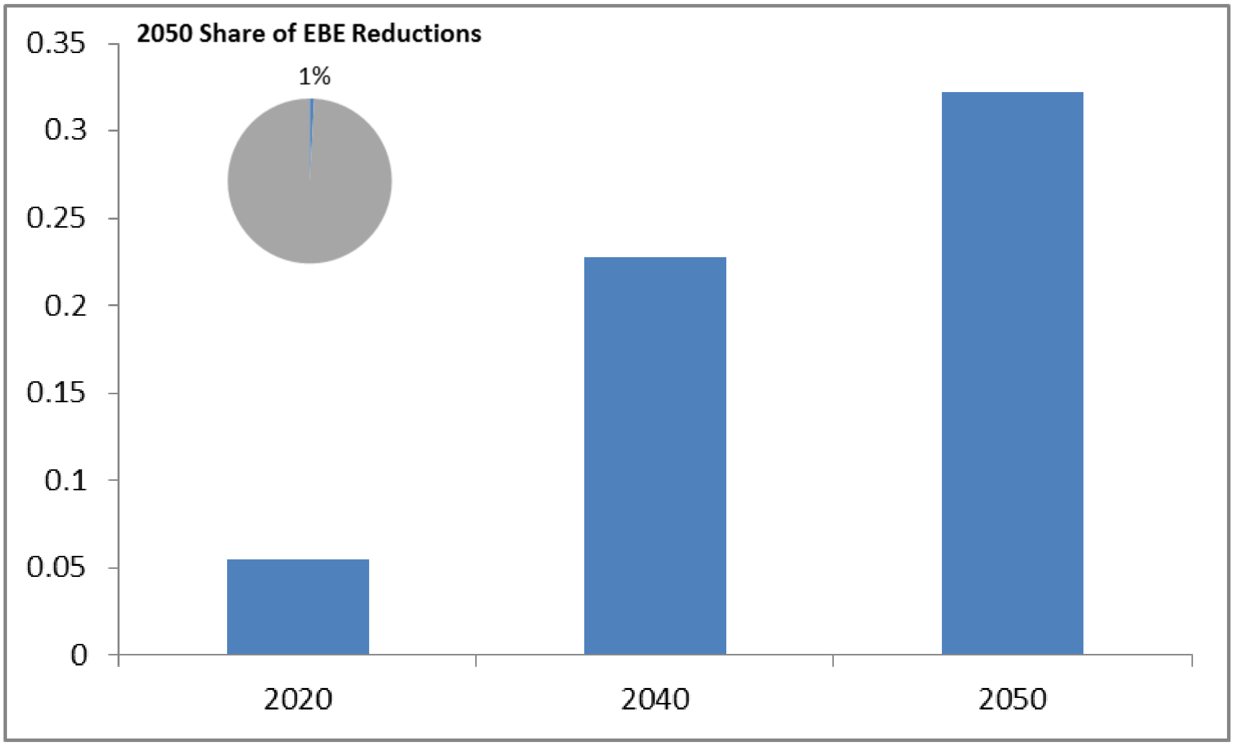
These kinds of initiatives indicate that the nominal scenario target may be modest. However, because these institutions account for less than 3% of total power sector-related emissions, additional reductions would not show marked increases in total scenario impacts. Nonetheless, because these initiatives are proving viable and actionable within the region, they merit continued focus and emphasis.

A 1% annual, 35% cumulative reduction in non-renewable electricity and natural gas usage was applied and generated the following results in Table 18, comprising approximately 1% of the 2005 COG baseline.

Table 18. Greenhouse Gas Reductions for EBE-5

Summary Metric	2020	2040	2050
GHG Reductions ($MMTCO_2e$)	0.05	0.23	0.32
Electricity Reductions (MWh)	68,435	398,109	562,946
Natural Gas Reductions (MMBtu)	13,574	155,840	226,972

Figure 15. EBE-5: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

MWCOG provided the following data that were used in the analysis for EBE-5:

- 2004 – 2015 electric data for Dulles airport
- 2005 – 2014 electric and natural gas data for Reagan National Airport
- 2005 and 2014 energy data for WMATA (electric, natural gas, diesel, CNG, and Gasoline
- DC Water Carbon Footprint 2007 and 2012 data and GHG reduction presentation
- UOSA 2012 electric and natural gas
- 2013 WSSC 2005 and 2012 electric and natural gas, GHG Action Plan
- 2014 Climate and Energy Survey Summary and Results
- Alex Renew 2005 and 2012 electric and natural gas data
- MS Excel to complete analysis for EBE-5

Assumptions

- Both 2005 and 2015 emissions baselines were established for the following institutions: Alex Renew, DCA, DC Water, Dulles Airport, UOSA, WMATA, WSSC, Fairfax Water, Loudoun Water, and PWCSA.
- When baseline year data was not available for a water or wastewater treatment institution, an average intensity per capita was calculated with available data in the sector and applied to the approximate service population. When possible, the analysis used adjacent years in place of calculated baselines.

Potential Co-Benefits

Energy improvements to the region's infrastructure have a number of co-benefits:

Table 19. Co-Benefit Results for EBE-5

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Energy efficiency and renewable energy lessen the demand for electricity and natural gas, and also reduce direct facility emissions, resulting in fewer emission from facilities and power plants.
Local Job Growth	Efficiency and renewable investments are typically more labor-intensive than energy supply investments, creating more jobs per dollar invested. Jobs in engineering and architecture, building trades, and the supply chain tend to increase, with most new jobs developing locally. Energy supply jobs tend to be generated outside the region.
Improved Regional Infrastructure	Technology upgrades can make the region's infrastructure more reliable and resilient, by reducing energy demand, increasing onsite supply, reducing water leaks, and improving overall efficiency.

Costs

Many efficiency and renewable improvements are currently planned or already in progress, so some costs have already been incurred. Future costs would be borne through institutions' capital costs, water and wastewater rates, and other mechanisms. However, the expectation is that net costs generally would be lower over the long-term, based on life-cycle cost analysis.

Table 20. Costs for EBE-5

Level	Public Sector Costs	Private Sector/Other Costs
Low	Building, infrastructure upgrades	Possible increases in rates, fares, other fees
Cost Savings Efficiency encompasses cost-effective measures that typically would yield positive net present value over the study period. Numerous analyses typically show a range of efficiency measures costing less than available energy supply options. Renewables also reduce purchased energy costs.		

EBE-6: Targeted reductions in power sector emissions

The scenario target set for this strategy was to reduce power sector emissions 30% by 2020 on a total emissions (mass) basis. This could be accomplished through a variety of the following implementation actions. However, it is important to note that most, if not all, of these potential actions are out of the direct control of MWCOG members, in the purview of state and federal regulators.

- Support state plans to achieve a 30% mass-based reduction in electrical generation emissions.
- Support increases in state Renewable Portfolio Standards (RPS) to 40% by 2030.
- Increase electric-grid energy storage capacity by supporting utility investments in grid storage technology.
- Reduce energy waste from transmission and distribution of energy by supporting utility efforts to upgrade grid efficiencies via efficient transformers, smart grid technologies, etc.
- Expand natural gas supply infrastructure to existing and new power plant sites.
- Sustain and expand federal, state and local grid-scale renewable energy incentives, e.g. federal PTC.

On August 3, 2015, the EPA final rule on the Clean Power Plan (CPP) regulation set 2030 powerplant emission reduction targets that represent an 11% reduction in Maryland's average emission rate, and a 16% reduction in Virginia's average emission rate, from 2030 baseline emission rates. While the mass-based reduction equivalents in each state are substantially lower, the CPP will nonetheless drive substantial emission reductions in the region's power sector, contributing to the reductions assumed in the 30% EBE-6 scenario target.

However, it is also important to note that the analysis for EBE-6 necessarily based its estimates on the PJM power market region, which extends well beyond the MWCOG region; PJM system wide emissions rates and total emissions are thus driven by several exogenous factors. This makes attributing additional emission reductions to any given EBE-6 action challenging, and as a general rule, tends to dilute the effects of any one action.

GHG Results

After establishing a Business-as-Usual (BAU) forecast, and estimating "on-the-books" reductions, the analysis evaluated individual impacts of implementation actions based on those included in the strategy memo, the impact of the scenario target of reducing regional power sector emissions 30% by 2030, and the combined impacts of a subset of "stretch" policy actions as an additional scenario. The impacts on GHG emissions for the individual implementation actions are summarized in Table 21 below. These actions are considered to be independent and not additive due to their cross-cutting impact and potential for over-counting. To address these issues, Table 22 shows the impact of a subset of "stretch" actions that, combined with the initial 30% emission-reduction scenario target, are referred to a "high-impact actions scenario."

Table 21. Greenhouse Gas Reductions for Individual EBE-6 Actions ($MMTCO_2e$)

Action	Description	2020	2040	2050
1	Replicate District of Columbia's 12.5% GHG reduction in Maryland	1.09	0.91	0.91
2	Phase out coal use in local coal plants by 2030	1.34	1.72	1.72
3	Explore the possibility of installing additional units at existing regional nuclear plants	0.00	4.28	4.28
4	Increase efficiency of thermal power plants 5%.	0.76	1.24	1.24
5	Support increases in state Renewable Portfolio Standards (RPS) to 40% by 2040. Increase Solar PV capacity via RPS carve-outs or other policies.	8.74	21.4	21.4
6	Increase electric-grid energy storage capacity by supporting utility investments in grid storage technology.	0.00	0.01	0.01
7	Reduce energy waste from transmission and distribution of energy by supporting utility efforts to upgrade grid	0.11	0.27	0.27
8	Expand natural gas supply infrastructure to existing and new power plant sites.	1.11	3.36	3.36
9	Sustain and expand federal, state and local grid-scale renewable energy incentives, e.g. federal PTC	1.13	0.79	0.79
10	20% Renewables Offset by 2022 in MD (Considered to be "On the Books")	2.88	3.28	3.28
11	Increase to 40% Renewables Offset by 2040 in MD	0.00	3.28	3.28
12	10% additional Renewables Offset VA & DC	0.64	1.46	1.46

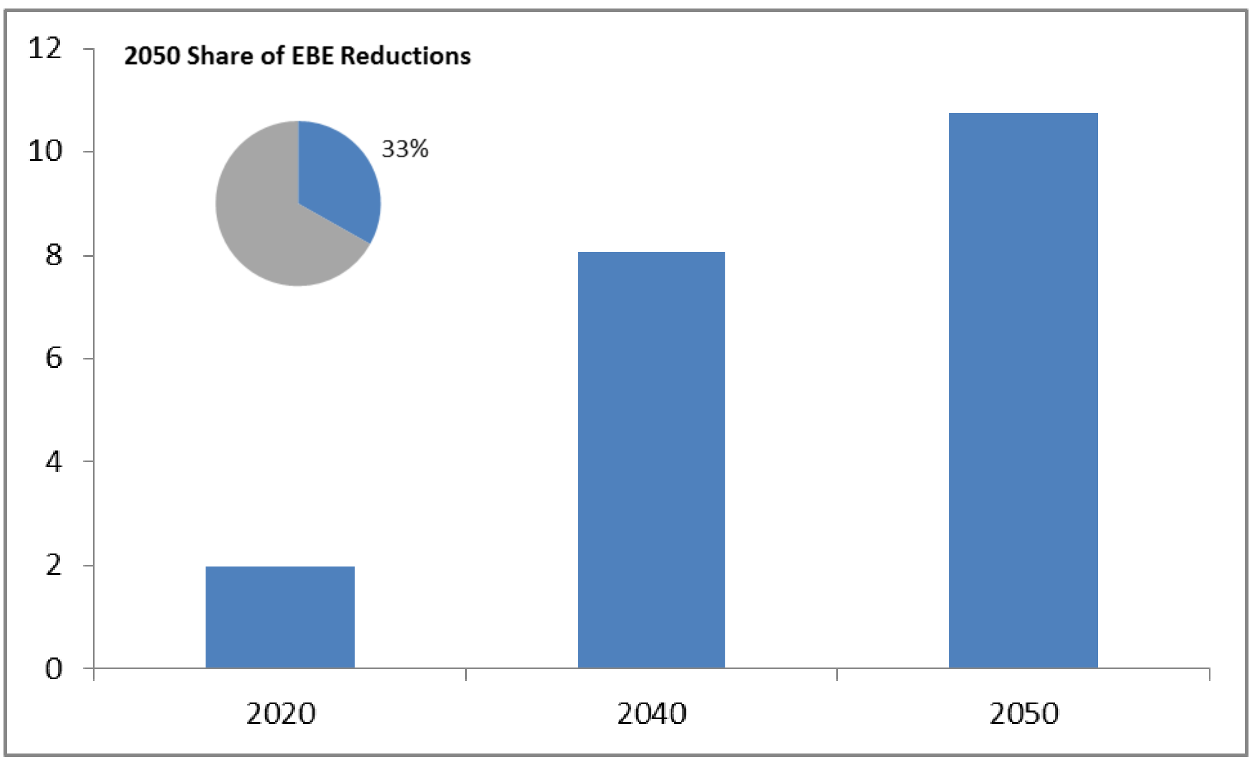
The high impact actions scenario consisted of the five actions shown in Table 22 below. Focusing on these actions in would drive substantial GHG emission reductions for the region. Specifically, this scenario projects the impact from Action 2 (phase out local coal plant use) in parallel with actions 3, 11 and 12. These simulate aggressive regional policies: actions 11 and 12 raising RPS goals to 40% from 20% in MD increase the share of renewables by 10% in DC and VA, replacing coal–fired power with natural gas (Action 2), and building an additional nuclear reactor at Calvert Cliffs or North Anna (Action 3).

Table 22. Greenhouse Gas Reductions from a High Impact Actions Scenario for EBE-6 ($MMTCO_2e$)

Action	Description	2020	2040*	2040 – Stretch*	2050
	Reductions needed to reach 30% reduction in power sector emissions from 2012 levels*	--	8.05	--	--
2	Phase out coal use in regional coal plants by 2030	1.34	--	1.72	1.72
3	Explore the possibility of installing additional units at existing regional nuclear plants	0	--	4.28	4.28
11	Increase to 40% Renewables Offset by 2040 in MD	0	--	3.28	3.28
12	10% additional Renewables Offset VA & DC	0.64	--	1.46	1.46
	"High Impact Actions Scenario" Total	**1.97**	**8.05**	**10.74**	**10.74**

*Emission reductions in 2040 can be reached by a combination of measures from the high impact actions scenario. The 2040 – Stretch column shows the impact of all measures in the high impact actions scenario fully implemented.

Figure 16. EBE-6: High Impact Actions Scenario GHG reductions – stand-alone ($MMTCO_2e$)

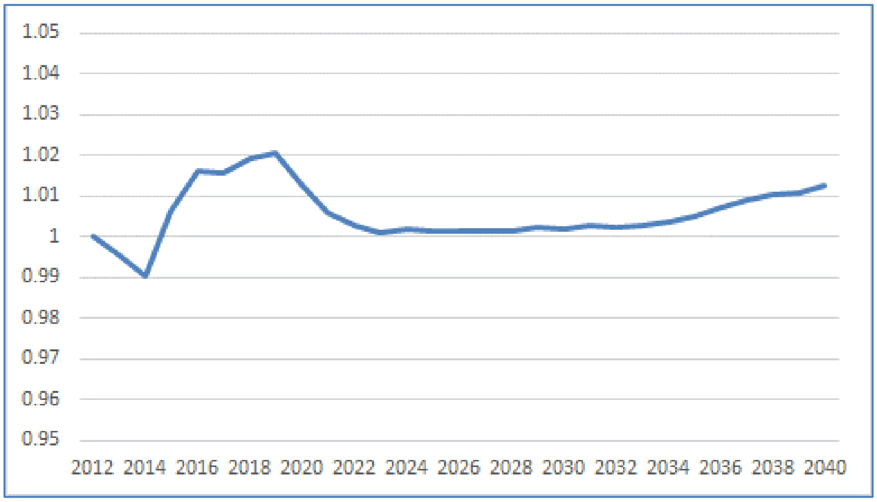


Overview of Methods and Key Assumptions

Baseline Assumptions

- Baseline MWCOG regional electric use for calendar year 2012 is assumed to escalate less than through 2040 per EIA 2015 Annual Energy Outlook reference case Table 2.2 for the Mid-Atlantic region. Assumed load growth is shown in Figure 17.

Figure 17. Assumed MWCOG Regional load growth from 2012-2040 (Index 2012 = 1)



- An average CO_2e emissions factor of 0.451 Metric Tons/MWH was used to establish 2012 MWCOG regional baseline CO_2e emissions.
- Annual percentage changes to MWCOG baseline average regional CO_2e emissions factors through 2040 are equal to the annual percentage changes in average annual CO_2e emissions factors calculated using electric power consumption data and carbon dioxide emissions data from the EIA 2015 Annual Energy Outlook reference case for the Mid-Atlantic region in Table 2.2 and Table 18.2.
- CO_2e emissions impact for each of the nine evaluated actions are based on marginal emissions factors calculated using 2013 and 2014 PJM marginal fuel mix data and heat rates for coal, natural gas combined cycle, natural gas combustion turbine and oil-fired combustion turbine generators from 2013 EIA-923 fuel consumption and power generation data. Marginal on-peak, off-peak and baseload emissions factors that were used for these evaluations are summarized in Table 23 below.
- To reflect other regional efforts to reduce the carbon intensity of the power grid, a 30% reduction in the marginal emission factor is applied for reductions taking place in 2040 and 2050.

Table 23. CO_2e Marginal Emissions Factors

Description	Fuel CO_2e (lbs/mmbtu)	Heat Rate (btu/kW)	Baseload Fraction	Weighted CO_2e (lbs/kwh)
Baseload Marginal CO_2e Emission Factor				
Coal	204	10,613	53.0%	1.15
Natural Gas CC	116	7,325	22.8%	0.19
Natural Gas CT	116	11,838	15.2%	0.21
Oil CT	160	13,027	9.0%	0.19
Marginal CO_2e			100.0%	1.738
Marginal CO_2e, MT/MWH = 0.788				
Marginal CO_2e - Solar PV to Load (On-Peak)				
Coal	204	10,613	38.0%	0.82
Natural Gas CC	116	7,325	30.1%	0.26
Natural Gas CT	116	11,838	20.1%	0.28
Oil CT	160	13,027	11.8%	0.25
Marginal CO_2e			100%	1.602
Marginal CO_2e, MT/MWH = 0.727				
Marginal CO_2e - Solar PV from Storage (Off-Peak)				
Coal	204	10,613	68.0%	1.47
Natural Gas CC	116	7,325	15.5%	0.13
Natural Gas CT	116	11,838	10.4%	0.14
Oil CT	160	13,027	6.1%	0.13
Marginal CO_2e			100%	1.875
Marginal CO_2e, MT/MWH = 0.850				
Marginal CO_2e – NO COAL				
Coal	204	10,613	0.0%	0.00
Natural Gas CC	116	7,325	100.0%	0.85
Natural Gas CT	116	11,838	0.0%	0.00
Oil CT	160	13,027	0.0%	0.00
Marginal CO_2e			100%	0.853
Marginal CO_2e, MT/MWH = 0.387				

- The CO_2e impact associated with each of the 9 actions evaluated for EBE-6 are assumed to be independent and are each incremental to the MWCOG regional baseline CO_2e emissions using the appropriate marginal numbers above.

Action EBE-6.1: Replicate District of Columbia's 12.5% GHG reduction in Maryland

- Per the DC GHG inventory fact sheet (http://green.dc.gov/node/384852), the District of Columbia reported a 12.5% reduction in GHG emissions between 2006 and 2011.
- An energy efficiency program designed to reduce electricity consumption in the MWCOG region 7.2% would be required to result in 12.5% reduction in CO_2e using a marginal baseload emissions factor of 0.788MT/MWH (see Table 23).

- The estimated CO_2e impact associated with this action assumes a 5-year energy efficiency program implementation schedule (2017-2021) for each electric distribution company operating in the MWCOG region.

Action EBE-6.2: Phase out coal use in regional coal plants by 2030

- CO_2e emissions from the three coal plants operating in the MWCOG region in 2013 (see Table 24 below) were estimated using EIA-923 fuel consumption and power generation data.
- The estimated CO_2e impact associated with this action assumes that coal plants are shut down beginning in 2018 with all plants retired by 2030 and that replacement power would be supplied with the adjusted PJM baseload marginal emissions factors assuming no coal in Table 23 above.
- Note that counting ALL emissions from these coal plants may yield a greater impact regionally because some of the power generated at these facilities may serve load not within MWCOG jurisdictions.

Table 24. Maryland Coal Plants with MWCOG Region

State	Plant
MD	Chalk Point LLC
MD	Dickerson
MD	C P Crane

Action EBE-6.3: Explore the possibility of installing additional units at existing regional nuclear plants.

- Evaluation of this action assumes that the amount of incremental nuclear power generated by installing additional units would be equal to what would have been generated if the recently cancelled 1,600 MW Calvert Cliffs expansion were to take place in 2025 assuming 10 year construction period. The forecast is indifferent to the location – either Calvert Cliffs or North Anna – and that all of the net benefit from GHG reductions is realized in MWCOG energy consumption (not exported to others.)
- Marginal CO_2e impact was estimated assuming 93.1% capacity factor for the additional units equal to the reported performance of Calvert Cliffs Units 1 and 2 in 2014 and the PJM marginal baseload emissions factor of 0.788 MT/MWH (see Table 23).

Action EBE-6.4: Increase efficiency of thermal power plants.

- Evaluation of this action assumes that 5% improvement in heat rate of all coal plants operating in Virginia and Maryland takes place over a 10-year period beginning in 2017 and ending in 2026.
- EIA-923 fuel consumption and power generation data was used to estimate 2013 actual heat rates and the associated CO_2e emissions.
- Coal plant power output through 2040 are assumed to be equal to power generated in 2013.

Action EBE-6.5: Support increases in state Renewable Portfolio Standards (RPS) to 40% by 2030. - Increase Solar PV capacity via RPS carve-outs or other policies.

- Statewide power use data from EIA-861 was used to estimate renewable energy output that would result from attainment of current RPS goals in Virginia, Maryland and the District of Columbia.
- For evaluation of this action, RPS requirements were increased to 40% of all power consumed in Maryland with Virginia and DC going from zero to 10%. Renewable energy production was assumed to increase linearly staring in 2022 from 20% to 40% of power consumed in 2040.
- CO_2e impact was estimated assuming all incremental RPS requirements are met using solar PV power and marginal on-peak CO_2e emissions factor of 0.727 MT/MWH (see Table 23).

Action EBE-6.6: Increase electric-grid energy storage capacity by supporting utility investments in grid storage technology.

- The renewable power generated for action 5 with current RPS standards was used as a proxy for the solar PV market.
- Evaluation of this action assumes that battery storage captures 0.1% of the solar market starting in 2017 and increases 0.1% annually thereafter.
- 45% of estimated total PV power output was shifted to the storage battery which discharges power to load during off-peak hours.
- Battery round-trip efficiency was assumed equal to 92%.
- Power was assumed discharged from the battery during off-peak hours therefore the off-peak marginal CO_2e emissions factor of 0.85 MT/MWH (see Table 23) was used to estimate the emissions impact associated with this action.

Action EBE-6.7: Reduce energy waste from transmission and distribution of energy by supporting utility efforts to upgrade grid efficiencies via efficient transformers, smart grid technologies, etc.

- Evaluation of this action assumes that the following improvement are made throughout the MWCOG region starting in 2017 and ending in 2026 that results in 0.8% reduction in T&D losses.
    1. Accelerate distribution transformer replacement
    2. Install smart meters to facilitate CVR programs
    3. Install Capacitor Banks to Improve Power Factor
    4. Right Size Transformers
- The baseload marginal CO_2e emission factor of 0.788 MT/MWH (see Table 23) was used to estimate CO_2e emissions impact associated with this action.

Action EBE-6.8: Expand natural gas supply infrastructure to existing and new power plant sites

- Evaluation of this action assumes:
    1. Pipeline expansion incentivizes incremental combined cycle gas turbine construction,
    2. Natural gas basis differentials decline,
    3. The share of power produced by natural gas-fired generating units increases 0.75% per year from 2018 through 2030,

4. The share of power produced by coal and oil-fired fired generating units increases 0.5% per year from 2018 through 2030,

- The impact of these changes decreases the baseload marginal emissions factor from 0.788 MT/MWH to 0.710 MT/MWH in 2030.

Action EBE-6.9: Sustain and expand federal, state and local grid-scale renewable energy incentives, e.g. federal PTC

- Evaluation of this action assumes that 30% federal tax credit and accelerated depreciation benefits remain available after 2016 through 2030. As a result renewable energy generation was assumed to be 5% greater that the renewable energy generation baseline in Maryland, Virginia and the District of Columbia assumed in Action EBE-6.5.
- CO_2e impact was estimated assuming all incremental RPS requirements are met using solar PV power and marginal on-peak CO_2e emissions factor of 0.727 MT/MWH (see Table 23).
- This analysis did not explicitly consider a wider range of renewable generation options such as offshore and onshore wind, biomass, or hydroelectric power. However, these resources could play into state and local implementation actions.

Action EBE-6.10: 20% Renewables Offset by 2022 in MD

See above description for Action EBE-6.5

Action EBE-6.11: Increase to 40% Renewables Offset by 2040 in MD

See above description for Action EBE-6.5

Action EBE-6.12: 10% Additional Renewables Offset VA & DC

See above description for Action EBE-6.5

Potential Co-Benefits

There are overall societal benefits from pursuing EBE-6 actions that provide both economic growth and collateral improvements to the environment even outside of MWCOG jurisdictions as described below.

Table 25. Co-Benefit Results for EBE-6

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Retiring coal plants, and increasing low-emission generation from renewables and other sources, will also reduce emissions of criteria air pollutants such as sulfur dioxide and oxides of nitrogen, as well as toxic emissions such as mercury.
Large-scale impact regionally	Retiring all coal plants regionally will benefit non-MWCOG jurisdictions and all local residents who are impacted by emissions from these facilities.

Co-Benefit	Description of Co-Benefit
Regional job creation	Building additional natural gas infrastructure and gas-fired plants to replace coal will generate new jobs within regional communities and provide economic stimulus via private and public sector investments.

Costs

EBE-6 implementation would entail large capital investments, primarily from generation owners in the power sector, as they build, decommission, or improve power plants in the wider region. Public sector costs are expected to be minimal. Costs could also be borne by electric ratepayers in the form of higher electricity prices, though studies differ on whether the CPP and other power sector emissions policies would create net costs or net savings.

Estimates for costs of individual projects are not available given the broad scope of this analysis, but costs per kW of installed capacity for new power generation run as high as $8,000 per kW. That equates to as much as $8 billion per 1,000 MW of capacity built. Figure 18 illustrates the range of capital costs associated with power generation options.

Figure 18. Powerplant Capital Costs

	Plant Characteristics		Plant Costs (2012$)		
	Nominal Capacity (MW)	Heat Rate (Btu/kWh)	Overnight Capital Cost ($/kW)	Fixed O&M Cost ($/kW-yr)	Variable O&M Cost ($/MWh)
Coal					
Single Unit Advanced PC	650	8,800	$3,246	$37.80	$4.47
Dual Unit Advanced PC	1,300	8,800	$2,934	$31.18	$4.47
Single Unit Advanced PC with CCS	650	12,000	$5,227	$80.53	$9.51
Dual Unit Advanced PC with CCS	1,300	12,000	$4,724	$66.43	$9.51
Single Unit IGCC	600	8,700	$4,400	$62.25	$7.22
Dual Unit IGCC	1,200	8,700	$3,784	$51.39	$7.22
Single Unit IGCC with CCS	520	10,700	$6,599	$72.83	$8.45
Natural Gas					
Conventional CC	620	7,050	$917	$13.17	$3.60
Advanced CC	400	6,430	$1,023	$15.37	$3.27
Advanced CC with CCS	340	7,525	$2,095	$31.79	$6.78
Conventional CT	85	10,850	$973	$7.34	$15.45
Advanced CT	210	9,750	$676	$7.04	$10.37
Fuel Cells	10	9,500	$7,108	$0.00	$43.00
Uranium					
Dual Unit Nuclear	2,234	N/A	$5,530	$93.28	$2.14
Biomass					
Biomass CC	20	12,350	$8,180	$356.07	$17.49
Biomass BFB	50	13,500	$4,114	$105.63	$5.26
Wind					
Onshore Wind	100	N/A	$2,213	$39.55	$0.00
Offshore Wind	400	N/A	$6,230	$74.00	$0.00
Solar					
Solar Thermal	100	N/A	$5,067	$67.26	$0.00
Photovoltaic	20	N/A	$4,183	$27.75	$0.00
Photovoltaic	150	N/A	$3,873	$24.69	$0.00
Geothermal					
Geothermal – Dual Flash	50	N/A	$6,243	$132.00	$0.00
Geothermal – Binary	50	N/A	$4,362	$100.00	$0.00
Municipal Solid Waste					
Municipal Solid Waste	50	18,000	$8,312	$392.82	$8.75
Hydroelectric					
Conventional Hydroelectric	500	N/A	$2,936	$14.13	$0.00
Pumped Storage	250	N/A	$5,288	$18.00	$0.00

Source: U.S. Department of Energy, Energy Information Administration. *2015 Annual Energy Outlook.* *h*ttp://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf

Implementation Issues

Because EBE-6 represents the largest single source of potential emission reductions in this analysis, it entails a host of implementation issues. However, these will occur mostly in the wider regional power sector, such as most MWCOG member actions, with the exception of some state agencies' responsibilities, will be indirect. MWCOG member implementation issues are expected to revolve around these two processes:

- **CPP Implementation.** Maryland and Virginia will develop implementation plans for achieving the required emission reductions for powerplants in those states. MWCOG members can actively participate in the planning processes associated with these efforts.
- **Powerplant and related infrastructure siting.** To the extent that new generation facilities will be built in or near the region, MWCOG members will be able to express their views through federal, state and local comment and stakeholder processes.

EBE-7: Reduce natural gas pipeline leaks

This strategy is designed to reduce natural gas distribution system leaks and fugitive emissions in the COG region. The scenario used for analysis is a 20% reduction in total methane emissions by 2030. The WGL Corporate Performance report (http://www.wglholdings.com/2014-corporate-performance-report/index.html), on the "Building a Sustainable Future" page, says that they have a goal to achieve an 18% reduction in GHG emissions from their gas delivery system by 2020 from a 2008 base year, which is more aggressive in earlier years than the 20% by 2030 scenario goal.

The implementation action for COG members is to encourage gas utility investment in emission reduction by supporting cost recovery requests at regional utility commissions.

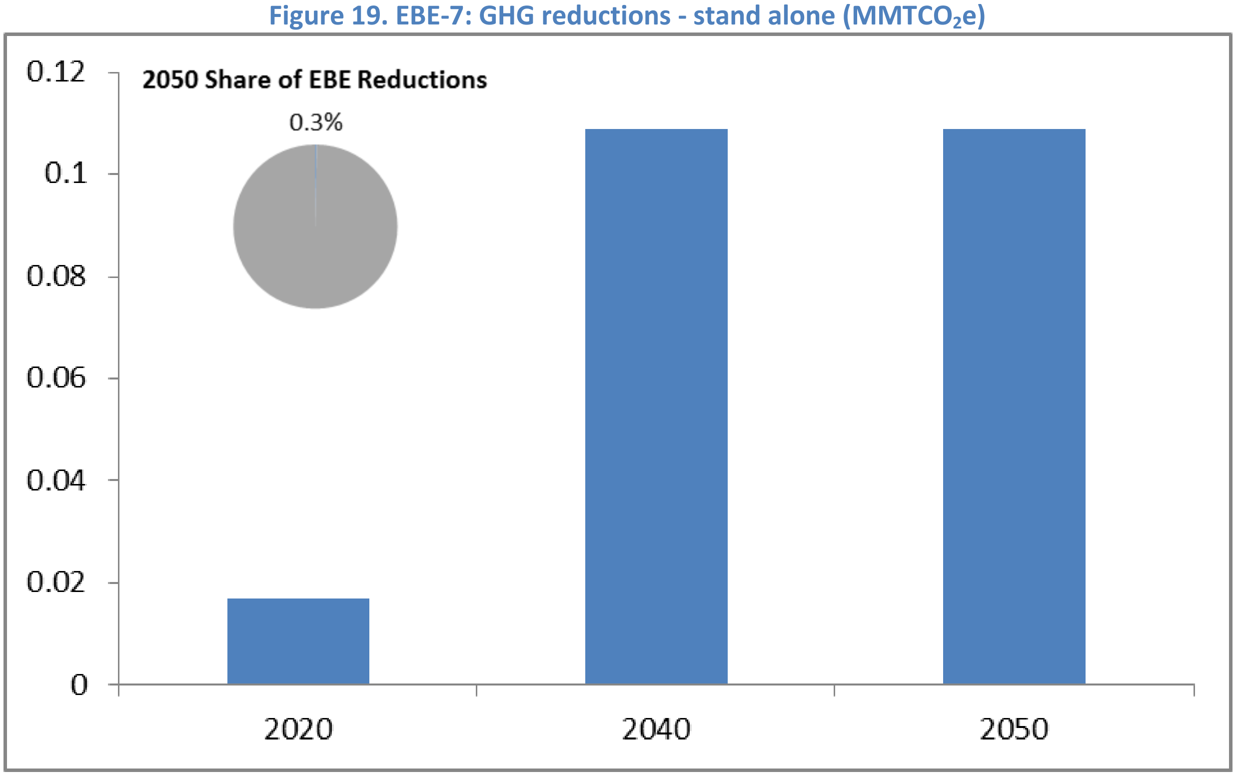
GHG Results

The estimated results for EBE-7 are summarized below.

Table 26. Greenhouse Gas Reductions for EBE-7

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	0.02	0.11	0.11
Methane (CH_4) emissions (MT)	601	4,205	4,205

Figure 19. EBE-7: GHG reductions - stand alone (MMTCO$_2$e)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

Data supplied by MWCOG: Washington Gas Light and other sources provided a set of data and assumptions. Through evaluating the datasets, it was concluded that Washington Gas is using the industry (AGA) emission rates for each type/distance of pipe to calculate their distribution system emissions. WGL indicated they may have improved data in fall 2015, which might be too late to incorporate into this analysis. To provide a more rigorous alternative basis, a guidance manual produced by federal Pipeline and Hazardous Materials Safety Administration (PHMSA) for operators of small natural gas systems was reviewed. It includes a chapter on unaccounted for gas.[7] These sources were used to calculate total emissions from WGL, Columbia Gas, and Baltimore Gas and Electric data on miles of pipe by type in the PHMSA report, using the AGA emission factors. The analysis first calculated WGL's 2008 emissions using the 2008 PHMSA company numbers for WGL's DC, VA and MD service territories. The analysis then calculated a 20% reduction from that baseline to obtain the scenario result.

This approach assumes that the companies have not taken efforts to reduce fugitive emissions before 2008 (a conservative assumption as they could not recover replacement costs under separate riders until 2010 and later).

This approach calculates methane emissions from the entire Washington Gas, Columbia Gas, and BGE systems, and therefore slightly overestimates COG region natural gas usage and savings from the scenario.

Tools: MS Excel

Assumptions

BAU Projection: 2020 BAU emissions are estimated at 0.180 MMTCO_2e; 2030 emissions are estimated at 0.210 MMTCO_2e

Potential Co-Benefits

Reducing methane leaks in utility pipes also have the following benefits

Table 27. Co-Benefit Results for EBE-7

Co-Benefit	Description of Co-Benefit
Cost Savings	Reductions in gas distribution system emissions will reduce utility losses. The resulting loss reductions will reduce utility fuel costs,

[7]Pipeline and Hazardous Materials Safety Administration, Guidance Manual for Operators of Small Natural Gas systems. Available online at: http://phmsa.dot.gov/staticfiles/PHMSA/DownloadableFiles/Files/5%20-%20Guidance%20Manual%20for%20Operators%20of%20Small%20Natural%20Gas%20Systems-2002.pdf

The PHMSA natural gas files, that includes the lost and unaccounted for data, is available at http://phmsa.dot.gov/pipeline/library/data-stats/distribution-transmission-and-gathering-lng-and-liquid-annual-data

Co-Benefit	Description of Co-Benefit
	which will offset capital investments in leak reduction
Local Job Growth	Leakage reduction investments will support jobs in the gas utility, pipe and materials manufacturing, engineering, and construction sectors

Table 28. Costs for EBE-7

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium	Ratepayer-funded leakage reduction investments	Rolled into gas utility rates; net effects of capital cost increases and fuel cost reductions not quantified.

EBE-8: Targeted reductions in municipal solid waste

This strategy is designed to reduce emissions from municipal solid waste in the COG Region using the strategy below. This scenario assumes increasing the recycling rate to 75%; increasing reuse of construction and demolition waste by 15% by 2020 and 100% by 2050; diverting 100% of organic waste by 2040; and net zero waste to landfill by 2050.

Implementation actions to support this strategy include: implementing green purchasing programs and fees such as Pay as You Throw; and increasing use of landfill gas projects. Because of the complexities involved in calculating GHG emissions from the total lifecycle of solid waste, defining the terminology involved with this strategy is important. For this analysis the term “net zero waste” is defined as net zero waste from MWCOG member jurisdictions going to landfills. That definition can be complicated by the fact that if waste does not go to landfills, its alternative destinations may include incineration. Incineration has its own set of issues, including air emissions and ash disposal, which can include landfilling of ash. The measurement of net zero waste also depends on crediting recycling, composting, and incineration as negative emissions; doing this can get the region to a net zero waste goal sooner and less expensively, but some may have concerns about the specifics of this approach.

The term “recycling” can include direct recycling of waste materials such as paper, glass, and plastic, in the broader sense recycling can also include source reduction (which can involve reducing the material content of packaging). Composting is also part of the larger recycling picture; it can include not only composting of organic material such as food, landscaping, and agricultural waste, but also increasing the use of biodegradable materials that can be added to compost streams. This broader view of recycling also leads logically toward a lifecyle view of the systems that generate waste traditional handled in municipal solid waste systems; while outside the scope of this analysis, MWCOG members may want to take such considerations into account in pursuing this strategy.

GHG Results

The results below were estimated for EBE-8. The emissions were estimated using EPA’s LandGEM model, which incorporates multiple years of GHG emissions from waste decomposing in a landfill. The analysis compared the 2020, 2040, and 2050 forecasted values for landfill emissions with the values calculated in LandGEM, assuming a linear decrease from 2015 with 0 tons of waste landfilled in 2050. Additionally, the analysis applied methane recovery at landfills representing half of all emissions beginning in 2030. With the success the COG region has shown recently in improving its recycling rate from 33 to 53% in just 8 years, as well as a current 65% incineration rate, this scenario should be attainable with some public investment since further reductions may bring additional challenges.

Table 29. Greenhouse Gas Reductions for EBE-8

Summary Metric	2020	2040	2050
GHG Emissions ($MMTCO_2e$)	0.08	0.15	0.27
Tons Landfilled	839,723	279,908	0
Life Cycle GHG Co-Benefit ($MMTCO_2e$)			4.8

Figure 20. EBE-8: GHG reductions – stand-alone ($MMTCO_2e$)

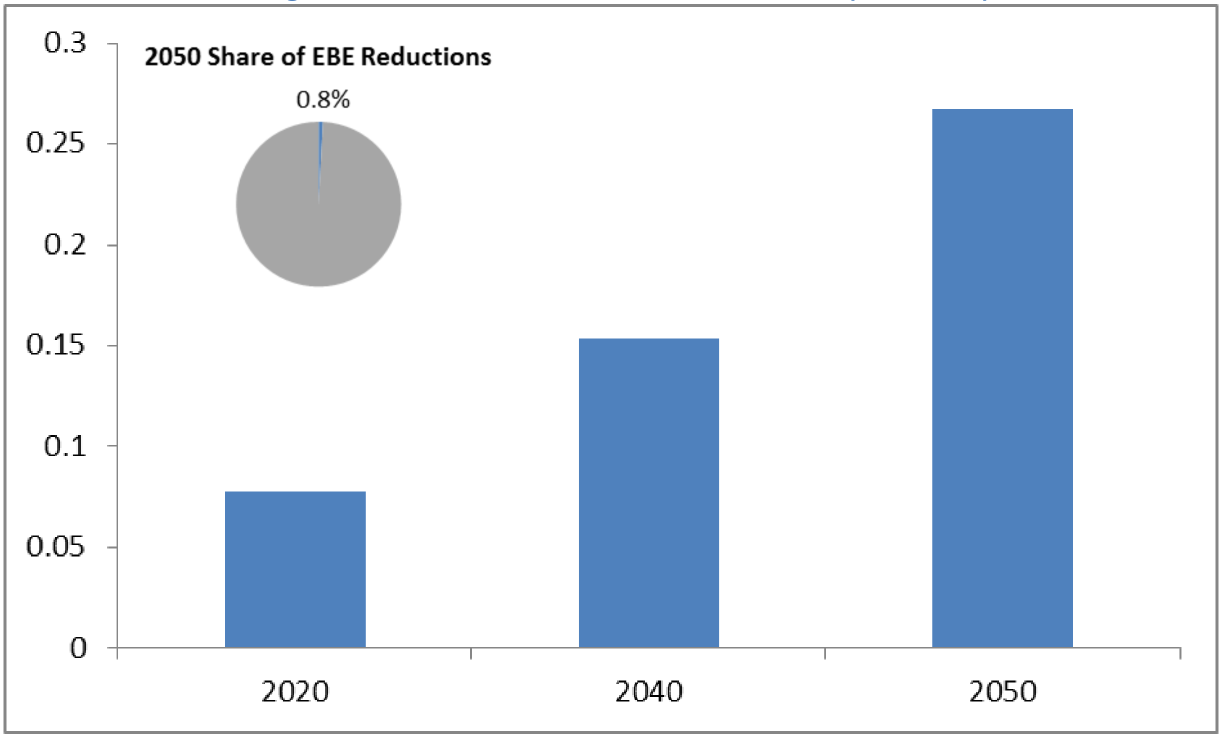


Table 30. Waste Diversion Rates

Summary Metric	2020	2040	2050
Landfill Diversion Rate	69%	92%	100%
C&D Reuse Rate	31%	77%	100%

Overview of Methods and Key Assumptions

Data, Models, and other tools used

Data supplied by MWCOG: 2012 solid waste data; Round 8.3 Population Forecasts through 2050, 2005 landfill greenhouse gases water consumption for COG region.

External Data: Landfill data retrieved from Virginia and Maryland 2014 Solid Waste reports[8][9]

Tools: MS Excel, EPA's LandGEM and WARM models, SMART BET calculator

Assumptions

- The analysis assumed that COG members will be aiming for net zero waste to landfill. Since WARM counts recycling, composting, and waste incineration as negative emissions, net zero emissions would be feasible in a much shorter timeframe. A longer timeframe out to 2050 allows COG to aim for no waste to landfill.
- The analysis modeled life cycle emissions of zero waste pricing policies using EPA's SMART BET tool; however, these results are shown in Table 31 as a GHG co-benefit since it is outside the scope of the region's GHG inventory. [10]
- The analysis assumed, based on EPA's AP-42 methodology, that methane recovery projects have an efficiency of 75% during this timeframe
- The benefits of Pay-As-You-Throw (PAYT) policies were estimated using EPA's SMART BET tool, which estimates the impact of PAYT by using nationwide average waste disposal data, typical PAYT results, and greenhouse gas emission factors originally created for EPA's Waste Reduction Model (WARM) to provide the greenhouse gas and cost savings that a community is likely to see after implementation of PAYT.
    - The estimates of PAYT were assembled by using 2012 waste data to estimate the impact on waste generation using current waste trends.
    - GHG Emissions reductions from PAYT are significant, but would be full life-cycle GHG estimates and not attributable to the landfill sector. Implementing PAYT, using 2012 waste generation rates, could reduce emissions by 4,834,817 metric tons of CO_2-equivalents per year, decrease per capita waste disposal by 600 pounds, and savings over $100 million in disposal costs.[12]

Potential Co-Benefits

Aside from reducing waste and mitigating GHG emissions, reducing municipal solid waste shares the following benefits.

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[8] Virginia Department of Environmental Quality, Solid Waste Managed in Virginia During Calendar Year 2014. Available online at: http://www.deq.virginia.gov/Portals/0/DEQ/Land/ReportsPublications/2015_Annual_Solid_Waste_Report.pdf

[9] Maryland Department of the Environment, Maryland Solid Waste Management and Diversion Report 2014. Available online at: http://www.mde.state.md.us/programs/Land/RecyclingandOperationsprogram/Publications/Documents/%2714%20MSWMR.pdf

[10] These emissions reductions are full *life-cycle* emissions estimates, which reflect emissions and avoided emissions upstream and downstream from the point of use. As such, this considers the net benefit of waste management to the environment. This life-cycle approach is not appropriate for use in inventories because of the diffuse nature of the emissions and emission reductions contained in a single emission factor.

[12] Estimated typical rate of disposal following SMART implementation. Your actual results may vary depending on demographic and existing waste disposal characteristics.

Table 31. Co-Benefit Results for EBE-8

Co-Benefit	Description of Co-Benefit
Land availability	By reducing land area needed for landfills, this strategy could increase flexibility in land use planning, freeing up land for other uses and support various TLU strategies.
Local Job Growth	Many of the jobs for improving recycling and C&D reuse rates require local staff to perform on-site work.

Costs

The following costs are associated with reducing municipal solid waste:

Table 32. Costs for EBE-8

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium	Tipping fees and waste collection fees	Tipping fees and waste collection fees
Cost Savings Efficient waste stream management is an investment that can realize cost savings through producing energy via incineration or landfill gas, or new materials via recycling and composting. Materials reuse allows companies and individuals to avoid spending on new products.		

Implementation Issues

The region's solid waste systems are complex in themselves, and also engender a complex set of issues as MWCOG members strive to reach the net zero waste goal. These issues include:

- **Refining definitions**. The current definition of net zero waste includes negative emissions credits for recycling, composting, and incineration. MWCOG members may want to refine this given concerns about incineration.
- **Engaging key actors**. To effectively reshape the region's solid waste systems, MWCOG members may need to engage key actors such as retailers, large corporations, building owners, and federal facility managers to begin to shape life cycle, source reduction, recycling, and other actions.
- **Who pays**. Some residents and businesses may face additional fees, whether through initiatives like Pay as You Throw, increases in property tax- based fees, or tipping fees. These issues aside, given extended timeframe to realize this strategy's goal, and the COG region's demonstrated ability to increase recycling rates and manage waste incineration, the implementation actions associated with EBE-8 can make it a low-to-moderate-cost and attainable strategy.

EBE-9: Reduce emissions from non-road engines

This strategy is designed to reduce CO_2 emissions from non-road engines. The scenario for analysis is a 2% annual reduction, with a 30% cumulative reduction by 2030. This will be accomplished through implementation actions including public programs to encourage switching to lower-emitting equipment. These programs would focus on increasing the market penetration of energy-efficient alternatives for non-road engines including back-up generators, construction equipment, agriculture, lawn and garden equipment, commercial and industrial equipment, and recreational equipment, as listed in the MWCOG Gold Book.

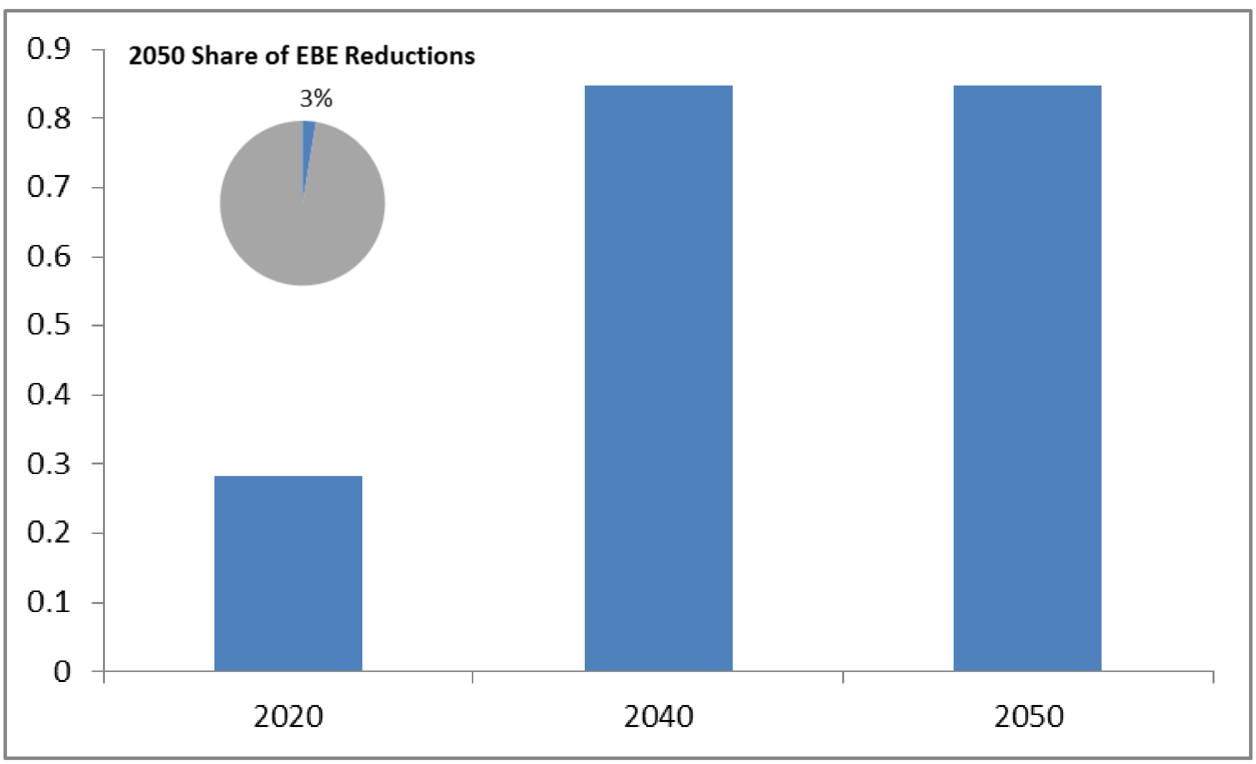
GHG Results

The following results were estimated for EBE-9.

Table 33. Greenhouse Gas Reductions for EBE-9

Summary Metric	2020	2040	2050
GHG Reductions ($MMTCO_2e$)	0.28	0.85	0.85

Figure 21. EBE-9: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

COG staff provided detailed emissions data by jurisdiction and engine type for non-road sources by extracting information from COG's transportation modeling data libraries. An Excel spreadsheet was used to compile and analyze this data. The initial scenario impacts were estimated by projecting 10% reductions in emissions for 2020, 20% for 2025, and 30% for 2030, holding the 30% reduction constant for 2040 and 2050.

Electrification of non-road engines has been taken into account, too. While the process reduces direct emissions, it also increase emissions from the power sector. It has been assumed that 30% of the reductions from non-road engine emissions by 2030 can be attributed to electrification. Note that electrification of engines would increase electricity demand on the regional grid and cause increases in power sector emissions. However, because data on the electricity usage of specific technologies was not available, the analysis did not estimate specific electricity usage or related emissions increases. Generally speaking, beneficial electrification strategies show higher total-cycle efficiency at the end-use level, and lower incremental emissions increases at the power sector level. So it is reasonable to assume that any increases in power sector emissions would be lower than fuel-engine emission reductions.

Assumptions

The analysis used 2011 data used for the 2005 baseline, applied each state/District growth rates from Round 8.3 Forecast to 2011 data to interpolate 2015 emissions, started implementing 2% annual reduction in 2015-2020 time period.

Potential Co-Benefits

Co-benefits of reducing emissions from non-road engines include the following.

Table 34. Co-Benefit Results for EBE-9

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Many alternative technologies will have lower criteria air pollutant emissions as well as lower CO_2 emissions.
Energy savings	Higher-efficiency technologies will reduce fuel use and operating costs

Costs

The cost associated with limiting non-road emissions falls under the public sector:

Table 35. Costs for EBE-9

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium	Public program costs to encourage switch to lower-emitting technologies	Costs for alternatives to current engine technologies

Cost savings

Some EBE-9 actions have the potential to reduce certain costs, by increasing off-road vehicle efficiency and reducing fuel costs, or by reducing fuel use through idling and related operational actions.

Implementation Issues

Off-road engine emission actions will be largely in the purview of MWCOG members. For example, the District of Columbia has extended its on-road truck anti-idling policy to off-road vehicles, an action that other jurisdictions could take as well. However, each jurisdiction will have its own set of issues and stakeholders within this strategy, depending on the mix of construction, landscaping, and other off-road engine uses.

EBE-10/ TLU-0: Educate and motivate public through community engagement

Engaging citizens and communities through education and motivation efforts is a cross-cutting strategy that is essentially to the success of most strategies. While more challenging to quantify in terms of direct measured impacts, the education and engagement challenge remains fundamental to marshalling public awareness and support. In addition, every MWCOG member has the capacity and the connections to its constituents needed to put this strategy into effect. While this strategy was initially identified for the Energy/Built Environment sectors, it clearly is also important to the Transportation/Land Use sectors, and is a fundamental component of many of these strategies. The implementation actions listed below are only some of the steps that MWCOG members can take to engage their citizens and other constituents in support of the GHG reduction strategies.

- Educate on benefits and costs of clean energy technologies and behaviors, via school curricula and public information campaigns.
- Increase motivation through incentives and other measures, linked to utility customer education and information services.
- Use utility advanced metering data to monitor and influence behavior.
- Promote the benefits of clean and fuel efficient vehicle options.
- Create a culture of responsibility via school curricula and public information campaigns.
- Encourage employee behavior change to increase teleworking and commuting by public transportation through actions such as the "Commuter Connections" program.

GHG Results

Results from EBE-10/TLU-0 are subsumed in other strategies. For example, utility metering-based feedback and education efforts are captured under EBE-1. While some data exists on the short-term effects of education and behavior change efforts, there is no long-term evidence that such effects are reliably or discretely measurable. Rather, experience suggests that education and information campaigns are essential enabling elements of effective GHG reduction policy strategies.

For planning purposes, however, a portion of the impacts of many strategies be attributed to education and engagement activities, so that policymakers have some basis for evaluating benefits and costs. While no specific numbers have been assigned to EBE-10/TLU-0 or reported in the summary results, it is important to recognize the fundamental importance of this strategy in supporting the achievement of other strategies.

TLU-1: Increase tree canopy and reduce loss of vegetation through sustainable development patterns

This strategy focuses on increasing carbon sequestration due to programs to increase the regional tree canopy and to reduce tree loss due to more sustainable development patterns (associated with the development patterns analyzed under TLU-2). Natural land cover in the form of trees, grasses, and shrubs, can help offset greenhouse gas (GHG) emissions through the vegetation's ability to sequester carbon. It is estimated that 1 metric ton of sequestered CO_2 is equivalent to the GHG emissions of about 2,400 vehicle miles of travel[13]. Land development can impact sequestration capacity by replacing forest and other vegetative cover with structures and impervious surface. Hence, both the overall scale of development and the form of that development (land footprint) will determine future sequestration capacity.

This strategy includes two components:

- Analyzing the carbon sequestration benefits of a pro-active program to increase the current (2012) tree canopy by 5% by 2050.
- Analyzing the carbon sequestration benefits associated with vegetation and tree cover that would be saved through more efficient land use, specifically the sustainable development patterns analyzed under TLU-2.

GHG Results

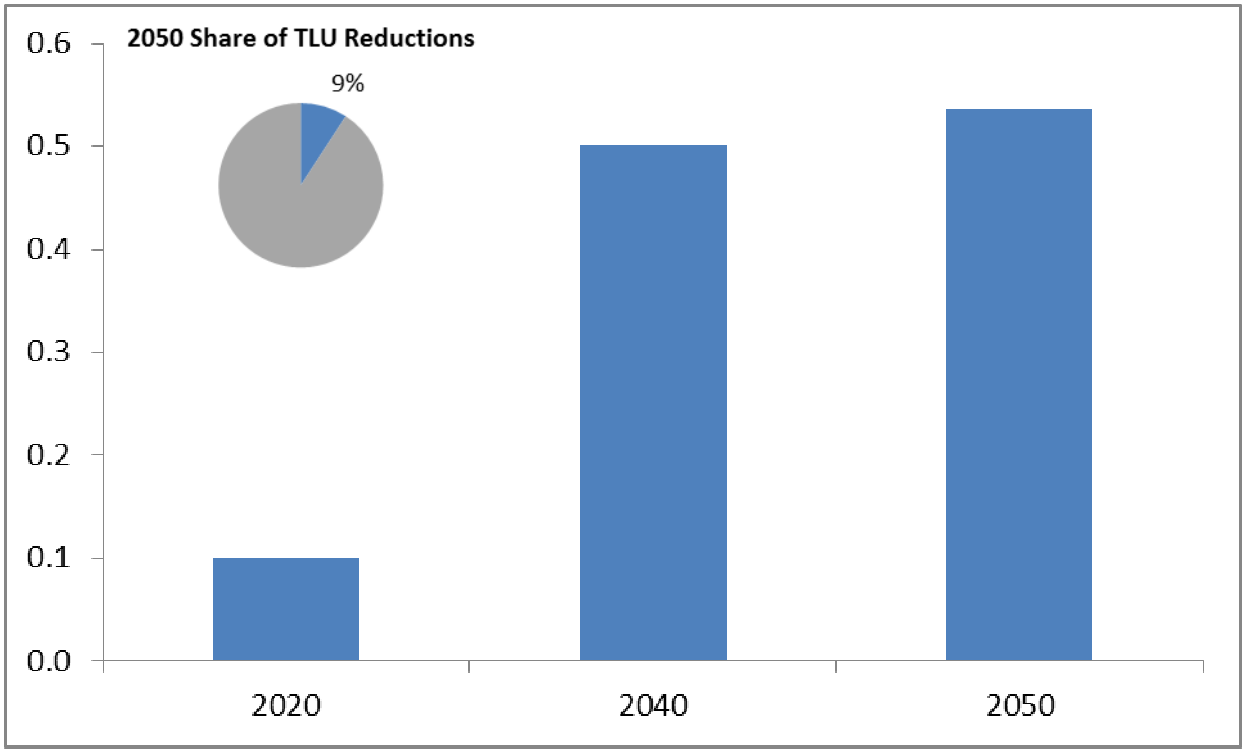
The results of the sequestration analysis are summarized in Table 36.

Table 36. Greenhouse Gas Sequestration Benefits for TLU-1

Summary Metric (MMTCO$_2$e)	2020	2040	2050
GHG Sequestration benefits from increased tree canopy	0.09	0.32	0.44
GHG Sequestration benefits from reducing loss of vegetation due to sustainable development patterns	0.10	0.50	0.54

[13] US EPA. Greenhouse Gas Emissions from a Typical Passenger Vehicle. Office of Transportation and Air Quality, EPA-420-F-14-040a (May 2014).

Figure 22. TLU-1: Carbon Sequestration Benefits ($MMTCO_2e$)



Note: These figures are not included in the total GHG reductions off of the 2005 BAU scenario, since carbon sequestration is not accounted for in the inventory and forecasts. Also, the GHG sequestration benefits due to sustainable development patterns are not GHG benefits compared to 2005 levels, but in relation to estimated losses in tree cover.

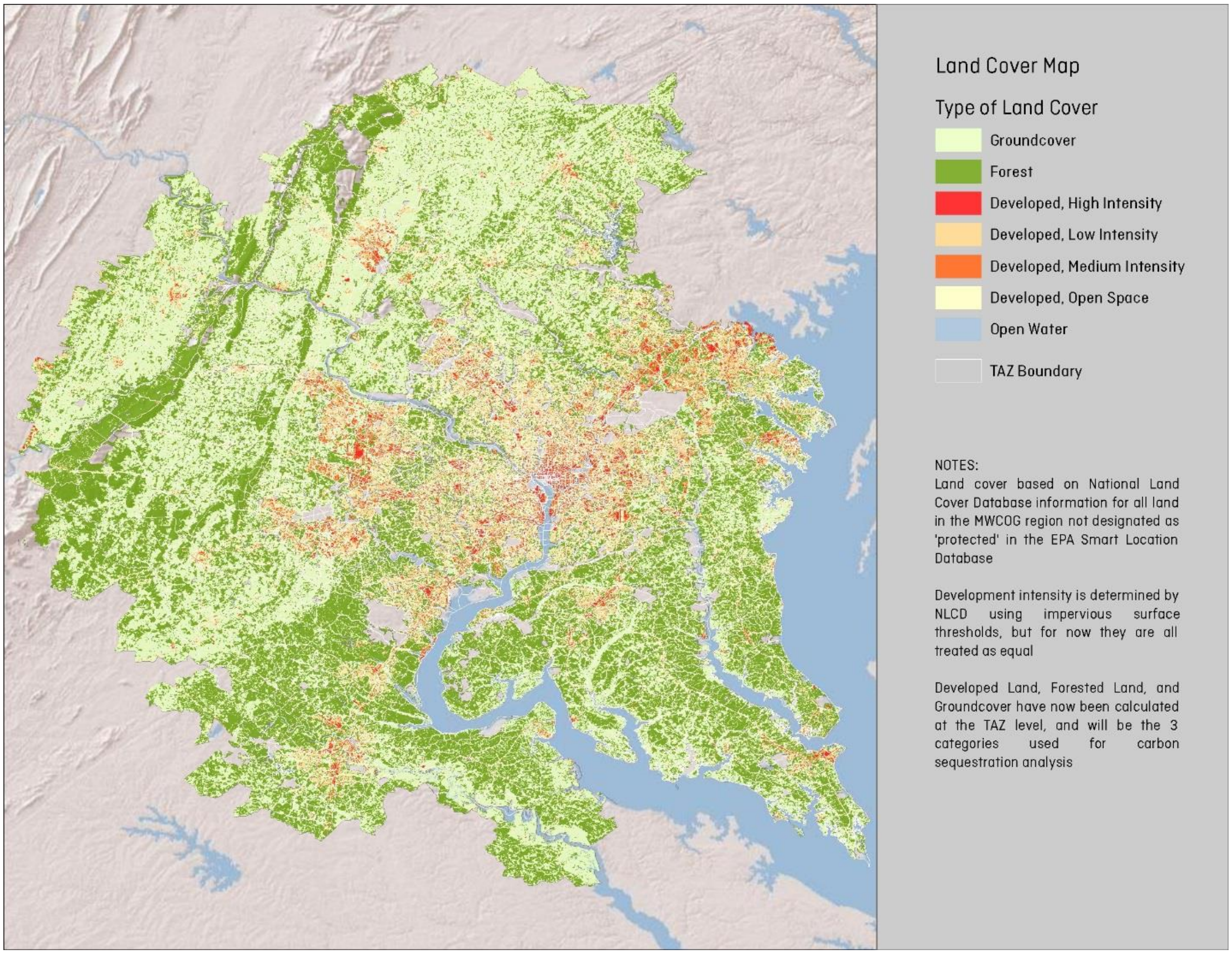
(1) Impact of Increasing Tree Canopy Policies

This strategy considered an active tree planting program to increase regional tree canopy by 5 percent by 2050. The National Land Cover Database (NLCD) was used to determine current land use proportions in the MWCOG region. These land uses are highlighted in Figure 23, and categorized for TLU-1 purposes as already developed land, forest, and grassland, for which the 2012 acreages are:

Total Forest Acres	949,891
Total Developed Acres	737,918
Tree cover @ 24%	*177,100*
Effective Tree coverage	**1,126,991**
Total Grassland Acres	599,179

The NLCD also revealed that the current tree cover in the developed land category accounted for approximately 24% of that acreage. Including these 177,100 acres along with the official forested acres yields a total of 1,127 million acres of regional tree canopy.

Figure 23. Land Use Land Cover in MWCOG Region



Carbon sequestration was estimated using data from the Federal Highway Administration's Carbon Sequestration Pilot Program Report (2010), which specifies sequestration rates of 7.92 annual tons of CO_2 per acre of forest and 2.57 annual tons per acre of grassland. Accounting only for the sequestration associated with the 1.127 million acres of tree canopy yields a sequestration total of 8.93 million metric tons of CO_2 per year. Sequestration from grassland was not included in this strategy.

Implementation of a policy to increase the regional tree canopy by 5% over current levels by 2050 would result in 1.183 million acres of canopy and 9.37 MMT of annual sequestration. It was assumed that the 5% increase in canopy would reach full deployment by 2050, with proportionate improvements occurring between 2012 and 2040 estimated through straight-line interpolation, resulting in the following time stream of benefits:

Table 37. Carbon Sequestration Levels from 5% Expansion of Tree Canopy

Summary Metric	2012	2020	2040	2050
Total tree canopy (million acres)	1.127	1.139	1.168	1.183
Annual GHG Sequestration (MMT CO_2e)	8.93	9.02	9.25	9.37
Net Sequestration Gain (MMTCO_2e) compared to 2012		0.09	0.32	0.44

(2) Impact of Sustainable Development Patterns (TLU-2 Carbon Sequestration Benefits)

Because the alternative land use scenarios result in more compact land use patterns and urban infill, the impacts of trend development on regional land consumption would be lessened. Starting with the assessment of the urban tree canopy in TLU-1, an estimate was made of the likely loss of forest and other natural ground cover that might result from new development. Subsequently, the same assessment was made for the land use scenarios in 2040 and 2050 to determine the comparable land consumption. These savings in tree and grassland acreage can then be correlated with the corresponding loss or gain in carbon sequestration.

To estimate the losses in forest and grassland acreage due to new development, projected household and employment growth for each TAZ by 2020 and 2040 was introduced to the TAZ based on 2012 development relationships. Activity density, defined as the sum of households and jobs divided by the developed acreage in the TAZ, was used as a guide for introducing the new increment of activity. The new development was inserted at the current activity density rate in order to determine the additional acres of land that would be required. New acreage was first taken from the reserves of grassland, assuming that such area would be cheaper to convert to dwelling use than forest. The procedure was to take as much grassland as necessary to support the new growth; if the reserves of grassland were insufficient to accommodate all new growth, the remaining acreage would be taken from forest. If all remaining reserves were consumed by this process, then density itself was allowed to increase to fit on the total developed acreage. For those TAZs where there was little or no existing development, a minimum activity density was established at 2.71 units per acre, representing the 15th percentile of TAZs by activity density (i.e., 15% of all zones currently had densities of 2.71 or less).

The estimated acreage of grassland and forest lost to trend development is summarized in Table 38. Developed land area is projected to increase by 135,348 acres by 2040, or 18%, while grassland declines by 86,935 acres (14.5%) and forest by 48,465 acres (5%). Assuming sequestration levels of 2.57 metric tons of CO_2 per acre of grassland and 7.92 tons per acre of forest results in losses of 0.17 $MMTCO_2e$ by 2020 and 0.60 $MMTCO_2e$ by 2040. For 2050, the rate of growth with trend development was assumed to be at a considerably lower rate, reflecting less available greenfield land for development, resulting in an estimate of 0.64 MMTCO2e lost by 2050.

Table 38. Carbon Sequestration Losses Due to Trend (CLRP) Development

Summary Metric	2012	2020	2040	2050[1]
Total Developed Acres	737,918	782,740	873,319	880,895
Total Forest Acres	949,891	938,923	901,426	898,290
Total Grassland Acres	599,179	565,326	512,244	507,804
Total Sequestration ($MMTCO_2e$)	9.06	8.89	8.46	8.42
Sequestration Loss from 2012 ($MMTCO_2e$)	-	0.17	0.60	0.64

[1] Straight line extrapolation from 2012-2040 trend.

As can be seen in Table 39, considerably less land is consumed by development under the alternative land use scenarios: about 70,000 to 75,000 acres of grassland and 40,000 to 44,000 acres of forest, sparing 0.5 annual $MMTCO_2e$ in 2040 and 0.54 in 2050. This doesn't fully make up for the overall losses due to new growth, but comes close to balancing the losses due to trend development.

Table 39. Carbon Sequestration Loss Mitigation from TLU-2 Alternative Land Use Scenarios

Summary Metric	2012	2020	2040	2050
Total Developed Acres	737,918		761,869	761,869
Total Forest Acres	949,891		942,057	942,057
Total Grassland Acres	599,179		583,063	583,063
Total Sequestration (MMTCO2e)	9.06	8.99*	8.96	8.96
Sequestration Savings Over Trend Development ($MMTCO_2e$)		**0.10***	**0.50**	**0.54**

* Straight line extrapolation from 2012-2040
For purposes of analysis, 2050 assumes all development beyond 2040 is accommodated within the 2040 footprint.

Overview of Methods and Key Assumptions

Impact of Tree Canopy Policies

Data, Models, and other tools used

- National Land Cover Database (NLCD) for current land use and tree canopy
- EPA Smart Location Database (SLD) for protected lands
- MWCOG TAZ geography
- Sequestration rates from FHWA's Carbon Sequestration Pilot Program Report (2010) using data from the now-defunct Chicago Climate Exchange

Assumptions

- The land use/land cover database was used to partition base year 2012 land use in each TAZ into four categories: C1 (developed space); C2 (forested); C3 (developable open space); and C4 (non-developable or protected space) for each TAZ in the region.
- An average of 24% of C1 developed acreage was determined to be tree covered through the NLCD.
- A CO_2 sequestration rate of 7.92 tons per acre of C2 forest land C1 tree canopy was used to estimate total regional sequestration from tree cover in 2012.
- All tree cover was treated as deciduous, the predominant tree type in the MWCOG region.

Impact of Reduced Vegetation Loss from Sustainable Development Patterns

Data, Models, and other tools used

- Round 8.3 CLRP forecasts (by TAZ) from MWCOG for 2012, 2020 and 2040
- National Land Cover Database (NLCD) for current land use and tree canopy
- EPA Smart location Database for protected lands
- Sequestration rates from Chicago Climate Exchange

Assumptions

- CO_2 sequestration rates were applied to the acreage of forested land and developable open space in each of MWCOG's Traffic Analysis Zones (TAZ). Sequestration rates of 7.92 tons per acre of forest and 2.57 tons per acre of grassland were taken from the FHWA's Carbon Sequestration Pilot Program Report (2010), which itself adopted rates collected from the now-defunct Chicago Carbon Exchange.
- All tree cover was treated as deciduous, the predominant tree type in the MWCOG region. All undeveloped ground cover was treated as grassland.
- The land use/land cover database was used to partition base year 2012 land use in each TAZ into four categories: C1 (developed space); C2 (forested); C3 (developable open space); and C4 (non-developable)
- Current 2012 development densities were calculated as activity density = population + employment divided by developed acreage (C1).
- Future growth for 2020 and 2040 was introduced into the respective TAZ according to the starting density computed for 2012 above in order to estimate the amount of new land area that would be required to support that development. However, to avoid overly-pessimistic rates of land consumption in existing low-density/developing areas, the starting activity density was set at a minimum of 2.71 activity units per acre, reflecting the 15th percentile of density for the region.
- New development acreage needs were taken first from the C3 (grassland) land use category, and subsequently from the forest category C2 to meet remaining need. When/if both of those donor areas were exceeded, density was increased to allow remaining development to fit within the C1 + C2 + C3 acreage.
- Sequestration losses were based on the acres of C3 and C2 land lost to development according to the above rules.

Potential Co-Benefits

Co-benefits from increased tree coverage could include reduced building energy costs due to the cooling effect of tree canopy on reduced air conditioning energy costs. Less loss of natural ground cover would also contribute to reduced storm water runoff and treatment, habitat protection, and possibly protection of urban agriculture.

Table 40. Potential Co-Benefits from Retention of Tree Canopy

Co-Benefit	Description of Co-Benefit
Air quality	Forested areas do not require landscaping and other activities that use high-emitting appliances like lawnmowers and leaf blowers.
Weather resiliency	Trees and natural cover are an important buffer against global warming and severe weather events
Storm water	Retaining natural ground cover aids in both reducing runoff from impervious surfaces, as well as having fewer contaminants in the runoff
Community Amenity	Arguably, trees add important natural beauty to inhabited areas, as do forests and rural/agricultural lands to metropolitan areas.

Costs

Table 41. Costs for TLU-1

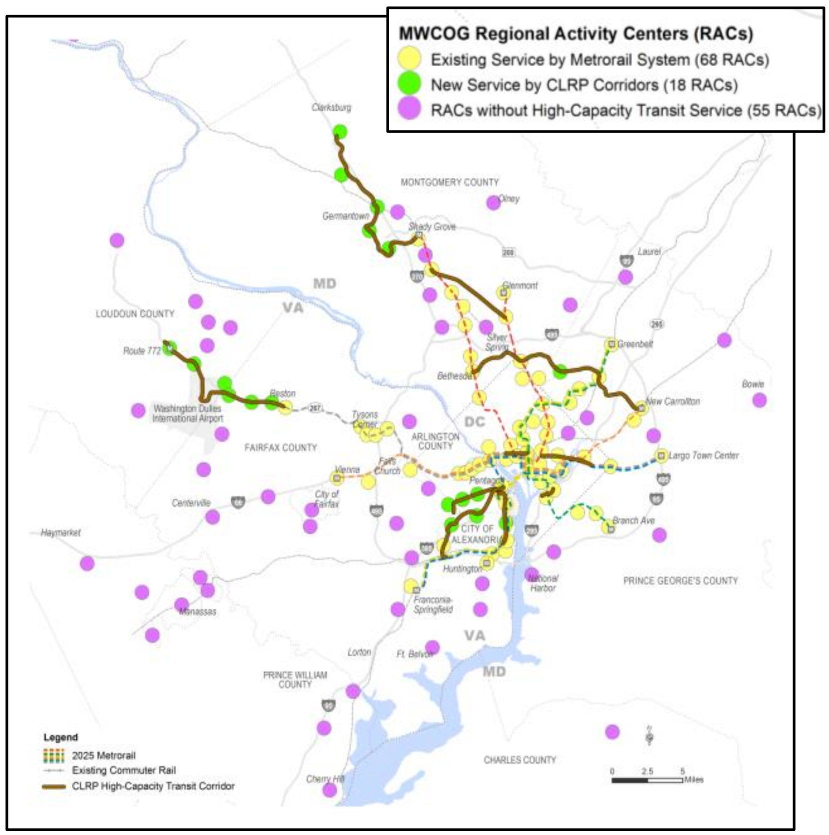
Level	Public Sector Costs	Private Sector/Other Costs
Medium ($245 million)-	Potential loss of land area for economic development , corresponding tax revenues – traded off against lower per-capita infrastructure and service costs	If compact development is key mitigation strategy, that should reduce housing and transportation costs for households, improve access for employers and commercial establishments

Maryland charges 10 cents per square foot of trees removed (over 1 acre of forest) for state highway construction, and replanting occurs at the rate of 400 trees/mitigated acre. This equates to a cost of $4,356 per acre of trees. Under the 5% reforestation policy, it would be necessary to plant the equivalent of 56,350 acres, which would cost approximately $245 million. This investment would be made gradually over time, however, at an average cost of $6.5 million per year, and the investment would continue to deliver benefits indefinitely (assume that the forests, once planted, will replenish themselves – perhaps even multiply).

TLU-2: Sustainable development patterns and urban design, including bicycle/pedestrian enhancements

The MWCOG region is projected to add 623,186 new households and 1,243,753 new jobs between 2012 and 2040, representing increases of 32.2% and 39.6%, respectively. How and where this growth occurs is likely to have significant impact on travel demand and GHG production from motor vehicles. While MWCOG has adopted a vision that urges direction of much of this future growth into activity centers, this strategy explores whether even more can be done to focus future growth and reduce vehicle travel.

Figure 24: MWCOG Activity Centers



While MWCOG's regional plan of centers includes 141 activity centers across the region, it is likely that not all of these centers have the same potential for accepting new growth or channeling that growth into less auto travel and VMT. Some are (or will be) serviced by premium transit, some have (or will have) densities and population/employment mix that encourage walking and local travel, and, based on the current growth forecasts, some are much more committed to increasing their activity levels meaningfully by 2040.

Strategy TLU-2 has developed and tested a set of alternative scenarios that re-allocate anticipated future growth into locations and configurations that are less auto-reliant and, hence, likely to result in lower levels of vehicle miles traveled (VMT). Key criteria in devising these scenarios included better balancing of jobs and housing, focusing more growth in activity centers in general, and prioritizing location in activity centers served by premium transit (Metro, commuter rail, LRT or BRT).

GHG Results

The results derived from analysis of these scenarios are summarized in Table 42.

Table 42. VMT and GHG Reductions for TLU-2 Land Use Alternatives

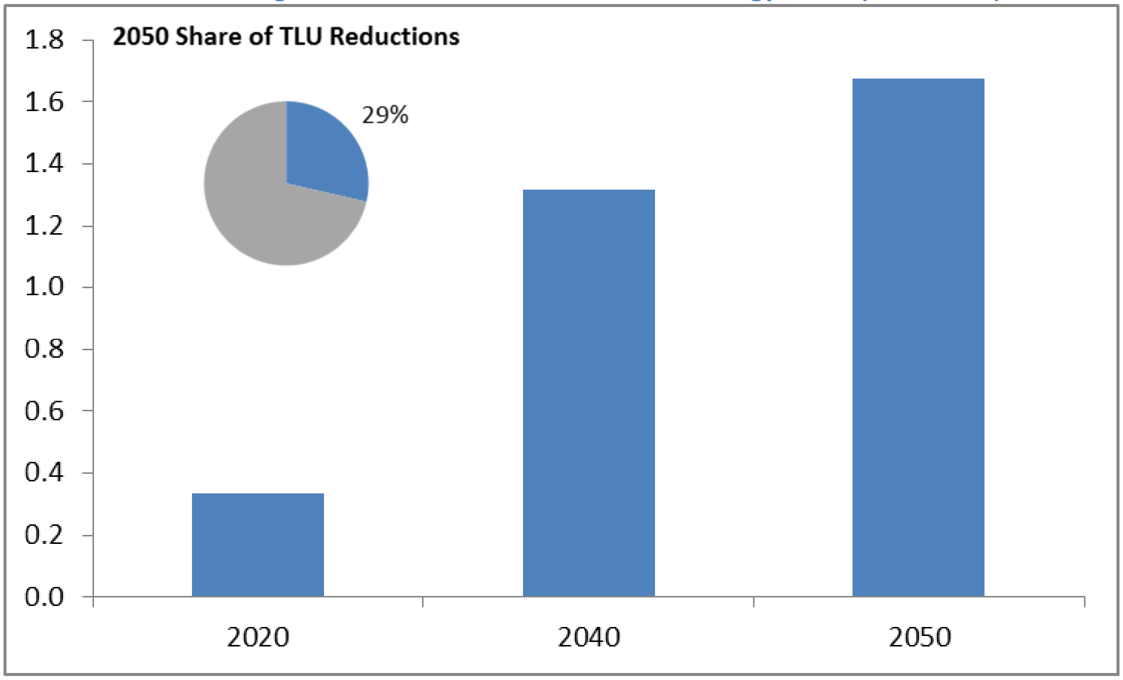
Summary Metric	2012	2020	2040	2050
Annual Passenger Vehicle VMT (millions)	37,402	40,264	46,732	48,149
Estimated VMT Reduction from Land Use Scenarios (percent)		3.3%[1]	11.6%	14.1%
Total Annual VMT Reduction (millions)		1,328	5,421	6,789
Annual GHG Reductions ($MMTCO_2e$) – strategy alone		0.34	1.32	1.67
Annual GHG Reductions ($MMTCO_2e$) – combined with vehicle fuel economy and operational improvement strategies		0.33	1.13	1.30

[1] Interpolated from 2012-2040

The table above shows the GHG reductions associated with this strategy alone, and in combination with additional vehicle fuel economy and operational improvement strategies (TLU-3, TLU-7, and TLU-8) that would reduce the amount of GHG emissions per vehicle mile. Even with significant improvements in vehicle fuel efficiency, this strategy yields significant GHG benefits.

In addition, it is important to note that the GHG benefits of EBE-3 and TLU-1 are closely linked to and stem in part from the changes in land use and urban development patterns associated with TLU-2. Consequently, this one strategy yields additional GHG reduction benefits that may contribute up to 0.84 $MMTCO_2e$ in 2040 (0.34 MMT from building energy savings and 0.50 MMT from carbon sequestration) and up to 1.18 MMTCO2e in 2050 (up to 0.44 MMT from building energy savings and 0.74 MMT from carbon sequestration).

Figure 25. TLU-2: GHG reductions - strategy alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

The land use scenarios in TLU-2 were developed explicitly as alternatives to the growth projections and allocations for 2040 from TPB's Constrained Long-Range Transportation Plan (CLRP) which used MWCOG's Cooperative Forecast Round 8.3. No attempt was made to investigate changes in land use by 2020, given the proximity of that date to today and the reality that sufficient time must be allowed for land use changes to transpire. And while 2050 is the target year for meeting the regional GHG 80% reduction goal, no official forecasts of land use or transportation activity have been developed for that year by the MWCOG planning process. Hence, 2050 benefits have been extrapolated from the analysis, while 2020 benefits were estimated through interpolation.

The research team considered both a moderate scenario that would embody significant (but reasonably implementable) changes over the status quo, as well as a more aggressive scenario that would "stretch" the assumptions toward what might be considered the technical upper limit of the strategy.

The following two scenarios were used as the basis for the Potentially Viable and Stretch approaches:

- **Viable**: This scenario focused on major reallocations of growth, but attempted to retain overall CLRP control totals within the host jurisdiction, focusing instead on allocating as much of that growth as possible into activity centers. Top priority was given to locating in activity centers that include premium transit service (ACTR). Second priority was given to premium transit station areas (TR) that were not formerly designated as activity centers, and third priority was given to those remaining activity centers that were not served with premium transit.
- **Stretch**: This scenario relaxed the constraint on moving jobs or households across jurisdictional lines, and sought to achieve a better regional distribution of employment

opportunity and a better balance between jobs and housing. In general, jobs-housing targets were set in relation to distance from the regional core (1.8 for the closest-in non-core areas to 1.1 at the fringe). Jobs and housing were then moved across jurisdictional lines, up and down radial corridors, and even across corridors to try to achieve as reasonable a balance as possible given that only the 2012 – 2040 *increment* of growth was available for allocation. Once reallocated by sector, the resulting housing and jobs in each sector were moved into the sector's activity centers with the earlier priority rules.

The impact of the scenarios on VMT was determined through a sketch planning approach consisting of a spreadsheet tool that enabled manipulation of the location and amount of future household and employment growth, coupled to a model of household VMT production linked to accessibility scores.

First, a framework was developed to carve up the region into geographic segments that were expected to have different travel characteristics, based on proximity to transportation services (highway corridors and transit lines), and distance from the regional core. This framework is depicted in Figure 26. It partitions the region into 41 segments, defined by its 8 major corridors and a system of 5 concentric rings designating 10-mile increments of distance from the downtown core, plus the core itself. The sectors were made to conform to actual COG TAZ boundaries to simplify application and accounting, and the 2012-2040 increment of households and jobs from the CLRP were allocated to each sector by individual TAZ. This process also allowed for identification of the activity centers (by zone, see Figure 27), and their existing and projected activity levels.

Figure 26. Framework of Dividing Region into 8 Radial Corridors and Concentric Rings

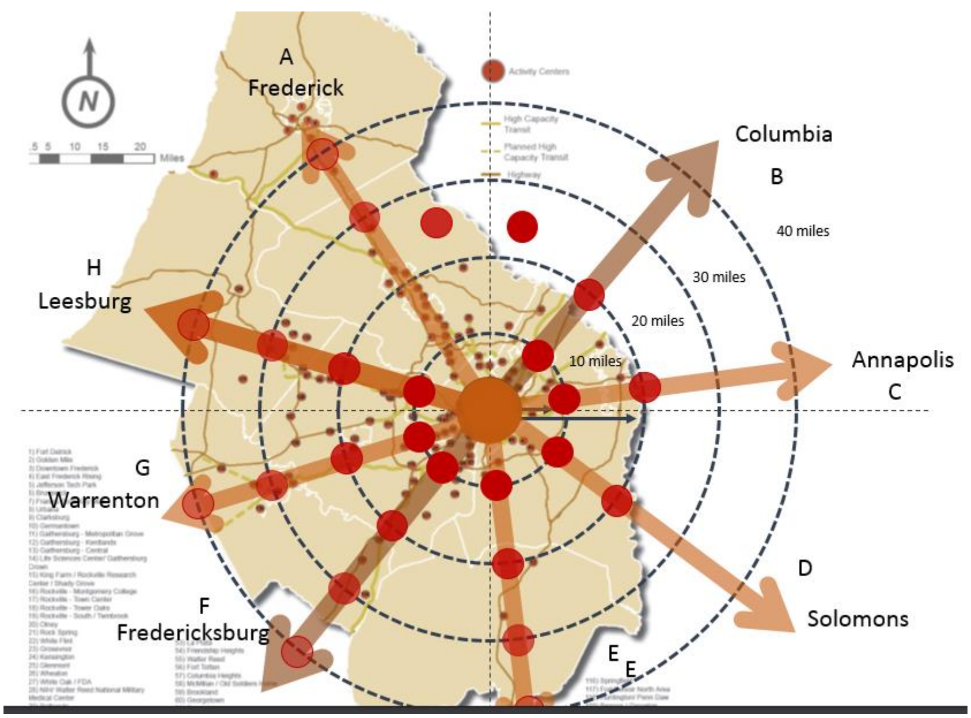
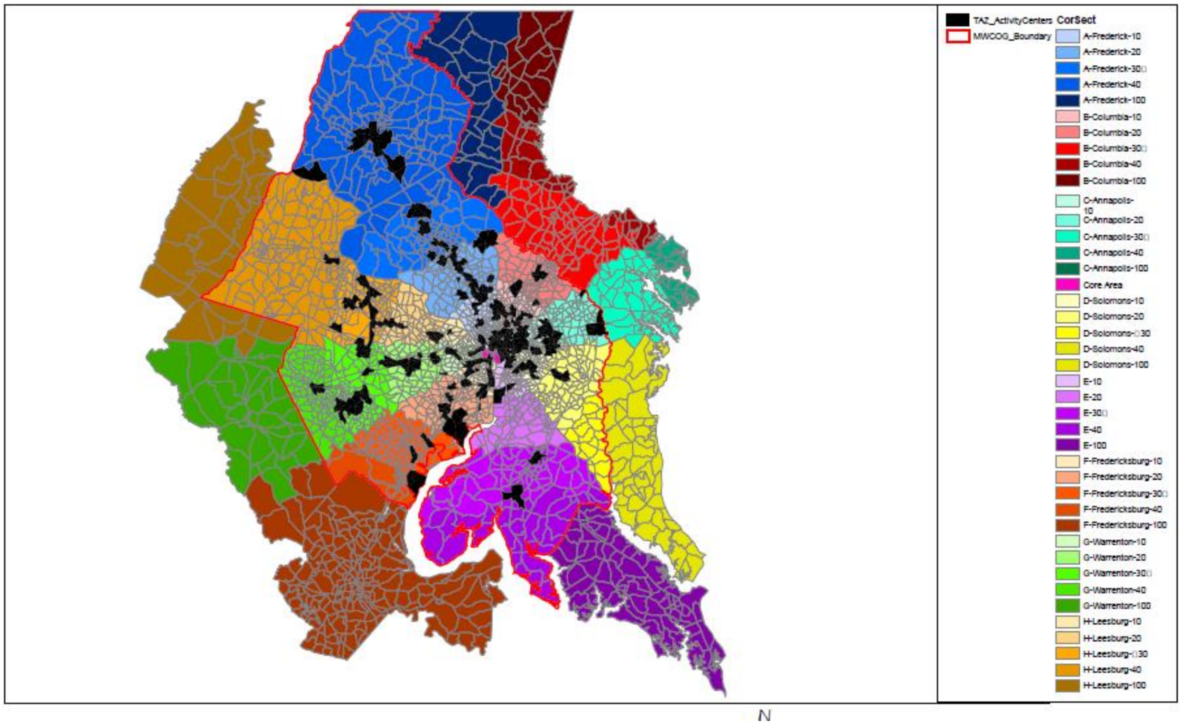


Figure 27. Sector Map Adapted to MWCOG TAZs Showing Sectors and Activity Centers



To estimate the influence of location in any of these areas on travel demand and VMT, a set of models was developed from the MWCOG regional travel survey data and accessibility scores calculated using GIS-derived land use/transportation network relationships; separate scores were calculated for auto, transit and walk modes, and for work and non-work travel opportunities. This accessibility based approach was initially developed under an NCHRP project (Report 770) for Arlington County using data from MWCOG, and subsequently applied and tested in the MD-355 corridor for the Maryland Department of Transportation. These models, illustrated in Figure 26, predict household vehicle ownership as a function of household size, income, and the ratio of transit to auto accessibility scores for work travel (TAR_HBW) and walk accessibility to non-work opportunities (HH_HBO_W). Auto ownership, which is very sensitive to land use context, is estimated first and then used as an input variable in the household VMT model.

Table 43. Calculated Average Daily HH VMT by Location

Accessibility scores based on 2040 land use allocations and travel conditions were calculated for each TAZ, then subsequently used to estimate per household VMT for each TAZ, and then total VMT based on the number of TAZ households. The daily household VMT rates are illustrated in Table 43 (blank rows indicate areas that are outside the MWCOG region). Note the tendency toward much lower rates in the AC+TR locations, generally TR over AC areas, and all activity center areas over non-activity center locations. These VMT rates also generally increase as one moves outward from the core. This table makes it clear why some locations are more favorable than others as targets for concentrating future growth.

This template was used to estimate total VMT for the base 2040 land use allocation, and then for the viable and stretch land use scenarios. A special spreadsheet program allows the analyst to move various numbers of households and jobs across sectors and among activity centers, while making sure critical control totals are not violated through an internal normalization program.

Theviable land use scenario assumptions were used to estimate the VMT and GHG reductions for 2040, while the stretch scenario was used to represent conditions in 2050. COG estimates annual VMT from passenger vehicles in 2040 at 46.732 billion, an increase of 9.330 billion over 2012, or about 25%. Using the household VMT model, and the relocation of households and jobs in accord with each scenario resulted in reductions in household-generated VMT of 11.6% in 2040 and 14.1% in 2050, or net annual reductions of 5.241 billion and 6.789 billion VMT, respectively.

It should be noted that the 14.1% reduction in VMT generated from the 2040 stretch scenario was applied to 2050 VMT. However, over the 10 years between 2040 and 2050, additional development would occur,

	AC+TR	AC	TR	None	AVG
Core	8.84	14.10	7.14	0.00	9.12
A-1	9.93	22.19	21.50	34.34	21.40
A-2	10.62	31.25	19.03	34.45	26.64
A-3	15.17	30.10	18.58	35.39	30.37
A-4	0.00	30.63	0.00	50.04	44.76
A-5					
B-1	15.99	23.74	15.32	28.47	21.84
B-2	11.08	28.53	18.73	35.43	33.91
B-3					
B-4					
B-5					
C-1	14.92	24.47	25.57	30.00	24.07
C-2	0.00	27.62	32.11	40.81	38.58
C-3					
C-4					
D-1	14.04	17.66	11.18	22.48	17.68
D-2	5.00	39.22	0.00	40.15	39.37
D-3	0.00	0.00	0.00	51.79	51.79
D-4					
D-5					
E-1	10.72	26.20	5.61	25.32	21.06
E-2	0.00	39.05	0.00	37.69	37.73
E-3	0.00	21.51	0.00	25.95	25.50
E-4	0.00	0.00	0.00	52.04	52.04
E-5					
F-1	20.81	20.11	23.16	28.22	23.05
F-2	15.49	19.14	10.49	32.97	29.87
F-3	5.00	5.31	5.00	23.58	19.78
F-4	0.00	0.00	0.00	25.38	25.38
F-5					
G-1	14.21	21.98	21.86	32.99	25.13
G-2	22.30	31.20	31.80	39.10	35.32
G-3	19.10	30.65	0.00	45.25	39.74
G-4	0.00	41.70	29.22	54.21	52.14
G-5					
H-1	18.24	29.76	36.98	44.40	38.68
H-2	15.70	21.98	0.00	42.25	29.59
H-3	17.07	31.56	29.45	43.66	38.61
H-4	0.00	28.91	0.00	48.22	46.34
H-5					

which implies that the 14.1% reduction may not require such an aggressive redistribution of new development, but rather may be more consistent with the viable strategy being applied over an additional 10 years.

Data, Models, and other tools used

- TPB's CLRP growth forecasts by TAZ for 2012, 2020 and 2040
- Travel networks and travel time skims for same time periods
- Multimodal accessibility tool, developed for Arlington VA under NCHRP study 08-78[14] with COG data/support, subsequently applied in Montgomery County for MDOT, expanded in this study to include all TAZs in the MWCOG region.
- Household VMT model developed from MWCOG travel survey data and accessibility scores

Assumptions

- The MWCOG socioeconomic data and travel networks were used to generate accessibility scores for auto, transit and walk for work and non-work travel for each TAZ in the region. This was done for the base 2040 CLRP scenario and each of the subsequent test scenarios.
- A set of models predicting household vehicle ownership and daily household VMT which incorporate the accessibility scores (along with household size and income) were developed using the households in the extended MWCOG 2007-2012 travel surveys.
- The region was divided into sectors defined by 8 radial corridors and concentric rings representing 10-mile distance increments from the regional core. Analysis was keyed to these sectors, in addition to a regional core.
- Activity centers were also located within each sector, identified in terms of their respective TAZs, and assigned a functional category as activity center with premium transit, premium transit with no activity center, and activity center with no premium transit.
- 2040 population and employment were allocated to the sector and activity center framework.
- Accessibility scores (plus household size and income) were used to calculate daily household VMT rates for each zone in the 2040 CLRP configuration; these were then used to estimate total household VMT for the base.
- Using the scenario criteria described earlier, both households and employment were moved about in different patterns from the 2040 base, attempting to take maximum advantage of low-VMT locations (activity centers with transit, other areas with higher density and good mix of uses)
- Only growth between 2012 and 2040 was considered available for reallocation; no pre-existing growth was moved.
- Population and employment located outside the MWCOG region was not changed or used to adjust population and employment numbers in the analysis region; however, the attractiveness of job opportunities located outside the region was included in the calculation of modal accessibility scores.
- The VMT models were applied to the new distribution of households and employment, resulting in different VMT totals for the region.

[14] NCHRP Report 770: Estimating Bicycle and Pedestrian Demand for Planning and Project Development. Renaissance Planning, et al., for National Cooperative Highway Research Program, National Academy of Sciences (August 2014).

- Since jobs were moved about in addition to households, a second iteration was performed in which the multimodal accessibility scores were recomputed to account for the redistribution of employment opportunities. The new scores were used to recompute VMT rates for each zone, and this was used to compute new regional household VMT totals for each scenario.

Potential Co-Benefits

Adjusting land use development patterns, together with investments in bicycle/pedestrian infrastructure, and corresponding transit, is expected to yield a wide array of co-benefits.

Table 44. Co-Benefit Results for TLU-2

Co-Benefit	Description of Co-Benefit
Safety	Compact development should lead to less auto use and VMT, which should reduce both exposure to and rates of incidents
Congestion Reduction	Compact development should lead to less auto use and VMT, which may lead to less regional congestion overall; however, the distribution of congestion may vary
Reliability	Lower congestion should mean fewer breakdowns of level of service and greater predictability of travel time; shorter trips should be less prone to unpredictability
Air Quality (Criteria Pollutants)	Fewer vehicle trips and reduced VMT should be helpful in reducing criteria pollutants
Economic Vitality	More travel choices, shorter trips and less congestion should reduce travel costs, which is good for both workers and employers/investors
Mobility	Mobility should improve due to availability of more options, including transit, bicycling, and walking for more trips
Accessibility	There should be more travel options, shorter trips, and overall more destinations available within accessible trip distances
Weather resiliency	Travel in compact multimodal environments may be less vulnerable to severe weather events than driving.
Storm water	Compact development results in less impervious surface, both for buildings and for supporting infrastructure – notably roads
Community Amenity	Neighborhoods become safer and more attractive with greater pedestrian orientation.

This strategy is also anticipated to yield reductions in criterial air pollutant emissions, associated with the reduction in vehicle trips and VMT.

Table 45. Estimated Criteria Pollutant Emissions Benefits for TLU-2 – Strategy Alone

Year	NOx (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	0.65	0.72	14.23
2040	0.80	1.79	56.49
2050	1.02	2.28	71.88

Note: These estimates account for changes in emissions rates forecast in the MOVES2014 model through 2040, but do not account for further changes in emissions rates that may occur over this period due to other strategies that alter vehicle fuel economy and operating conditions or that may occur between 2040 and 2050.

Costs

Further efforts to target development toward activity centers, particularly those with high quality transit, will not entail direct costs to government, since policy mechanisms include zoning and related development incentives (e.g., allowing higher density, fewer parking spaces). Overall, compact development should be less expensive to build and sustain than more dispersed development. However, there likely would be costs associated with additional transit services needed to accommodate anticipated demands, as well as costs associated with developing grid street networks, bicycle and pedestrian infrastructure, and community amenities and services in areas with higher land values. Some of these costs can be passed onto developers.

Table 46. Costs for TLU-2

Level	Public Sector Costs	Private Sector/Other Costs
Tradeoffs between costs and savings are complex, but compact development should be cheaper to build and sustain.	Potential loss of land area for economic development , corresponding tax revenues – traded off against lower overall infrastructure and service costs	If compact development is key mitigation strategy, that should reduce housing and transportation costs for households, improve access for employers and commercial establishments

TLU-3: Improve fuel economy of light-duty vehicle fleet

This strategy is designed to incentivize more fuel-efficient light-duty vehicles in the private sector through programs that a) speed up the replacement rate of older, less fuel-efficient vehicles; b) incentivize the purchase of electric vehicles and charging equipment; c) implement disincentives for inefficient vehicle purchases (e.g. feebates), and; d) adopt new low emission vehicle standards.

The scenarios developed for this measure include:

- 2020: Increase light-duty zero emission vehicles (ZEVs) to 2% of total vehicle population in region (beyond those anticipated with existing policies)
- 2040: Increase light-duty ZEVs to 15% of total vehicle population in region (beyond those anticipated with existing policies)
- 2050 (stretch): Increase light-duty ZEVs to 25% of total vehicle population in region (beyond those anticipated with existing policies)

In particular, strategies to support/promote ZEVs include investing in a system of public-access vehicle recharging stations, offering tax credits to businesses that install recharging stations, offering benefits (HOV access, priority parking) to owners of electric vehicles, and offer tax credits for ZEV vehicle purchases, among others. In addition, electric vehicle-ready design can be incorporated into new development and existing redevelopment projects, and so can be supported via strategies targeting the built environment sector.

GHG Results

This measure is estimated to have large GHG reduction impacts since it focuses on passenger vehicles, which make up a sizable share of the total transportation emissions inventory. Passenger vehicles are estimated to be responsible for 84% of VMT and 72% of on-road CO_2e emissions in the National Capital Region in 2012.[15] Consequently, strategies that significantly shift the passenger vehicle stock toward ZEVs provide significant GHG reductions.

It is important to note, however, that some of the direct tailpipe emissions from vehicles that are eliminated via ZEVs are offset by emissions associated with the electricity usage. The level of GHG emissions associated with the electricity consumption, and the overall net GHG benefit, is heavily dependent upon EBE strategies related to power sector emissions and renewable energy.

The following results were estimated for this strategy – shown both with this strategy independently and combined with lower VMT associated with other TLU strategies.

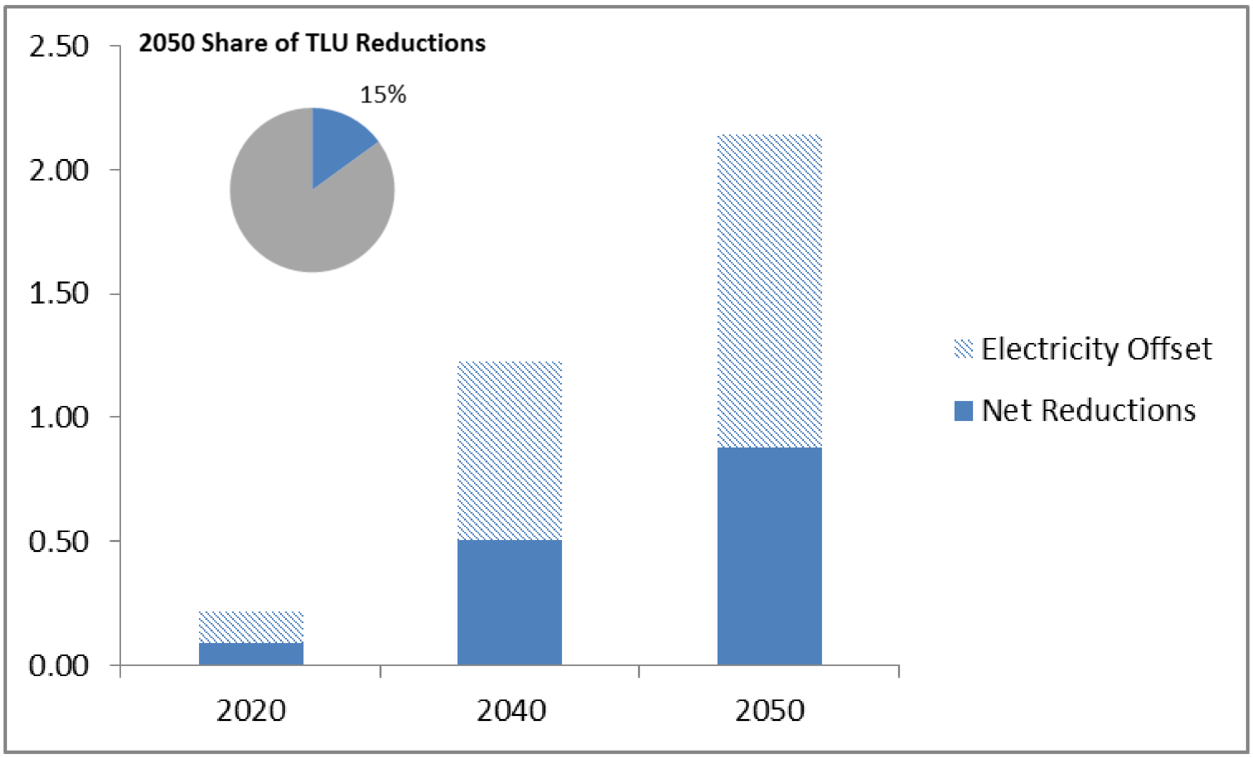
[15] Figures are based on MOVES regional emissions analysis runs provided by MWCOG. The share of CO_2e emissions from passenger cars drops through 2020 and 2040 as vehicles become more fuel efficient.

Table 47. Greenhouse Gas Reductions for TLU-3: Improve Fuel Economy of LD Vehicle Fleet

Summary Metric ($MMTCO_2e$)	2020	2040	2050
Strategy Alone			
GHG Reductions: Fuel Consumption (strategy alone)	0.22	1.23	2.14
GHG Increase from Electricity Use (strategy alone)*	(0.13)	(0.72)	(1.26)
Net GHG Reductions (strategy alone)	0.09	0.50	0.88

*The increase in GHGs associated with the increased electricity consumption assumes none of the EBE strategies are implemented. If EBE strategies that reduce power sector emissions are implemented, the level to which electricity emissions offset the mobile source reductions will be considerably reduced.

Figure 29. TLU-3: GHG reductions – stand-alone ($MMTCO_2e$)



These estimates may over-estimate the GHG reductions attributable to state, regional, and local actions since future federal policy actions may create additional requirements or incentives for increased ZEV adoption over this time.

Overview of Methods and Key Assumptions

Data, Models, and other tools used

The analysis assumed that in order to achieve an increase in the fuel economy of light-duty vehicles that the share of so-called zero emission vehicles (ZEVs) would increase to a defined percentage of the overall fleet. The corresponding percentages of the overall light-duty vehicle fleet were characterized as follows:

- 2% of the light-duty fleet as ZEVs in 2020, beyond those anticipated with existing policies
- 15% of the light-duty fleet as ZEVs in 2040, beyond those anticipated with existing policies
- 25% of the light-duty fleet as ZEVs in the 2050 stretch scenario, beyond those anticipated with existing policies

The analysis assumed that ZEVs would include a combination of plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and hydrogen fuel cell vehicles (FCVs). The mix of these vehicles was assumed to be consistent with a deployment referred to as the "likely compliance scenario" developed by the California Air Resources Board (CARB) for the development of California's ZEV program (which applies to MY2018-MY2025 vehicles). The California ZEV program requires about 15% of new light-duty vehicle sales in California be ZEVs by the year 2025. Between 2018 through 2025, about 62.5% of ZEVs are assumed to be PHEVs, 26.0% BEVs, and 11.5% FCVs. The analysis assumed that the distribution of ZEVs in the study region would be consistent with the ZEV scenario.

The analysis assumed that the 2% share of the light-duty fleet in 2020 traveled the same share of VMT. To calculate GHG emission reductions, the analysis estimated the amount of VMT that would be traveled with zero emissions, after adjusting for miles traveled using gasoline in PHEVs. PHEVs were further disaggregated by the vehicle's all-electric range, including 10-, 20-, and 40-mile ranges (i.e., PHEV10, PHEV20, and PHEV40). The analysis assumed that PHEVs were comprised of 50% PHEV40s, 25% PHEV20s, and 25% PHEV10s. Based on data presented by the EV Project (see table below), the analysis assumed that PHEV40s travel 75% of their miles in all-electric mode (referred to as electric vehicle miles traveled, eVMT). The analysis made a simplifying assumption that PHEV10s and PHEV20s will have a percent eVMT of 19% and 38%, respectively.[16] After making these adjustments, the weighted average of eVMT (at zero emissions) for PHEVs is about 52%.

[16] These values could conceivably be higher with interventions for vehicle charging; however, it is unclear to what extent eVMT can be increased through these types of interventions.

Table 48. Vehicle Miles Traveled by Region in The EV Project for Chevrolet Volts and Nissan LEAFs[17]

Region	Chevrolet Volt			Nissan LEAF	
	VMT	%eVMT	Total Vehicles	Daily VMT	Total Vehicles
Overall	**41.0**	**74.6%**	**1,895**	**29.5**	**4,261**
Phoenix	39.6	76.7%	129	31.0	184
Tucson	n/a	n/a	<10	26.5	51
Los Angeles	39.0	75.8%	320	26.9	274
San Diego	40.2	71.9%	256	29.0	478
San Francisco	n/a	n/a	<10	30.0	1,311
Washington DC	42.5	75.9%	266	32.5	39
Oregon	39.3	77.6%	130	28.7	382
Chattanooga	52.5	60.3%	13	32.4	39
Knoxville	43.4	72.5%	31	32.5	78
Memphis	39.5	72.8%	31	26.9	41
Nashville	43.4	73.3%	50	31.9	515
Dallas / Ft Worth	42.3	73.3%	177	31.0	19
Houston	42.7	71.5%	73		
Washington State	38.0	77.7%	160	28.0	658
Chicago	43.6	76.6%	128	29.2	23
Atlanta	44.6	70.4%	72	29.6	141
Philadelphia	44.0	68.0%	51	26.2	24

As shown in the table above, it is conceivable that limited range BEVs like the Nissan LEAF (with a battery range of 80-100 miles depending on a variety of parameters) may have lower VMT per vehicle than the overall average among vehicles. Anecdotal evidence suggests that longer range BEVs like the Tesla Model S do not have the same reduced VMT compared to conventional gasoline vehicles. To simplify the analysis, the analysis assumed that by 2020 and by 2040 that BEVs would have sufficient range to have similar annual VMT as conventional vehicles.

The most effective market driver for ZEVs is likely a ZEV Program like the one that CARB has implemented, and that other states will likely emulate based on an MOU signed by seven other states (including Maryland). Outside of this type of regulatory action, regional objectives to deploy ZEVs are unlikely to yield a fleet that consists of 2% ZEVs by 2020. Based on information presented by the TPB Technical Committee, the region's fleet turnover has been slowing since 2008 (i.e., vehicle age is

[17] The EV Project, Q2 2013 Quarterly Report

increasing).[18] The TPB Technical Committee presentation also indicates that about 2.74% of the light-duty fleet is comprised of hybrid electric vehicles. Although vehicle registration data indicate significant growth since 2001, it has taken 13 years to achieve that penetration of 2.74%. With ZEVs being deployed since 2011, it is unlikely that they will achieve the 2% penetration put forth in this measure without significant intervention in the near-term future. These levels are conceivable with incentives like vehicle buydowns/rebates for consumers – which are available in many states, in addition to the federal tax credit for electric vehicles.

The longer-term goals of 15% and 25% are more probable given the likelihood that the federal government will continue to regulate GHG tailpipe emissions and fuel economy, which will continue to drive hybridization and electrification (which includes batteries and fuel cells). These levels of penetration fleetwide, however, require near-term actions, otherwise there is significant pressure in the out-years to push ZEVs into the fleet. Considering that the fleet is turning over at a slightly lower rate – and it is unclear how long this trend may persist – ZEV sales must reach between 15% to 25% of new sales by 2030 in order to reach a target of ZEVs comprising 15% of the fleet by 2040.

The increase in electricity consumption attributable to increased PHEV and BEV deployment was calculated assuming a vehicle efficiency of 0.35 kWh per mile. Note that this was only applied to the eVMT for PHEVs

Assumptions

As a simplifying assumption (as detailed above), the analysis calculated the emission reductions as equal to the product of VMT for ZEVs and the fleetwide emissions rate. However, when considering new vehicle sales, even if a ZEV is replacing an older vehicle, the result of the strategy may be the displacement of an efficient new vehicle with a ZEV; consequently, this analysis may be over-estimating emissions reduction benefits of ZEV strategies

In addition, the analysis assumed that ZEVs travel the same average distance as conventional vehicles (by calculating the emissions reduction based on share of VMT for ZEVs using the share of vehicles). This assumption also may overestimate emission reduction benefits of ZEVs in the near-term (2020).

Potential Co-Benefits

Co-benefits of this strategy are primarily associated with reductions in criteria air pollutants. The increase in use of ZEVs reduces tailpipe emissions of criteria pollutants, including NOx and VOC, significantly.

Table 49. Co-Benefit Results for TLU-3: Improve Fuel Economy of LD Vehicle Fleet

Co-Benefit	Description of Co-Benefit
Criteria Air Pollution	Improving the fuel economy of light duty-vehicles via the deployment of ZEVs reduces the amount of motor fuels used, which in turn reduces all criteria pollutant emissions.

[18] 2014 Vehicle Registration Data Analysis, TPB Technical Committee, January 9, 2015.

Costs

As there are several measures proposed to help meet the proposed ZEV deployment targets, the costs of this program may vary widely, making it difficult to develop a specific cost estimate. Table 50 provides a brief summary, followed by some information on expected costs.

Table 50. Costs for TLU-3: Improve Fuel Economy of LD Vehicle Fleet

Level	Public Sector Costs	Private Sector/Other Costs
Medium ($50 million to $500 million)	Infrastructure improvements for widespread plug-in electric vehicles use ZEV incentive costs, and program implementation costs	Cost savings from driving a PEV can be up to $950/year due to reduced fuel costs

- Feebate programs are generally revenue neutral as the fee collected for the purchase of less efficient vehicles are used to offer a rebate to more fuel efficient vehicles. The value of the fee and rebate can be modified to reflect the targeted level of reductions; the main cost of this program for public agencies is the administration of the program, which would require processes fees and rebates, while also working with dealerships and other regional stakeholders to implement the program.
- ZEV incentives are expensive. California provides an incentive (in addition to the federal tax credit) of up to $2,500, depending on vehicle architecture. This program is primarily funded annually via a small fee on vehicle registration. Georgia used to have a $5,000 income tax credit for the purchase of EVs.
- The ZEV Program requires program administration. However, it is generally administered at the state level. Generally, ICF views a regional ZEV Program as impractical to implement, because it would require authority that regional actors do not have. This type of measure is better left to state agencies e.g., via the eight-state MOU regarding ZEVs.
- Charging infrastructure incentives can be cost-effective; however, it is unclear to what extent they accelerate adoption of ZEVs. This is also a program that could be taken up by regional utilities rather than regional public agencies.

It should be noted that while not a direct program cost to government, the indirect effect of a shift to ZEVs is less motor fuel tax revenues; as a result, this strategy can exacerbate problems associated with transportation funding, unless additional funding mechanisms are designed.

TLU-4: Increase alternative fuels in public sector fleets

This strategy is designed to increase the number of alternative fuel vehicles, including ZEVs, in public sector fleets through programs that a) fund purchases of alternative fuel school buses and transit bus fleets; b) convert existing garages and share alternative fuel facilities for school bus fleets, and; c) increase the share of electric vehicles in light-duty public sector fleets (e.g., police cars, government vehicles, etc.). The strategy scenarios are defined as follows:

- 2020: Add 200 zero emission vehicle (ZEV) buses to public transit fleet in the study region (replacements).
- 2040: Increase ZEVs in municipal light-duty fleets to 15% of total fleet population; require B5 in all municipal fleets and school buses; require 15% of public transit fleet to be ZEVs.
- 2050 (stretch): Increase ZEVs in municipal light-duty fleets to 25% of total fleet population; require B20 in all municipal fleets and school buses; require 25% of public transit fleets to be ZEVs.

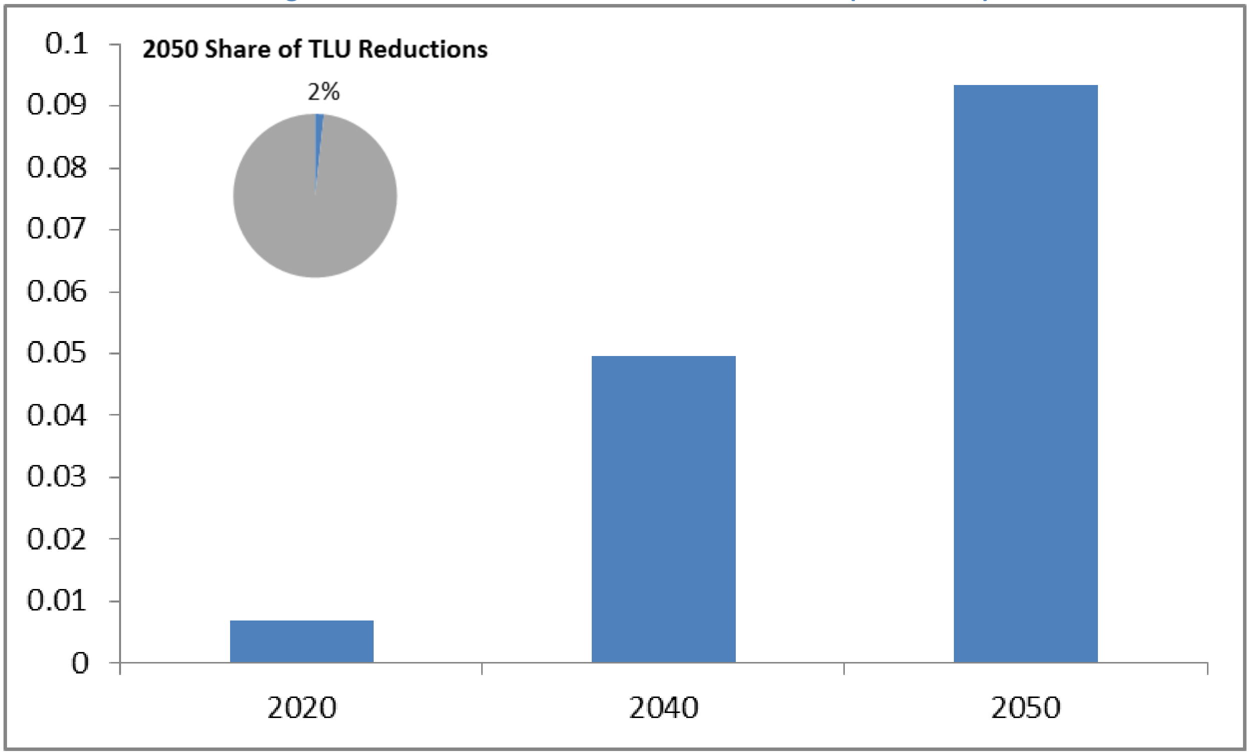
GHG Results

This measure results in relatively low GHG emissions reductions, given that public sector fleets comprise a small share of the total vehicles in the metropolitan area. However, it is a very actionable and discrete policy that shows leadership and commitment of governments to climate action goals. In addition, buses have much lower fuel economy than light-duty vehicles and travel more miles per vehicle, so actions that affect bus fleets will have a larger impact than their share of total vehicles.

Table 51. Greenhouse Gas Reductions for TLU-4: Increase Alternative Fuels in Public Sector Fleets

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (strategy alone)	0.007	0.050	0.093

Figure 30. TLU-4: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

For 2020, the analysis assumed that 200 zero emission vehicle buses will be deployed as replacements for conventional buses. The analysis was performed by calculating the VMT per bus and estimating the GHG emissions by multiplying the number of buses deployed (200) by the CO_2e emissions factor (for running emissions and starts) for the bus fleet.

For 2040, the analysis increased ZEVs in the municipal fleet (as light-duty vehicles), increased amount of biodiesel blended into biodiesel to B5, and increased the ZEV fleet to 15% of total transit buses.

ZEVs in Municipal Light-Duty Fleet: 15% or 25%

- The analysis assumed that the municipal fleet represents 1.3% of the passenger car fleet in the study region based on ICF's analysis of municipal registrations in other jurisdictions, including California, Orlando, and the Delaware Valley.
- Of these 1.3% of vehicles, 15% (2040) or 25% (2040-Stretch) were assumed to be ZEVs. The analysis assumed only PHEVs and BEVs for municipal fleets, as these are ideal for fleet applications and do not have the same fueling infrastructure requirements as hydrogen FCVs. ICF assumed that the share of vehicles is equivalent to the share of VMT.
- The analysis multiplied the share of eVMT (69% of VMT; adjusted for PHEVs using both gasoline and electricity) by the percentage of the light-duty vehicle fleet (<0.35%) to calculate the GHG emission reductions attributable to this strategy.

Increase biodiesel blend to 5% or 20% in School Buses

- The analysis assumed that the biodiesel blend was equivalent to the share of VMT i.e., 5% of VMT occur using biodiesel instead of diesel.
- Biodiesel has a zero tailpipe GHG emissions.
- The analysis multiplied the total VMT from school buses by the biodiesel blend (5% or 20%) and the school bus emissions factor (in g/mi) to calculate the GHG emission reductions.

Increase ZEVs in Transit Bus Fleet: 15% and 25%

- The analysis assumed that the share of the fleet was equivalent to the share of VMT.
- The analysis multiplied the share of transit bus VMT (15% or 25%) by the emissions factor for transit buses to calculate the corresponding GHG emission reductions of this strategy.

Potential Co-Benefits

Co-benefits are associated with transitioning fossil fuel burning public vehicles to alternative fuels. This reduces the number of vehicle miles traveled by fossil fuel vehicles and thus reduces criteria air pollution.

Table 52. Co-Benefit Results for TLU-4: Increase Alternative Fuels in Public Sector Fleets

Co-Benefit	Description of Co-Benefit
Criteria Air Pollution	Public school buses, transit buses, and light-duty fleets represent thousands of vehicles. Transitioning these vehicles to an alternative fuel or ZEVs reduces gasoline and diesel consumption, in turn reducing criteria pollutant emissions, notably PM and NOx, from diesel fuel consumption

Costs

Cost estimates for TLU-4 are provided below, accounting for costs over the full time-frame of implementation.

Table 53. Costs for TLU-4: Increase Alternative Fuels in Public Sector Fleets

Level	Public Sector Costs	Private Sector/Other Costs
Medium ($50 million to $500 million)* *considering incremental costs of vehicle replacements and refueling/charging facilities	Incremental costs of purchasing alternative fuel vehicles Costs associated with fueling stations	-

The Federal Transit Association recently awarded about $55 million to 10 projects from the Low or No Emission Vehicle Deployment Program.[19] These projects are generally deploying 5-7 buses. It is feasible to scale these deployments; however, scaling this type of deployment to 200 buses by the 2020 timeframe will have considerable costs in the near-term. As a GHG reduction strategy, if the vehicles are replacing those generally at the end of their usable life, the primary issue is the incremental costs of selecting an alternative fueled vehicle compared to a conventional vehicle. Consider the following cost elements:

- A 40’ electric bus is about $800,000, an incremental price of $150k-$200k compared to diesel buses
- These include a "slow" chargers providing power in the range of 40-80 kW

The biodiesel transition is straightforward. The main sticking point will be getting a reliable supply to the region at a reasonable price. Biodiesel prices can fluctuate significantly, and a premium over diesel is generally paid.

Deploying ZEVs into the light-duty municipal fleet is also achievable, but can be at a significant upfront cost. Fleets, however, are generally good at considering the total cost of ownership and can realize cost savings over the life of a light-duty BEV or PHEV, depending on typical driving patterns of fleet vehicles and access to charging infrastructure. The challenge with fleets in this type of deployment is that there may be two different municipal revenue streams or accounts – one for vehicle purchasing and another for fuel purchases. Without the two being integrated, or with the potential of conflict between these two streams, it may be difficult to convince local and regional fleet managers to convert to ZEVs.

[19] Low or No Emission Vehicle Deployment Program Project Selections, available online at : http://www.fta.dot.gov/grants/15926_16268.html

TLU-5: Truck stop electrification

This strategy is designed to reduce idling by heavy-duty vehicles, specifically through the installation of truck-stop electrification (TSE) sites in the National Capital Region. The scenarios analyzed are as follows:

- 2020: One TSE location with 20 bays/site in the region.
- 2040: Six (6) TSE locations with 20 bays/site in the region.
- 2050 (stretch): Fourteen (14) TSE locations with 20 bays/site in the region.

There are currently 14 truck stops located within the metropolitan Washington region[20] so the long-term stretch scenario essentially assumes that all are fitted with TSE bays.

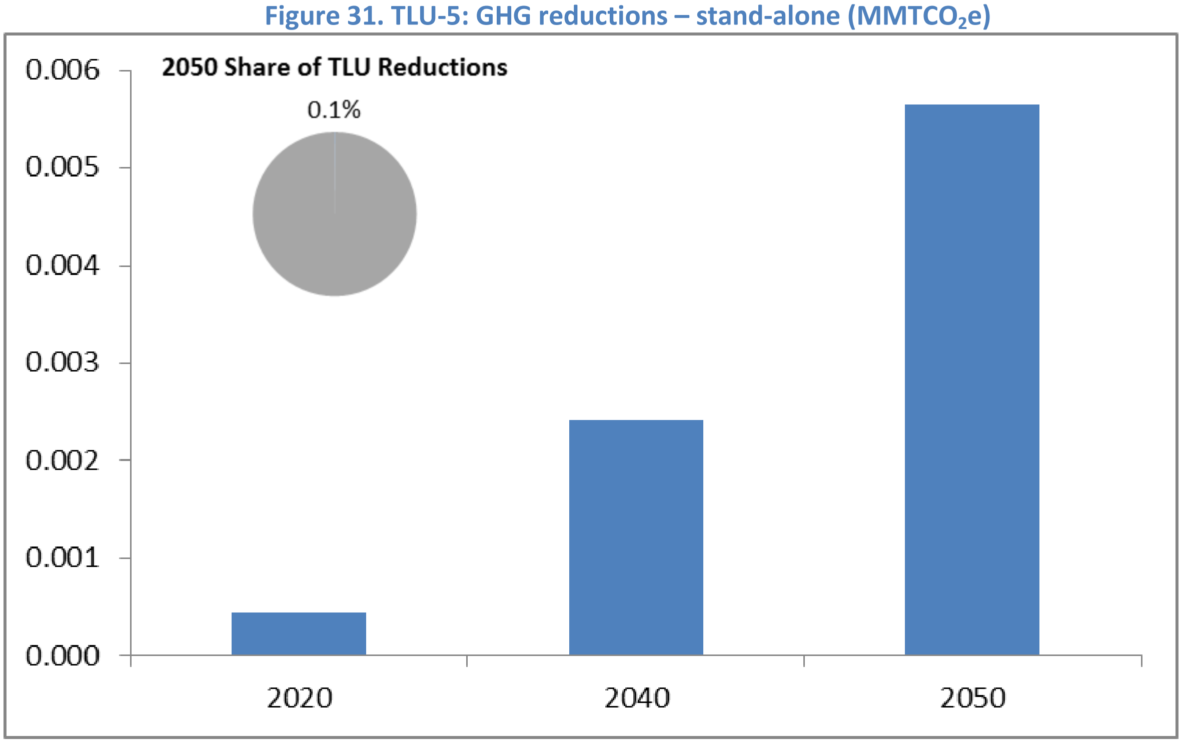
GHG Results

The following results were determined for this strategy.

Table 54. Greenhouse Gas Reductions for TLU-5: Truck Stop Electrification

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (Strategy alone)	<0.001	0.002	0.006

Figure 31. TLU-5: GHG reductions – stand-alone ($MMTCO_2e$)



[20] Based on data from http://www.findfuelstops.com/

These emissions reductions are not affected by strategies that affect light-duty VMT and technologies). As with strategy TLU-3, the increase in electricity consumption will generate some GHG emissions from electric utilities that will offset some of the emissions savings from the trucks. Given the small impacts of the TSE strategy overall, and expected implementation of strategies to reduce power sector emissions, these electric utility emissions are not presented.

Overview of Methods and Key Assumptions

Data, Models, and other tools used

Emissions reductions were calculated using the following procedures:

1) The number of TSE bays were calculated by multiplying the number of TSE locations in each scenarios by an estimated average of 20 bays per site.
2) The number of hours of use was calculated based on an assumption of eight hours of use per day (number of bays x 8 hours use each)
3) The extended idle emissions factor was developed for each analysis year based on use of the EPA MOVES Model. The EPA MOVES model was run at a national scale with all default inputs for the 10 county National Capital Region to generate emissions factors in grams/hoteling hour. These base emissions factors include use of auxiliary power units (APUs).
4) The number of hours of TSE use was multiplied by the extended idle emissions factors for each analysis year to calculate reduced truck idling emissions.
5) The increase in kilowatt hours of electricity use was assumed to be 3.8 kW per hour, based on figured used in the Moving Cooler report; the total electricity use was calculated by multiplying the kW per vehicle times the number of hours of usage.

The analysis assumes that all TSEs are utilized daily (365 days per year).

Potential Co-Benefits

The primary co-benefits of truck stop electrification are reductions in criterial pollutant emissions, as noted below, in summary Table 55. Estimates of criteria pollutant emissions reductions are provided in Table 56.

Table 55. Co-Benefit Results for TLU-5: Truck Stop Electrification

Co-Benefit	Description of Co-Benefit
Criteria Air Pollution	Reducing heavy-truck idle time reduces vehicle emissions, notably oxides of nitrogen and particulate matter emissions from diesel trucks. See Table 2B for estimated criteria pollutant emissions reductions by year (calculated based on MOVES2014 extended idle emissions factors)

Table 56. Criteria Air Pollutant Emissions Reductions for TLU-5: Truck Stop Electrification

Year	NOx (tons per day, ozone	VOC (tons per day, ozone	PM2.5 (tons per year)

	season)	season)	
2020	0.04	0.01	0.13
2040	0.18	0.03	0.29
2050	0.43	0.06	0.68

Costs

Installation of TSEs would require public sector expenditures for the infrastructure, as well as on-going operating and maintenance (O&M) costs. Capital costs were estimated as $10,000 per space, and O&M costs per space were $100 for maintenance, $25 for insurance, and $1,314 for overhead labor, based on data for two truck stops in New York, as cited in the Moving Cooler study.[21]

These technologies results in cost savings to freight carriers due to reduced vehicle fuel consumption during extended idling. These costs savings can be calculated by multiplying an estimate of annual diesel fuel savings by average diesel fuel costs per gallon.

Table 57. Costs for TLU-5: Truck Stop Electrification

Level	Public Sector Costs	Private Sector/Other Costs
Low (<$50 million)	Capital costs: $2.8 million Annual O&M costs: $403,000	Cost savings from reduced fuel consumption

[21] Antares Group, Inc., *Summary of Operations: Truck Stop Electrification Facilities on the New York. State Freeway,* prepared for the New York State Energy Research and Development Authority, January 2005, Section 5. As cited in Moving Cooler.

TLU-6: Low carbon fuel standard

This strategy is designed to implement market-based programs to reduce the carbon intensity of on-road fuels through the use of lower-carbon alternatives (e.g. natural gas, electricity, biofuels, and hydrogen). This will be accomplished through the adoption of Low Carbon Fuel Standard (LCFS) within the study region. The scenarios used for analysis assume:

- 2020: No reductions (assume measure will not be implemented by this date).
- 2040: Reduction in total on-road fuel emissions in region by 10%.
- 2050 (stretch): Reduction in total on-road fuel emissions in region by 15%.

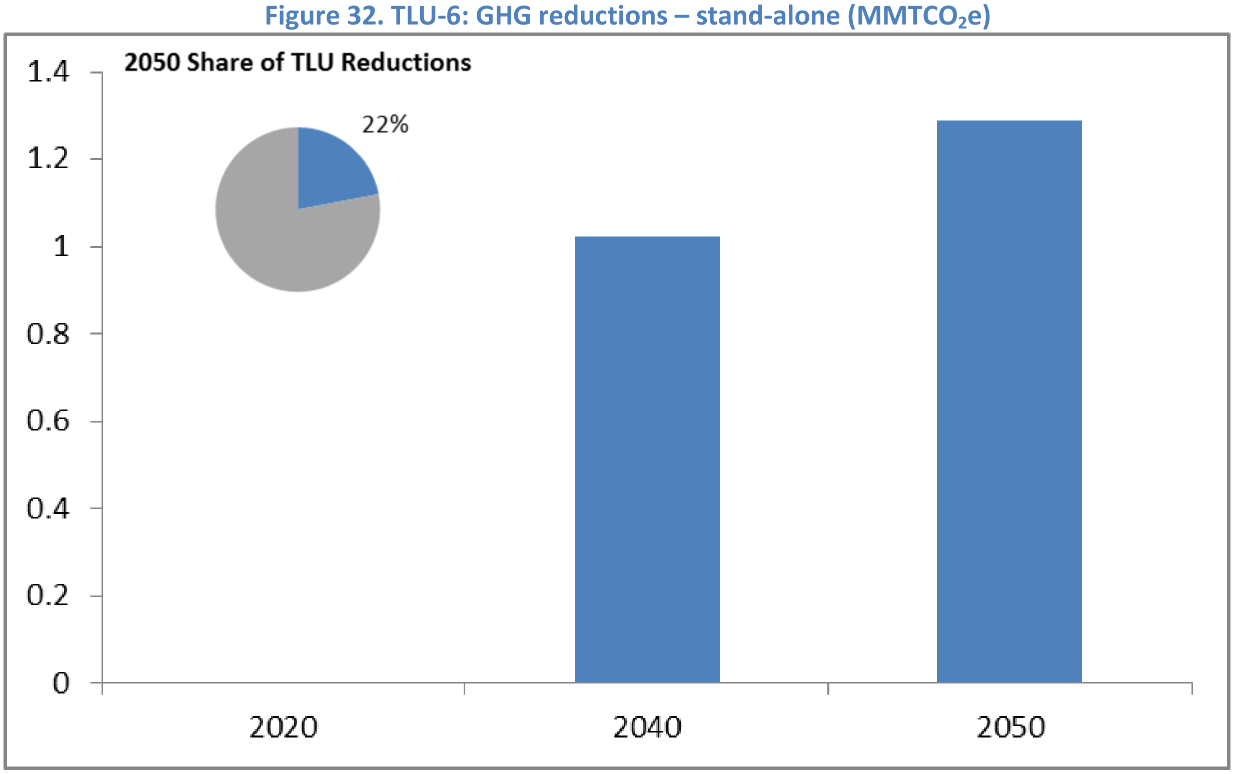
GHG Results

The adoption of a Low Carbon Fuel Standard results in large emissions reductions in the National Capital Region by 2040 since it affects motor fuels, which are used by all vehicle types. Table 58 shows estimated GHG reductions:

Table 58. Greenhouse Gas Reductions for TLU-6: Low Carbon Fuel Standard

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (strategy alone)	0	1.02	1.29

Figure 32. TLU-6: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

- The analysis limited consideration to fuels that would displace diesel vehicles because the primary options for compliance in the gasoline pool include a) ethanol feedstock switching (e.g., corn to sugarcane) and b) zero emission vehicles.
    - Feedstock switching helps achieve compliance on a lifecycle basis, but does not achieve GHG reductions on a tailpipe basis.
    - TLU-3 considers the deployment of ZEVs; including them here would be duplicative.
- ICF reviewed compliance scenarios developed by Northeast States for Coordinated Air Use Management (NESCAUM) in a 2009 analysis of a Northeast/Mid-Atlantic Clean Fuels Standard.[22] NESCAUM evaluated strategies that included a 5% carbon intensity reduction and a 15% carbon intensity reduction. The analysis used the latter for the 2040-Stretch scenario and the average of the two scenarios to develop the scenario for the 10% target in this analysis.
- The analysis focused on the deployment of diesel alternatives – including biodiesel and renewable diesel – and natural gas in the NESCAUM analysis. ICF looked at these fuels as a percentage of overall diesel demand. The analysis used these percentages and assumed that they would make up the same share of VMT across various vehicle types.
- The analysis considered the following vehicle types for biodiesel and natural gas: Transit bus, School bus, Combination Long-haul Truck, Combination Short-haul Truck, Intercity Bus, Light Commercial Truck, Motor Home, Refuse Truck, Single Unit Long-haul Truck, Single Unit Short-haul Truck. ICF has VMT and emission factors for each truck type included in the analysis.
- As noted elsewhere, biodiesel is assumed to have zero GHG emissions at the tailpipe. The GHG emission reductions attributable to biodiesel were then calculated as the product of the percentage of VMT for biodiesel used in trucks (corresponding to the blend percentage assumed) and the emission factors for the corresponding truck type.
- Natural gas is a non-zero GHG emissions solution. The analysis used emission factors reported by Argonne National Laboratory for natural gas vehicles.[23]
- The emission reductions were calculated as the difference between the diesel vehicle emission factors and the natural gas vehicle emission factors multiplied by the corresponding share of VMT.

Potential Co-Benefits

The primary co-benefit of a low carbon fuel standard strategy is reductions in criteria air pollutants. Additionally, there may be some regional jobs benefits associated with increased local production and distribution of alternative fuels.

[22] Analysis is available online at: http://www.nescaum.org/topics/clean-fuels-standard
[23] H. Cai, A. Burnham, M. Wang, W. Hang, A. Vyas. The GREET Model Expansion for Well-to-Wheels Analysis of Heavy-Duty Vehicles, May 2015. Available online at https://greet.es.anl.gov/publication-heavy-duty.

Table 59. Co-Benefit Results for TLU-6: Low Carbon Fuel Standard

Co-Benefit	Description of Co-Benefit
Criteria Air Pollution	Compared to conventional diesel fuel, use of biodiesel is generally found to reduce emissions of VOCs, carbon monoxide (CO), and particulate matter (PM); but to increase NOx emissions.
Economic Vitality, Jobs, Equity	There may be some economic benefits associated with increased local production and distribution of alternative fuels.

Costs

As a regulatory measure, public sector costs for implementing a low carbon fuel standard are very low. Costs borne on the private sector and consumers are somewhat difficult to estimate given the variety of ways in which a low carbon fuel standard could affect.

Table 60. Costs for TLU-6: Low Carbon Fuel Standard

Level	Public Sector Costs	Private Sector/Other Costs
Low (Under $50 million)	Regulatory development, compliance oversight	Incremental costs for consumers for 11 participating states is estimated at $4 billion to $19.5 billion over 10 years (NESCAUM).

TLU-7: Enhancing system operations

This strategy includes a wide array of strategies to improve the operational performance of freeways and arterial/collectors, including a) integrated corridor management on freeway and major arterial corridors; b) ramp metering; c) signal retiming; d) the use of roundabouts; e) intersection efficiency improvements; f) targeted roadway bottleneck improvements; g) increased adoption of eco-driving practices by drivers; and g) the use of connected and autonomous vehicles.

Strategy scenarios analyzed include:

- 2020: 20% of drivers adopt eco-driving practices (based on public campaigns); region wide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).
- 2040: 80% of drivers adopt eco-driving practices (based in part via connected vehicle/automated vehicle technologies); regionwide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).
- 2050 (stretch): 100% of drivers utilize eco-driving practices (via connected vehicle/automated vehicle technologies); regionwide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).

This analysis did not explicitly examine highway bottleneck improvements, but these improvements might be part of the overall improvement in vehicle operating conditions considered in these scenarios.

As one of the most congested urban areas in the nation, the roadway network in the National Capital Region already has extensive congestion, with about 85.1 million gallons of wasted fuel in traffic congestion in 2012;[24] this is equivalent to about 0.76 $MMTCO_2e$, or 3.4% of on-road transportation GHG emissions. Traffic congestion is projected to grow considerably worse under BAU conditions. According to MWCOG's travel forecasting, even with investments included in the CLRP, the share of VMT on congested roadways region-wide in the AM peak is projected to grow by 42% from 2015 to 2040.[25] Consequently, strategies to reduce traffic congestion and reduce vehicle idling in delay conditions (due to high traffic volumes, incidents, weather conditions, or other factors) can play a role in potentially reducing GHG emissions. Moreover, studies demonstrate that smoother driving, via less aggressive acceleration and deceleration, improve vehicle fuel economy and reduce GHG emissions, even when average speeds do not change.

It should be noted that many operational strategies are already in place or anticipated in BAU conditions, so this measure is associated with additional strategy deployments. For instance, benefits from retiming/optimization are limited to the extent that corridor optimization is already in place. Based on MWCOG's most recent survey, the majority (76%) of the region's traffic signals are already being re-

[24] Texas Transportation Institute, Urban Mobility Study.
[25] Transportation Planning Board, *Constrained Long Range Transportation Plan*, performance information available at: https://www.mwcog.org/clrp/performance/congestion.asp

timed/optimized or checked on a frequent basis.[26] Moreover, it should be noted that strategies that reduce vehicle travel times, such as bottleneck relief, will often encourage some additional vehicle trip-making (referred to as "induced travel") and may encourage more auto-oriented development, which can decrease some of the GHG benefits.

GHG Results

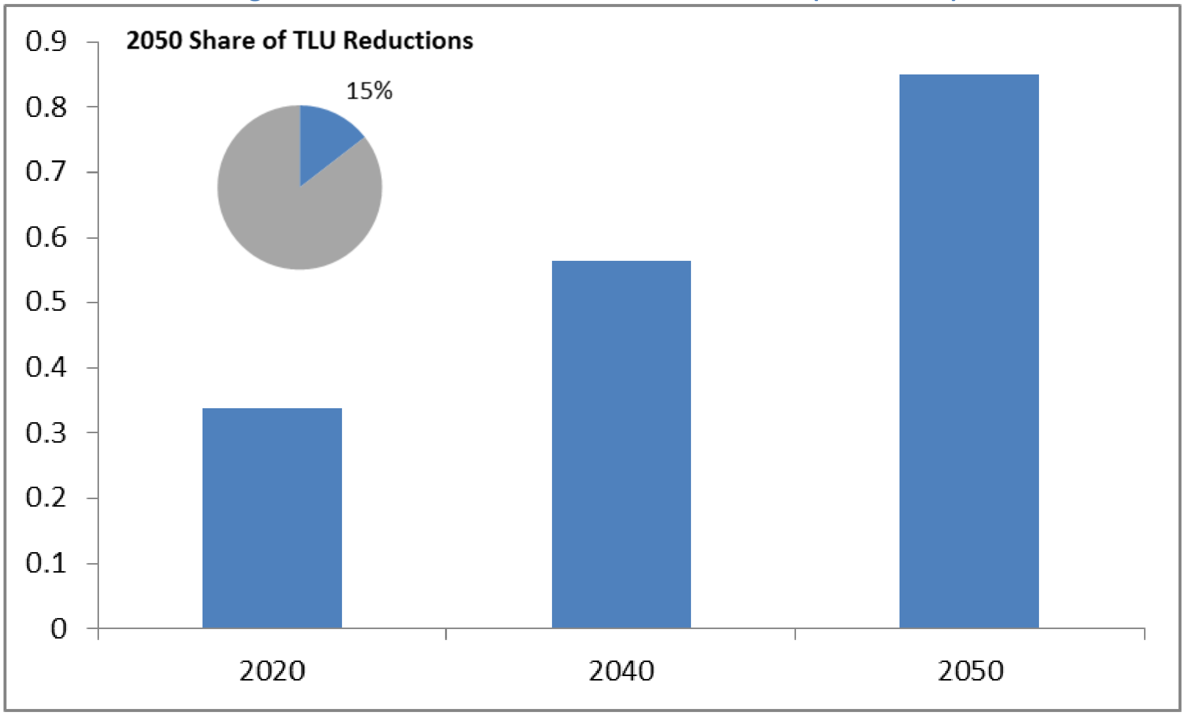
The various strategies encompassed under this measure provide significant reductions in GHG emissions, the majority of which comes from eco-driving/connected vehicles/autonomous vehicles. These significant effects occur in part because this strategy affects nearly all vehicles, and fuel economy improvements are estimated to occur across all travel activity (e.g., freeways, arterials, etc.), rather than affecting only a small share of vehicles or trips like several other strategies. The effectiveness of the strategy is somewhat diminished when combined with other strategies that reduce VMT and those that add electric vehicles to the fleet.

Table 61. Greenhouse Gas Reductions for TLU-7: Enhancing System Operations

Summary Metric (MMTCO$_2$e)	2020	2040	2050
GHG Reductions (strategy alone)	0.34	0.56	0.85
GHG Reductions (with VMT and vehicle / fuel strategy reductions)	0.33	0.44	0.57

[26] MWCOG, "Briefing on Traffic Signal Timing/Optimization in the Washington Region," February 19, 2014, available at: http://www.mwcog.org/uploads/committee-documents/al1ZXFpb20140212133426.pdf

Figure 33. TLU-7: GHG reductions – stand-alone (MMTCO2e)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

Analyzing the impacts of enhancing transportation system operations is complex due to the wide array of strategies and impacts that these strategies have on travel, including potential changes in trip-making, mode choice (i.e., via improved traveler information), and route choice, and resulting impacts on travel speeds and operating conditions at different times of the day. Consequently, analyzing the impacts of operations strategies in a somewhat rigorous manner would require simulation modeling to address changes in congestion, travel speeds, and travel demand in response to an array of bottleneck and technology strategies, as well as impacts of strategies that affect travel time reliability, that were beyond the scope of timing and analysis in this study. Moreover, EPA's MOVES model does not readily accommodate analysis of strategies that shift travel speed and changes in vehicle accelerations and decelerations, without considerable detail in assumptions regarding changes in vehicle travel and vehicle operating profiles. Consequently, this study relied largely on applications of figures from the literature on the changes in vehicle operating fuel efficiency associated with these strategies. Specifically, the analysis involved two components:

1) **Highway operations strategies and bottleneck reduction** – First, it should be noted that while many past studies have documented the positive effect of operations strategies on specific corridors or facilities immediately after implementation (reductions in delay and emissions), few studies have addressed the longer term impacts of these strategies, or addressed the complex relationships between vehicle operations improvements and potential induced travel. Based on a review of the literature, the analysis estimated the effects of these strategies (which reduce

vehicle delay and improve travel speeds) based on a recent study completed for the Federal Highway Administration (FHWA), which involved simulation modeling of several operational improvement strategies (ramp metering, incident management, active signal control, and active transportation demand management – meant to cover multiple improvement systems including lane control, queue warning, junction control, and traveler information) using a modeling framework developed by the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area.[27] The modeling framework included an activity-based travel model, application of the UrbanSim land use model to incorporate reliability into long-term travel decisions, and postprocessors to refine the speed estimates, calculate emissions using MOVES, and produce reliability statistics. The results of this modeling indicated that a combined strategy of ATDM and signal control, even with an increase in VMT, reduced in a reduction in regional GHG emissions, due to the more significant reduction in vehicle hours of travel and delay time. This study is the only comprehensive modeling analysis of operational strategies identified from the literature scan, and the application in the San Francisco Bay Area, which is a congested metropolitan region, suggested that these results would be reasonable to apply to the metropolitan Washington, DC region. Key regional metrics from the study (vehicle hours of travel, vehicle miles of travel, and carbon dioxide emissions) – from the near-term and longer-term analysis application are shown below in Table 62.

Table 62. ATDM + Signal Control, Percentage Change from Base, AM Peak Period Performance Results

Year	VHT	VMT	CO_2
2010	-4.636%	+1.229%	-0.600%
2015	-8.839%	+2.295%	-1.647%

Source: FHWA, "Travel and Emissions Impacts of Highway Operations Strategies," Final Report, dated March 2014, prepared by Cambridge Systematics (publication forthcoming).

It should be noted that based on these simulations, the VMT increase during the peak period was partially offset by VMT reduction during the off-peak period, suggesting that some travelers shift their time of travel to the peak period in response to the improved travel times and system performance.

The research team applied the -1.647% reduction in CO_2 emissions from the MTC study to the base CO_2 emissions in the National Capital Region estimated in the peak periods (AM and PM) for each analysis year (2020, 2040, and 2050). The methodology assumed no change in CO_2 emissions from operational strategies during off-peak periods when there is generally limited traffic congestion. This assumption may underestimate the impacts of operational strategies, since smarter traffic signals can reduce unnecessary idling at traffic signals during off-peak periods and several operations strategies affect non-recurring congestion (i.e., faster incident

[27] FHWA, "Travel and Emissions Impacts of Highway Operations Strategies," Final Report, dated March 2014, prepared by Cambridge Systematics (publication forthcoming).

response). However, given that many of these strategies are already in place in the metropolitan Washington region, this was believed to be a reasonable assumption.

2) **Eco-driving and Connected Vehicle/Autonomous Vehicle Applications that Smooth Accelerations and Decelerations)** – The effects of changes in driving behavior to reduce aggressive starts and stops was analyzed separately. Despite increasing interest in studying the impact of smart driving strategies on fuel efficiency, there is still no agreed upon estimate of the average fuel efficiency improvement that can be achieved by smart driving. A wide range of studies on “smart driving”, which refers to a set of strategies and techniques that maximize motor vehicle fuel efficiency by improving driving habits and vehicle maintenance, suggest that drivers can reduce their fuel consumption and associated GHG emissions through smart driving principles by 0 to 18%. However, the most recent and rigorous studies reviewed have demonstrated average fuel savings of 2% to 4%.[28] For instance, a 2013 study by Kurani et al. managed to overcome some previous shortcomings of other studies of ecodriving by conducting a study of 118 drivers that reside along Interstate 80 from San Francisco, CA to Reno, NV.[29] Kuani et al, collected one month of baseline information and one month of feedback from three types of in-vehicle fuel efficiency devices that conveyed information to drivers. The study achieved a statistically significant average reduction in fuel consumption of 2.7%, with the most efficient of the three displays producing a 2.9% decrease in fuel consumption. For this analysis, a 3% improvement in fuel economy for both passenger vehicles and medium/heavy-duty trucks was assumed; the percentage improvements to school buses or transit buses was not applied, given that these vehicles generally operate in the unique circumstance of having many stops and starts to pick up passengers (these vehicles make up a small share of total CO_2 emissions from motor vehicles, so the impact of this exclusion is minor). However, a 3.5% improvement for the 2050 case was applied to account for more significant enhancements enabled by connected vehicle/autonomous vehicle technologies. It should be noted that these assumptions are considerably lower than those applied in the previous MWCOG “What Would It Take?” study.

The impacts of eco-driving/changes in vehicle technologies that help drivers to travel smoother and optimize fuel economy were assumed to be additive to impacts associated with traffic control and related system operations strategies. The analysis does not specifically account for bottleneck reduction projects, due to the need to identify and model individual projects in order to gain a reasonable estimate of impacts. However, the assumed regional fuel consumption benefits of operational strategies may account for a combination of operational and bottleneck reduction projects.

Assumptions

The assumptions regarding induced travel have important implications on the results. The *Moving Cooler* report brought this issue to the forefront, as the induced travel estimates in that study essentially

[28] ICF International, “Smart Driving White Paper,” prepared for Metropolitan Transportation Commission, October 2014.

[29] Kurani, K., Stillwater, T., and Jones, M., 2013. *ECODRIVE I-80: A LARGE SAMPLE FUEL ECONOMY FEEDBACK FIELD TEST: FINAL REPORT.* Institute of Transportation Studies Report: ITS-RR-13-15. Available at http://www.fueleconomy.gov/feg/pdfs/EcoDrive%20I-80.pdf

offset all of the estimated GHG emissions reductions associated with highway operations strategies, and estimated a net increase in GHG emissions over the long-term (2050) due to induced travel. *Moving Cooler* used short- and long-run elasticities developed for the FHWA's Highway Economic Requirements System (HERS), and applied these elasticities to improvements in travel times estimated for strategies based on the literature. However, there is a significant amount of uncertainty associated with the application of elasticities to operations strategies in particular. For instance, while operations strategies may increase demand for vehicle travel by reducing travel times, some strategies such as traveler information may reduce travel demand by allowing travelers to make different choices for destinations, modes, or forego a trip altogether if they are aware of congestion. In addition, travel time savings from operations improvements are generally modest, and it is uncertain whether travelers respond in relation to small changes in travel times; the traveler response to strategies that reduce nonrecurring congestion and improve travel time reliability is also uncertain. This analysis used assumptions from the MTC simulation modeling, as described above, which accounted for both improvements in travel times and increases in VMT when calculating overall CO_2 emissions effects. No induced traffic would be expected to occur due to ecodriving practices, which generally reduce vehicles accelerations and decelerations but do not significantly affect overall vehicle speeds or travel times.

The analysis assumes nearly universal application of ecodriving techniques due to the introduction of semi-autonomous or autonomous vehicles to the fleet by the 2040-2050 time-frame. There is a high level of uncertainty regarding the implications of semi-autonomous/autonomous vehicles on travel demand. Moreover, while in the short-term, ecodriving campaigns, modeled on the Commuter Connections campaign, could be implemented, the long-term effects of introduction of autonomous vehicles to the fleet may happen with relatively limited state, regional, or local policies, so might ultimately be considered a "federal policy" action (although investments in vehicle-to-infrastructure technologies could help support adoption).

Potential Co-Benefits

A wide variety of co-benefits are associated with system operation improvements, as noted in Table 63 below. These benefits include safety, reliability, congestion reduction, criteria air pollutant reduction, economic vitality, mobility, accessibility, and weather resilience. It should be noted that additional highway capacity for bottleneck projects may increase impervious surface area and might increase runoff. Taken together, the associated strategies could have broad impacts.

Table 63. Co-Benefit Results for TLU-7: Enhancing System Operations

Co-Benefit	Description of Co-Benefit
Safety	Operational improvements, connected vehicle technologies, and incident management can reduce fatalities and injuries at high crash locations. For instance, secondary crashes can be reduced from incident management, which clears crashes more quickly.
Reliability	Improving travel time reliability is a key benefit of strategies such as incident management, road weather management, and active traffic management.

Co-Benefit	Description of Co-Benefit
Congestion Reduction	Bottleneck relief and operational improvements are generally designed with a primary benefit of congestion relief.
Criteria Air Pollution	Improved roadway operations generally reduces emission of criteria pollutants by reducing the share of traffic traveling in very low speed congested conditions and idling while stuck in traffic delay, which are associated with the highest rates of emissions. Speed-emissions curves vary by pollutant. Ecodriving practices also have been found to reduce criteria pollutant emissions.
Economic Vitality, Jobs, Equity	Improving system operations reduces time stuck in congestion, which can be a barrier to job growth. By enabling faster travel speeds, system operations strategies can increase access to jobs.
Mobility	Operational improvements allow the roadways to run more efficiently, thus improving drivers' mobility, allowing them to more easily get from one destination to another.
Accessibility	Access may be improved to the extent that these strategies provide improved information to enable travelers to make better decisions about travel modes and routes.
Weather Resilient	Enhanced road weather management and incident management can help the region to adapt to increases in severe weather frequency.
Chesapeake Bay/ storm water	Bottleneck relief projects (new highway capacity) may increase impervious surfaces, leading to increased runoff.

Costs

Operational strategies are generally low cost, although they can take on a wide array of forms. Bottleneck relief projects can vary significantly based on the size and scope of the bottleneck improvement project; costs of several million dollars to upwards of $50 million dollars are not uncommon (this analysis did not directly analyze bottleneck improvement projects, but generally assumes that the range of benefits captured in this analysis may encompass a number of relatively small bottleneck improvement projects, such as intersection improvements, beyond those already covered in the CLRP (not major highway expansion projects)).

An ecodriving campaign could be comparable in cost to a specific campaign under the Commuter Connections program. The development of the campaign can draw from existing resources developed by other public agencies.[30] Ecodriving techniques and smart driving messages also could also be incorporated into driver education materials by Departments of Motor Vehicles in Maryland, Virginia, and the District. Another component could be a rebate program for in-vehicle fuel efficiency meters. For example, MTC in the San Francisco Bay Area is conducting a pilot to offer a $25-$100 discount to consumers who purchase an OBD-connected after-market smart driving device. As more vehicles

[30] For example, Drive Clean Texas provides their print advertisements, PSAs and videos, children and teachers materials, and presentation materials free of charge at this link: http://drivecleantexas.org/resources.php. Likewise, North Carolina DOT provides their Drive Green, Save Green posters, and videos at http://www.ncdot.gov/travel/drivegreen/.

directly incorporate ecodriving displays and autonomous vehicles enter the fleet, these program elements are expected to no longer be needed over the longer-term 2040-2050 period.

Table 64. Costs for TLU-7: Enhancing System Operations

Level	Public Sector Costs	Private Sector/Other Costs
Low (under $50 million) to Medium ($50 million to $500 million)	Maryland Climate Action Plan estimated costs of $2.36 million from 2010-2020 associated with corridor/regional operational improvements; costs associated with outreach to promote ecodriving; costs associated with installing, operating, and maintaining V21 infrastructure.	Savings due to reduced fuel consumption and vehicle operating costs

TLU-8: Reduce speeding on freeways

This strategy is designed to provide greater enforcements of speed limits on freeways in the metropolitan Washington, DC region. Vehicle fuel economy degrades considerably at speeds above 55 mph, so freeway speed reduction has been proposed as a viable GHG reduction strategy in national studies. According to the Department of Energy, going from 60 to 70 mph degrades vehicle fuel economy by 13.6%, and going from 50 to 70 mph degrades fuel economy by 24.5%. In metropolitan Washington, DC region, very few highways operate at posted speeds above 55 mph, largely outside of the urbanized area (e.g., a portion of I-95 in Maryland beyond the Capital Beltway, a portion of I-270 beyond Clarksburg), as well as the Express Lanes that operate along the Capital Beltway and I-95 in Virginia. Consequently, this strategy would be implemented through increased speed enforcement, which may include more speed patrols and/or electronic monitoring of freeway speeds.

Scenario assumptions are aggressive and generally are designed as a maximum impact, assuming that all general purpose freeway travel occurs at no more than 57.5 mph (which is the start of the 60 mph speed bin in MOVES):

- 2020: One-third of freeway speeding eliminated (above 57.5 mph)
- 2040: All freeway speeding eliminated (through automated enforcement/autonomous vehicles)
- 2050: All freeway speeding eliminated (through automated enforcement/autonomous vehicles)

GHG Results

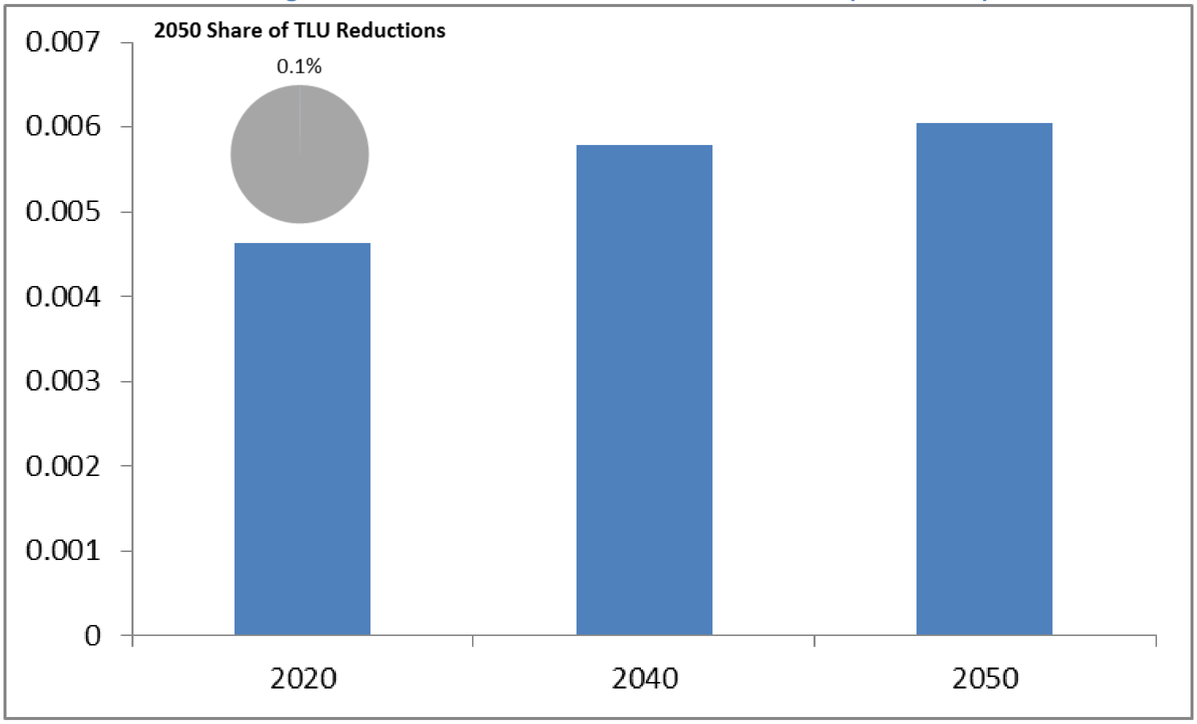
This strategy results in relatively small effects on GHG emissions. On the one hand, approximately 41 to 42% of all regional VMT occurs on freeways and this strategy affects all vehicle types traveling on those freeways. However, only a portion of the vehicles on those freeways are traveling at speeds above 57.5 mph, once accounting for congested travel conditions; for instance, about 20% of the time spent in urban freeway traffic is at speeds of about 60 mph or greater during peak hours, although this share is higher during off-peak hours.[31] The GHG reductions from this strategy decline considerably over time as the vehicle fleet gets more efficient and CO_2 emissions rates at all speeds decline.

Table 65. Greenhouse Gas Reductions for TLU-8: Reduce Speeding on Freeways

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (strategy alone)	0.005	0.006	0.006
GHG Reductions (with VMT reduction and vehicle/fuel strategies)	0.004	0.005	0.004

[31] Based on MOVES input files provided by MWCOG, for Prince George's County urban freeways during the 6 PM hour, about 20% of passenger car operating hours is in the 60 mph speed bin (57.5-62.5 mph) or higher speed bins.

Figure 34. TLU-8: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

The analysis was conducted using the following steps:

1) EPA's MOVES model was used to conduct 6 county-level simulations for Prince George's County. Prince George's County was selected because it was the county with the largest amount of freeway VMT in the region (26% of all freeway VMT), or which 95% is classified as urban. First, a business as usual case was run for 2012, 2020, and 2040 with all inputs as provided by MWCOG. Then the same runs were conducted with all average speed bins >57.5 mph on urban freeways removed and reallocated to the 55 mph bin. The running exhaust emissions factors for urban freeways resulting from these analyses were then derived and compared to estimate a reduction in the running emissions rate on the freeway network due to the limitation of high speed travel; these reductions range from 0.66 g/mi CO_2e in 2020 (a 0.17% reduction in the overall freeway emissions rate) to 0.23 g/mi CO_2e in 2040 (a 0.08% reduction in the freeway emissions rate).
2) Then the reduction in the GHG emissions rates on freeways was applied to the total VMT on freeways within the National Capital Region to calculate the reduction in GHGs on the freeway network. This figure may overestimate the impacts of the strategy slightly, since there are portions of highways with 65 mph speed limits, where one would not expect the all vehicles to drop to 57.5 or below.

Assumptions

This analysis is predicated on the assumption that freeway speeding can be limited through better speed enforcement (electronic or other means).

Potential Co-Benefits

The primary co-benefit of this strategy include safety improvements, since speeding is associated with fatal and non-fatal crashes. Although reducing speed limits would increase travel time, this strategy does not propose to reduce all speed limits to 55 mph, only to enforce existing laws, so the analysis did not consider an increase in travel time for those who are speeding to be a dis-benefit.

Table 66. Co-Benefit Results for TLU-8: Reduce Speeding on Freeways

Co-Benefit	Description of Co-Benefit
Safety	Less speeding will improve traffic safety, and is expected to reduce both fatalities and injuries.
Criteria Air Pollution	Limiting high speeds had mixed effects on criteria air pollutants, based on the MOVES analysis conducted.

Criteria pollutant emissions showed mixed results based on the MOVES analysis conducted, with NO_X and VOC being reduced while PM2.5 is estimated to increase.

Table 67. Criteria Air Pollutant Emissions Change for TLU-8: Reduce Speeding on Freeways

Year	NOx (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	-1.02-	+0.13	+6.60
2040	-0.58-	-0.02	+1.70
2050	NE	NE	NE

NE = Not Estimated

Costs

Reducing speeding will require additional highway speed enforcement, whether through deployment of additional law enforcement staff or electronic monitoring. Motorists ultimately will save money through reduced fuel consumption.

Table 68. Costs for TLU-8: Reduce Speeding on Freeways

Level	Public Sector Costs	Private Sector/Other Costs
Low (under $50 million) to Medium ($50 million to $500 million)	Costs primarily associated with increased enforcement of speed limits. A study by MTC estimated costs of increased enforcement of $260 million	Savings due to reduced fuel consumption and vehicle operating costs

TLU-9: Travel Demand Management

This strategy encompasses a wide range of strategies designed to reduce vehicle travel by shifting motorists to higher-occupancy modes (carpools, vanpools), public transit, walking, and bicycling, as well as telecommuting. These strategies include reducing the availability of free parking in activity centers by imposing parking impact fees and parking caps and create parking pricing for on- and off-street parking, and related strategies to encourage park-and-ride usage. They also include incentives to encourage carpooling and ridesharing, non-motorized modes of commuting, and telecommuting through the use of programs that establish: a) telecommuting opportunities; b) carpool incentive programs; c) vanpool incentive programs, and; d) employer outreach. Finally the measures includes ordinances that require employers to offer parking cash out and transit benefits.

- 2020: Expand employer-based incentives (subsidies of $50 per month for 40% of employers); 50% of parking in activity centers is priced at an average of $8 per day for work trips.
- 2040: Expand employer-based incentives (subsidies of $50 per month for 80% of employers); 90% of parking in activity centers is priced at an average of $8 per day for work trips.
- 2050 (stretch): Expand employer-based incentives (subsidies of $80 per month for 100% of employers); 100% of parking in activity centers is priced at an average of $8 per day for work trips.

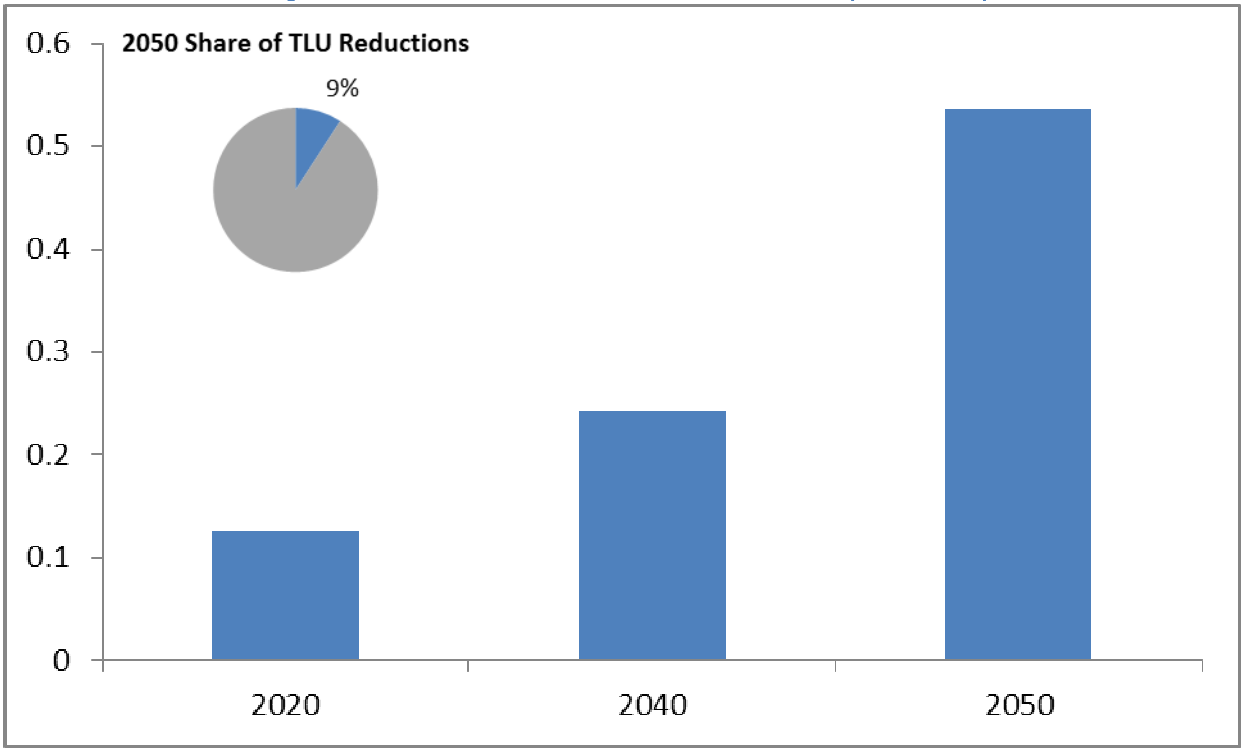
GHG Results

Travel demand management strategies result in notable reductions in VMT, due in part to the significant level of employer subsidies assumed and high level of parking pricing assumed in the stretch scenario. As shown in Table 69, this strategy is estimated to reduce passenger vehicle VMT up to 7.5% in the stretch scenario. Given that work trips make up less than a quarter of all vehicle trips, these reductions appear very high, but the inclusion of parking pricing affects all trips within the activity centers. Parking is a key determinant of travel choice, and an estimated $8 daily charge is significant. Given that many activity centers are located in suburban settings where parking is typically not priced, these assumptions are very aggressive in the 2040 and 2050 cases.

Table 69. Greenhouse Gas Reductions for TLU-9: Travel Demand Management

Summary Metric	2020	2040	2050
Vehicle Miles Traveled, passenger vehicles (percent change)	-0.9%	-2.4%	-5.3%
VMT reduced (millions, annually)	329	986	2,173
Transit ridership (percent change)	+2.3%	+7.0%	+38.5%
GHG Reductions (MMTCO$_2$e) – strategy alone	0.13	0.24	0.54

Figure 35. TLU-9: GHG reductions – stand-alone ($MMTCO_2e$)



In comparison, TDM strategies typically were estimated to reduce light-duty vehicle travel by 0.4% to 2.8%, based on several regional analyses conducted for EPA.[32] These impacts are showing more significant reductions based in large part on the significant parking pricing component.

Overview of Methods and Key Assumptions

Data, Models, and other tools used

The TRIMMS sketch planning model was used to estimate VMT reductions. The resulting percentage reduction in VMT for each analysis scenario was then applied to the passenger vehicle VMT estimates provided by MWCOG for the corresponding year.

Assumptions

Based on data from MWCOG's State of the Commute Survey, the analysis assumed that 38% of employees in the region have access to transit and vanpool subsidies of $50 per month from their employers in the business as usual scenario. For each strategy analyzed, the percent of employees was used as a proxy for percent of employers. The dollar amount of subsidies and percent of covered employees was increased according to the parameters in the Measure Description. To simplify the analysis, the analysis assumed that employees use the subsidy for transit, and that each employee makes 40 transit trips (5 days per week*4 weeks per month*2 trips per day) per month. Average transit trip costs were sourced from MWCOG's regional travel demand model.

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[32] U.S. Environmental Protection Agency, "Estimating Emission Reductions from Travel Efficiency Strategies: Three Sketch Modeling Case Studies," prepared by ICF International, June 2014.

The analysis assumed that parking in activity centers is currently priced at an average $2.50 per trip, based on data from MWCOG's regional travel demand model. The analysis assumed that 40% of parking in activity centers is currently priced. This assumption was adapted from parking surveys conducted in other regions, as MWCOG does not have any data on the percent of parking in the region that is priced versus free. For each strategy analyzed, the target parking charge per day was assumed to be the average charge per trip. The parking charge and percent of parking that is priced was increased according to the parameters in the Measure Description.

The analysis assumed that all mode shift to transit induced by this strategy is absorbed by existing transit capacity or zero emissions vehicles, so have not calculated corresponding increases in transit vehicles emissions.

Potential Co-Benefits

Co-benefits from park-and-ride and HOV investments, parking management, and transportation demand management are associated with reliability, congestion reduction, mobility, accessibility, weather resilience, and the Chesapeake Bay. The strategy incentivizes alterative commute modes, such as carpool, transit, and telework and dis-incentivizes the use of single occupancy vehicles. This results in reduced GHG emissions as well as the co-benefits listed in Table 70.

Table 70. Co-Benefit Results for TLU-9: Travel Demand Management

Co-Benefit	Description of Co-Benefit
Congestion Reduction	Demand management is designed to reduce VMT, and thereby reduce traffic congestion; strategies that encourage telecommuting, transit, and other alternatives to driving will help in managing congestion
Criteria Air Pollution	Emissions of all pollutants should be reduced due to reduced VMT. Congestion relief may yield additional benefits.
Economic Vitality, Jobs, Equity	Voluntary program support and incentives are viewed positively by businesses, but *requirements for employer trip reduction may be viewed negatively by businesses, Charging for parking may also be viewed negatively from an economic development and business perspective.*
Mobility	Mobility is generally improved though increased promotion, incentives, and support for travel options, such as transit, ridesharing, walking, and biking. However, parking prices can limit some mobility by drivers.
Weather Resilient	Employer-based programs to support telecommuting, flexible work hours, and ridesharing can help support business activity during severe weather.
Chesapeake Bay/ storm water	Parking management and pricing strategies are likely to result in a reduction in parking supply and may reduce impervious surfaces.

This strategy is also anticipated to yield reductions in criterial air pollutant emissions, associated with the reduction in vehicle trips and VMT.

Table 71. Estimated Criteria Pollutant Emissions Benefits for TLU-9 – Strategy Alone

Year	Nox (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	0.24	0.27	5.33
2040	0.15	0.33	10.44
2050	0.33	0.73	23.00

Note: These estimates account for changes in emissions rates forecast in the MOVES2014 model through 2040, but do not account for further changes in emissions rates that may occur over this period due to other strategies that alter vehicle fuel economy and operating conditions or that may occur between 2040 and 2050.

Costs

Costs for implementing TDM support programs can vary depending on the type of program (outreach, incentives, or mandate), but are generally relatively small. Parking pricing will generate revenues, which can be utilized for multimodal travel improvements and demand management activities.

Table 72. Costs for TLU-9: Travel Demand Management

Level	Public Sector Costs	Private Sector/Other Costs
Low (less than $50 million)	Incentive costs for TDM strategies Public outreach campaign costs Parking pricing can generate revenues that can be used for transportation improvements and demand management activities. However, increased transit capacity would likely be needed.	Parking pricing will increase costs on drivers. Employer incentives lower the costs of using transit or other options for commuters, but businesses will bear these costs (some of which may be decreased by reducing parking supply).

It should be noted that by reducing VMT and motor fuel consumption, TDM strategies will yield lower fuel tax revenue, which is a significant source of funding for transportation investments, including transit enhancements, highway projects, bicycle and pedestrian projects, and on-going maintenance and operations of transportation systems. Moreover, the significant level of increase in transit ridership beyond the base assumption for 2050 suggests that additional transit capacity, beyond what is currently assumed in the CLRP, would be necessary to accommodate the shift to increased transit use. Increased transit services may entail significant additional costs.

TLU-10: Transit enhancements

This strategy is designed to increase the share of transit trips through increased or improved services. Strategies may include: a) increased circulator buses; b) enhanced commuter bus services; c) real-time bus schedule information; d) transit signal priority improvements; e) bus rapid transit, streetcar, or light rail improvements; f) expanded metrorail/commuter rail; g) bus stop improvements; h) schedule coordination between transit agencies; i) permitting buses on highway shoulders; j) transit access improvements; k) establishing dedicated transit lanes; and l) bus infrastructure commitments. This analysis focused on transit enhancements that reduce transit travel times and reliability, as well as accessible traveler information and schedule improvements to reduce wait-times (these reductions in transit travel times could occur through expansion of rapid transit services to new areas).

- 2020: Reduce transit travel times by 10% and reduce headways (wait time) by 10%.
- 2040: Reduce transit travel times by 15% and reduce headways (wait time) by 15%.
- 2050 (stretch): Reduce transit travel time by 20% and reduce headways (wait time) by 20%.

GHG Results

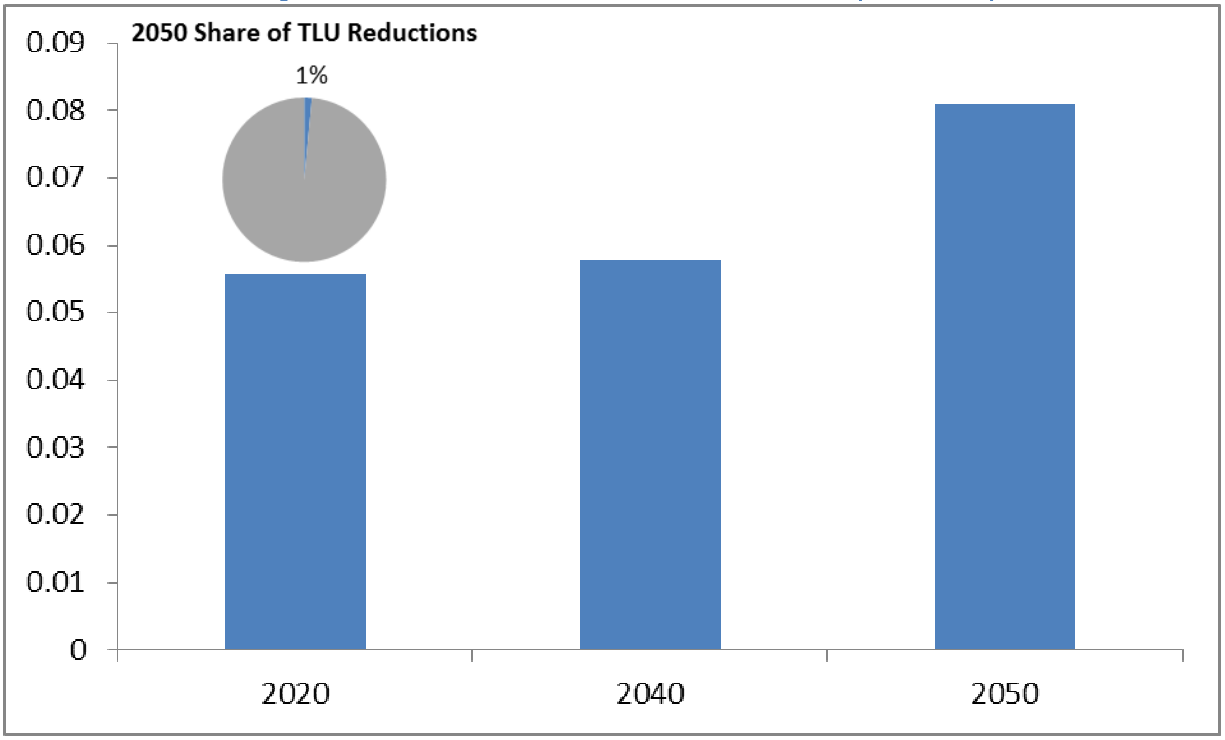
Transit service improvements generally have small to moderate effects on vehicle travel and greenhouse gas emissions. Overall, according to the CLRP, transit makes up about 7% of daily trips in 2015, and this figure is expected to remain relatively consistent at around 7% in 2040 under the BAU scenario.[33] Estimated VMT and GHG reductions, and transit ridership increases, are shown in the table below.

Table 73. Greenhouse Gas Reductions for TLU-10: Transit Enhancements

Summary Metric	2020	2040	2050
Vehicle Miles Traveled, passenger vehicles (percent change)	-0.4%	-0.6%	-0.8%
VMT Reduced (millions, annually)	146	235	329
Transit ridership (percent change)	2.2%	3.4%	4.7%
GHG Reductions ($MMTCO_2e$) - strategy alone	0.06	0.06	0.08

[33] See: https://www.mwcog.org/clrp/performance/travel_demand.asp

Figure 36. TLU-10: GHG reductions – stand-alone (MMTCO$_2$e)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

The TRIMMS sketch planning model was used to estimate VMT reductions. The resulting percentage reduction in VMT for each analysis scenario was then applied to the passenger vehicle VMT estimates provided by MWCOG for the corresponding year.

Assumptions

- Average transit trip times and vehicle wait times sourced from MWCOG's regional travel demand model.
- For each strategy analyzed, average travel times were reduced according to the Measure Description.
- All transit capacity added is assumed to be provided by zero emissions transit vehicles.

Potential Co-Benefits

Transit enhancements are associated with a number of co-benefits, including improved reliability, mobility, and accessibility and reductions in congestion and criteria air pollutants. Additionally, enhanced transit service will serve as a community amenity and can increase economic vitality, jobs, and equity. Increases in service frequency, additional real-time information, and infrastructure changes, such as dedicated lanes, serve to incentivize travel by transit.

Table 74. Co-Benefit Results for TLU-10: Transit Enhancements

Co-Benefit	Description of Co-Benefit
Reliability	Enhanced transit service through BRT, TSP, and other strategies should improve transit on-time performance and reliability, as well as better informed riders.
Congestion Reduction	The enhanced service will encourage commuters to use transit, instead of driving, thus reducing the number of cars on the road.
Criteria Air Pollutants	The enhanced service will encourage commuters to use transit, instead of driving, thus reducing single occupancy vehicle VMT. This reduction in VMT will yield reductions in criteria pollutant emissions
Economic Vitality, Jobs, Equity	Enhanced transit service provides faster, more reliability access to activity centers and jobs.
Mobility	The enhanced transit service will allow users to have increased mobility. Improved service indicates that users will have an easier time moving about the transit system.
Accessibility	The enhanced transit service means the services will be more easily accessible to riders. With more frequent and better service, more people will be able to access the system.
Community Amenity	Enhanced transit service is typically viewed as an important community amenity, and supports more healthy and livable communities.

In addition, transit service improvements are supportive of transit-oriented development, and as such, this strategy is linked closely to strategy TLU-2. Consequently, this strategy can support many of the benefits associated with using transit and creating transit-oriented communities, including improved safety (since transit is statistically safer than driving) and weather resiliency (less vulnerable to severe weather).

This strategy is also anticipated to yield reductions in criterial air pollutant emissions, associated with the reduction in vehicle trips and VMT.

Table 75. Estimated Criteria Pollutant Emissions Benefits for TLU-10 – Strategy Alone

Year	Nox (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	0.11	0.12	2.36
2040	0.04	0.08	2.49
2050	0.05	0.11	3.48

Note: These estimates account for changes in emissions rates forecast in the MOVES2014 model through 2040, but do not account for further changes in emissions rates that may occur over this period due to other strategies that alter vehicle fuel economy and operating conditions or that may occur between 2040 and 2050.

It should be noted that this analysis does not address emissions reductions associated with improved vehicle operations associated with transit signal priority, bus rapid transit, and other strategies, which may be substantial along individual routes. These reductions from operational improvements are considered to some extent under TLU-7 Enhancing System Operations, and the intent was to avoid double-counting these effects. In addition, this analysis does not address any improvements in fuel economy and criteria pollutant emission associated with congestion relief from VMT reduced.

Costs

Costs for implementing transit enhancements can vary considerably based on the type of enhancement and unique circumstances of individual corridors. Some travel time and operating enhancements are relatively low cost, such as transit signal priority improvements. Others such as new rapid transit lines may cost in the upwards of hundreds of millions or billions of dollars.

Table 76. Costs for TLU-10: Transit Enhancements

Level	Public Sector Costs	Private Sector/Other Costs
Medium ($50 million to $500 million) to High (Over $500 million)	Costs for significant transit enhancements were estimated at $1.55 billion to $1.74 billion for 2010-2020 in the Maryland Climate Action Plan	Significant cost savings for travelers who use transit, including those who switch from driving to transit

TLU-11: Transit incentives/ Fare reductions

This strategy is designed to incentivize transit use through lower fares, such as a) reduced price monthly transit passes; b) free bus-rail transfers, and c) free off-peak bus service.

- 2020: Reduce transit fares regionally by 20%.
- 2040: Reduce transit fares regionally by 25%.
- 2050: Reduce transit fares regionally by 40% partially funded through pricing strategies.

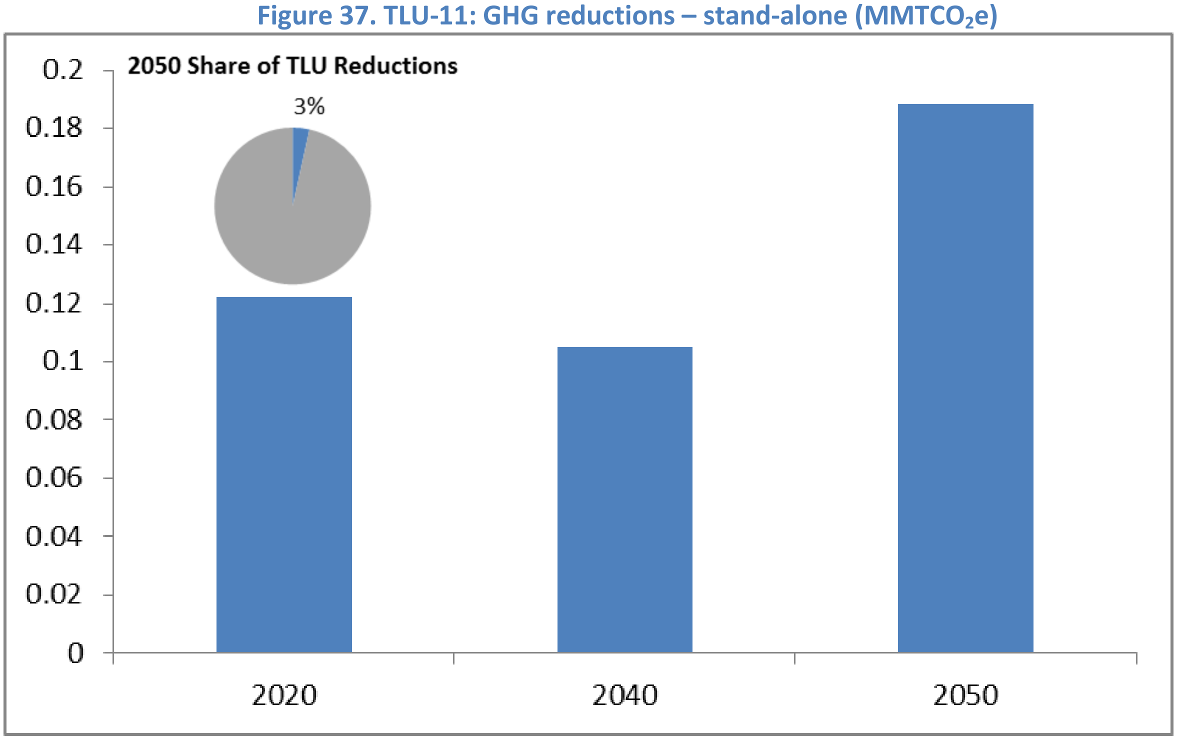
GHG Results

A reduction in transit fares would be anticipated to increase transit ridership. Estimated impacts on VMT and GHGs are shown below.

Table 77. Greenhouse Gas Reductions for TLU-11: Transit Incentives/Fare Reduction

Summary Metric	2020	2040	2050
Vehicle Miles Traveled, passenger vehicles (percent change)	-0.8%	-1.0%	-1.8%
VMT reduced (millions annually)	320	426	765
Transit ridership (percent change)	+4.6%	+5.9%	+10.8%
GHG Reductions ($MMTCO_2e$)	0.12	0.10	0.19

Figure 37. TLU-11: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

The TRIMMS sketch planning model was used to estimate VMT reductions. The resulting percentage reduction in VMT for each analysis scenario was then applied to the passenger vehicle VMT estimates provided by MWCOG for the corresponding year.

Assumptions

- Average transit trip fares were sourced from MWCOG's regional travel demand model.
- For each strategy analyzed, average transit fares were reduced according to the Measure Description.
- All mode shift to transit induced by the measure is assumed to be absorbed by existing capacity.

Potential Co-Benefits

Co-benefits for this strategy are associated with congestion reduction, criteria air pollution reduction, mobility improvements, accessibility improvements, and decreased pollution into the Chesapeake Bay. Reducing transit fares will encourage more transit ridership. This increase in transit ridership will lead to decreases in single-occupancy vehicle miles traveled.

Table 78. Co-Benefit Results for TLU-11: Transit Incentives/Fare Reduction

Co-Benefit	Description of Co-Benefit
Congestion Reduction	The reduction in VMT means that there will be fewer single occupancy vehicles on the road, which will reduce congestion, especially at peak times.
Criteria Air Pollutants	The increase in transit ridership is associated with reduced consumption of fossil fuels. This will lead to a reduction in particulate matter emissions.
Economic Vitality, Jobs, Equity	Reduced transit fares will improve equity and access to jobs for low-income populations.
Mobility	The reduction in transit fare encourages greater use of the transit system and enables riders to make the same number of trips for a lower cost, thus improving their mobility.
Accessibility	A reduction in transit fares makes riding transit more accessible.

This strategy is also anticipated to yield reductions in criterial air pollutant emissions, associated with the reduction in vehicle trips and VMT.

Table 79. Estimated Criteria Pollutant Emissions Benefits for TLU-11 – Strategy Alone

Year	Nox (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	0.24	0.26	5.17
2040	0.06	0.14	4.51
2050	0.12	0.26	8.10

Note: These estimates account for changes in emissions rates forecast in the MOVES2014 model through 2040, but do not account for further changes in emissions rates that may occur over this period due to other strategies that alter vehicle fuel economy and operating conditions or that may occur between 2040 and 2050.

It should be noted that this analysis does not address any improvements in fuel economy and criteria pollutant emission associated with congestion relief from VMT reduced.

Costs

The primary cost of this strategy is the forgone revenue associated with lower fares.

Table 80. Costs for TLU-11: Transit Incentives/Fare Reduction

Level	Public Sector Costs	Private Sector/Other Costs
Medium ($50 - $500 million)	Estimated at $60 million - $140 million for the period 2010-2020 in the Maryland Climate Action Plan	Savings for the consumer

Moreover, the increase in transit ridership beyond the base assumptions suggests that additional transit capacity, beyond what is currently assumed in the CLRP, may be necessary to accommodate the shift to increased transit use. Increased transit services would require additional expenditures.

TLU-12: Road pricing

This strategy is designed to implement road pricing measures and adding roadway pricing (i.e. cordon pricing) to enter major activity centers across the region such as: a) electronic tolling of major bridges and connectors; b) conversion to full electronic tolling; and c) VMT-based vehicle fees, including Pay-As-You-Drive insurance.

- 2020: None – long term scenario only
- 2040: Cordon pricing into downtown DC at $5/trip
- 2050 (stretch): Full VMT-based pricing on road network at $0.10 per mile peak. Cordon pricing into downtown DC at $5/trip.

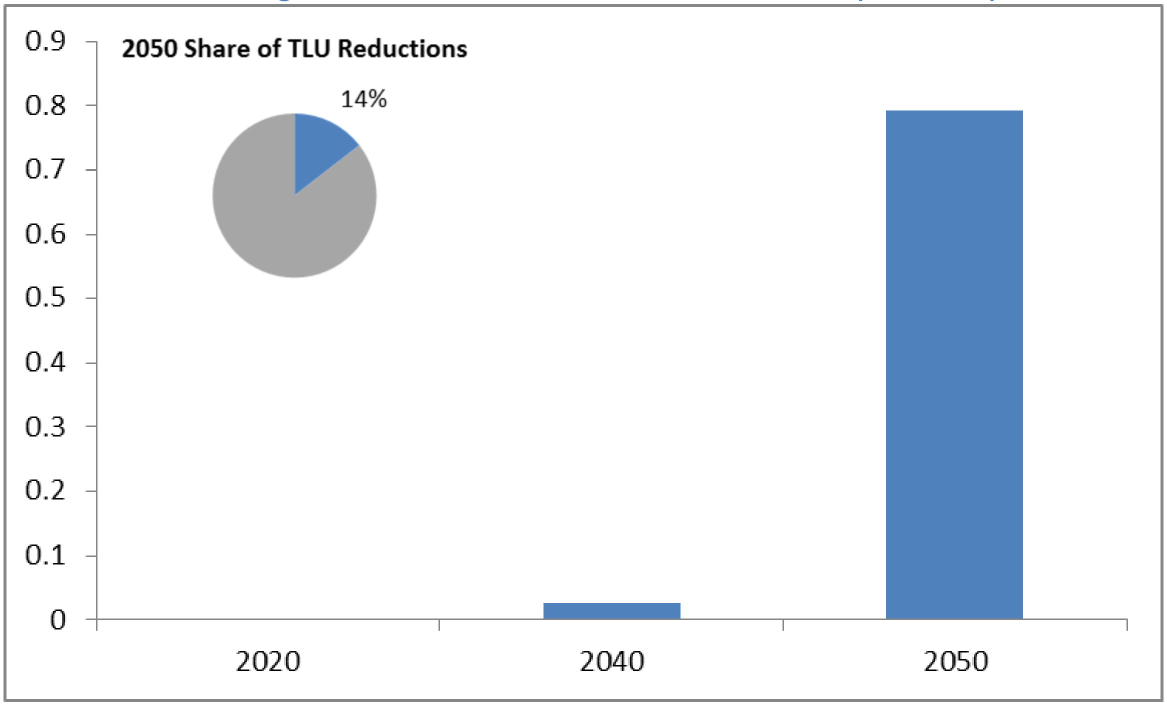
GHG Results

The implementation of full road pricing (assumed to be on-top of existing fuel prices and taxes) is estimated to have a significant impact on vehicle travel in the Metropolitan Washington region. Cordon pricing around downtown Washington, DC, has a relatively small effect on regional GHG emissions due to the fact that vehicle trips into DC only make up a very small portion of total regional vehicle trips.

Table 81. Greenhouse Gas Reductions for TLU-12: Road Pricing

Summary Metric	2020	2040	2050
Vehicle Miles Traveled, passenger vehicles (percent change)	-	-0.3%	-7.8%
Vehicle Miles Traveled reduced (millions annually)	-	104	3,211
Transit ridership (percent change)	-	+8.6%	+25.2%
GHG Reductions ($MMTCO_2e$) – strategy alone	-	0.03	0.79

Figure 38. TLU-12: GHG reductions – stand-alone ($MMTCO_2e$)



Overview of Methods and Key Assumptions

Data, Models, and other tools used

The TRIMMS sketch planning model was used to estimate VMT reductions. The resulting percentage reduction in VMT for each analysis scenario was then applied to the passenger vehicle VMT estimates provided by MWCOG for the corresponding year.

Assumptions

- Average auto trip costs (including fuel, maintenance, and tires) were sourced from MWCOG's regional travel demand model.
- To analyze each strategy, costs per trip were increased according to the Measure Description.
- Business as usual toll costs were assumed to be zero, given that the majority of trips in the region are not subject to a mandatory toll.

Potential Co-Benefits

Co-benefits of road/congestion and cordon pricing are associated with safety, reliability, congestion management, criteria air pollution, and the Chesapeake Bay. By dis-incentivizing driving through user fees, these strategies will likely reduce the number of cars on the road, especially during peak times.

Table 82. Co-Benefit Results for TLU-12: Road Pricing

Co-Benefit	Description of Co-Benefit
Safety	Fewer cars on the road may result in a fewer traffic accidents and a safer environment for pedestrians and bikers.
Reliability	-
Congestion Reduction	User fees dis-incentivize driving, reducing the cars on the road and thus reducing congestion.
Criteria Air Pollutants	Fewer cars on the road result in fewer vehicle miles traveled, thus reducing particulate matter emissions.

This strategy is also anticipated to yield reductions in criterial air pollutant emissions, associated with the reduction in vehicle trips and VMT.

Table 83. Estimated Criteria Pollutant Emissions Benefits for TLU-12 – Strategy Alone

Year	Nox (tons per day, ozone season)	VOC (tons per day, ozone season)	PM2.5 (tons per year)
2020	-	-	-
2040	0.02	0.03	1.10
2050	0.48	1.08	34.00

Note: These estimates account for changes in emissions rates forecast in the MOVES2014 model through 2040, but do not account for further changes in emissions rates that may occur over this period due to other strategies that alter vehicle fuel economy and operating conditions or that may occur between 2040 and 2050.

It should be noted that this analysis does not address improvements in fuel economy and criteria pollutant emission associated with congestion relief from VMT reduced.

Costs

Road pricing generates substantial revenues.

Table 84. Costs for TLU-12: Road Pricing

Level	Public Sector Costs	Private Sector/Other Costs
Low to Medium for direct costs of implementation; however, overall significant net revenue generation	Road/congestion and cordon pricing will generate revenues that can be used for other transportation improvements	Road pricing/congestion pricing costs are anticipated to range from $132 million to $708 million from 2010-2020

Moreover, the increase in transit ridership beyond the base assumptions suggests that additional transit capacity, beyond what is currently assumed in the CLRP, may be necessary to accommodate the shift to increased transit use. Increased transit services would require additional expenditures.

Appendix A: Selected Strategies for Analysis

Energy and Built Environment

First the Energy and Built Environment Strategies are presented in Table 1 by strategy groupings (e.g. existing buildings, new buildings), individual strategies (e.g. EBE-1, EBE-2) and potential implementation actions for each strategy (shown in the right-hand column). This list is a modified version of ICF's April 9, 2015 draft list, and incorporates edits discussed at that COG/ICF team meeting, as well as the Energy and Built Environment Working Group meeting that took place on April 13, 2015. Following the list of strategies is Table 2, presenting ICF's analysis approach to each of the strategies.

Table 1. Energy and Built Environment GHG Reduction Strategies

Strategy	Measure Description (including possible Implementation Actions)
I. Existing Buildings	
EBE-1: Achieve annual and cumulative reductions in energy and water consumption in existing buildings Scenario: • 2% annual reduction, 30% cumulative by 2030	Leverage utility ratepayer-funded programs to drive energy performance improvements via incentives and technical assistance • Implement continuous commissioning and monitoring, leveraging utility advanced metering data and related utility service offerings. Adopt Architecture 2030 goal, adapted for existing buildings. Extend enforcement of building energy code provisions to better address existing building stock • Adopt new building code-related requirements for energy improvements during renovations, additions, major alterations. Reduce water usage via planning/zoning policies, water utility partnerships • Reduce site water loss via rainwater harvesting and other re-use technologies, stormwater runoff reduction, low maintenance natural landscaping. • Improve water conservation in buildings via fixture efficiencies. Drive private building energy and water performance via mandatory benchmarking, and voluntary challenge initiatives • Adopt benchmarking and disclosure requirements. • Adopt green leasing requirements for public agencies, guidelines for private entities. • Implement occupant sustainability programs, such as upcoming EPA Tenant Star Expand low-income housing energy and water savings by leveraging federal, state, utility resources. • Implement programs to serve low-income residents

	and support affordability. Expand financing options for energy and water efficiency and renewable energy. • Enable PACE financing via property tax systems. • Develop Green Bank facilities (New York State, Virginia examples). • Provide credit enhancement mechanism such as loan loss reserves. • Support loan aggregation/secondary market development (e.g. WHEEL) • Drive public/institutional energy and water savings via performance contracting, especially for public and institutional buildings.
EBE-2. Support existing building-level renewable energy development Scenario: • Included in EBE-8 level	Support cooperative/aggregated renewable energy purchasing for public, residential and commercial sectors Provide incentives for building-level renewable technologies (e.g. property tax abatements, density allowances). Adopt solar access ordinances and similar regulations to support renewable development.
II. Location Efficiency	
EBE-3: Encourage development in activity centers Scenario: • increase in the proportion of new development built in Activity Centers by 2030. (Cross-referenced with Land Use strategies (L-2); primary assessment to be conducted by Land Use subgroup)	Update comprehensive plans to include energy and transportation efficiencies as a factor in public facility siting decisions. Update zoning policies and permitting guidelines to encourage low-impact site development, e.g. “rain garden” runoff landscaping, xeriscaping. Locate development at sites and in densities that can be served by efficient and renewable district energy systems. Encourage activity-center residential density to reduce average housing unit size and energy demand. Tie development review to GHG performance; e.g. locating new development in activity centers could be linked to a GHG credit or bonus.
III. New Buildings	
EBE-4: Improve new building energy and water efficiency performance Scenario: • 100% compliance with most stringent ICC (including IGCC) or ASHRAE building code/energy performance standards by 2020 • 100% of new buildings designed to meet ENERGY STAR Target Finder performance levels by 2030 • 50% of new buildings designed to be net zero energy by 2040 • 100% new buildings designed to	Adopt and enforce updated building codes and energy performance standards Develop building code compliance efforts, including utility programs. Create electric vehicle “charging-ready” infrastructure code provisions. Adopt Architecture 2030 goals in public policies. • Express preference for zero-energy performance levels via planning/zoning/permitting policies and practices (typically non-binding but encourage developers to bring such projects forward).

be net zero energy by 2050. • 100% of new buildings use WaterSense fixtures by 2030 to reduce energy needs of water and wastewater) *Targets may need to be adjusted by building type; green power/other offset mechanisms likely to be needed*)	Provide Net Zero building incentives, such as property tax abatements (e.g. Green Building tax credits) or permitting prioritization policies. Integrate green power purchasing into new building policies to offset any remaining site energy use. • Support development of long-term utility “green tariff” policies tied to meter address or other actions. Require new building sites to meet low-impact site development requirements, e.g. “rain garden” runoff landscaping, xeriscaping. Adapt planning/zoning policies and work with water utilities to increase rainwater harvesting and other re-use technologies, manage storm water, and encourage low-maintenance natural landscaping. Update planning/zoning policies and work with water utilities to improve water conservation in buildings to reduce water consumption. Create building code-related policies to mandate WaterSense or comparable performance levels in applicable fixtures.
IV. Public and Private Infrastructure	
EBE-5: Achieve annual and cumulative reductions in fossil energy use by improving Infrastructure efficiency and increasing renewable energy use Scenario: • 1% annual reduction in fossil energy use, 35% cumulative by 2050	Reduce energy use by water and wastewater systems by reducing leaks, increasing onsite generation, increasing system efficiency, and fostering process improvements, by working through institutional and utility programs. Implement outdoor lighting and other end-use efficiency technologies, working through institutional and utility programs. Install on-site renewable power systems at facility and transit sites by working through institutional and utility programs.
V. Energy Source and Supply	
EBE-6: Achieve targeted reductions in power sector emissions Scenario: • 30% reduction in emissions from energy generation by 2030 (on a total emissions (mass) basis rather than an emission-rate basis)	Support state plans to achieve a 30% mass-based reduction in electrical generation emissions. • Allow District of Columbia GHG successes to be leveraged in Maryland's Clean Power Plan. • Phase out coal use in regional coal plants by 2030. • Explore the possibility of installing additional units at existing regional nuclear plants. • Increase efficiency of thermal power plants. Support increases in state Renewable Portfolio Standards (RPS) to 40% by 2030. • Increase Solar PV capacity via RPS carve outs or other policies. Increase electric-grid energy storage capacity by supporting

	utility investments in grid storage technology. Reduce energy waste from transmission and distribution of energy by supporting utility efforts to upgrade grid efficiencies via efficient transformers, smart grid technologies, etc. Expand natural gas supply infrastructure to existing and new power plant sites. Sustain and expand federal, state and local grid-scale renewable energy incentives, e.g. federal PTC
EBE-7: Achieve targeted reductions to reduce natural gas pipeline leaks Scenario: • 20% reduction in methane leaks from natural gas pipelines by 2030)	Support utility investments by encouraging utility commission action on cost recovery.
VI. Resource Recovery, Conservation and Management	
EBE-8: Achieve targeted reduction in municipal solid waste Scenario: • Net Zero Waste by 2050	Increase the recycling rate of the region to 75%, via waste collection fees and other policies. Increase reuse of construction /demolition waste by 15% by 2020 and 100% by 2050 via tipping fees, builder incentives, and similar measures. Divert 100% of organic waste by 2040 via tipping fees, waste collection fees. Implement green purchasing and procurement programs via government agency and private sector commitments. Increase use of waste to energy plants, including landfill gas projects.
VII. Non-road Engines	
EBE-9: Reduce emissions from non-road engines Scenario: • 2% annual, 30% cumulative reduction in greenhouse gas emissions from non-road sources by 2030	Increase market penetration of energy efficient alternatives for non-road engines including back-up generators, construction equipment, agriculture, lawn and garden equipment, construction equipment, commercial and industrial equipment, and recreational equipment, as listed in the MWCOG Gold Book.
VIII. Awareness and Education	
EBE-10: Educate and motivate public through community engagement Move education to action - Create measurable results through community energy engagement.	Educate on benefits and costs of clean energy technologies and behaviors, via school curricula and public information campaigns. Increase motivation through incentives and other measures, linked to utility customer education and information services. • Use utility advanced metering data to monitor and influence behavior. Create a culture of responsibility via school curricula and public information campaigns. Encourage employee behavior change to increase teleworking and commuting by public transportation through actions such as the "Commuter Connections" program.

Emission factor considerations for power sector related strategies

After careful consideration, GHG reductions from power sector and energy efficiency related strategies, as well as electricity offsets from electric vehicles, have been modeled based on a marginal emission factor for the PJM region. The primary marginal emission factor used is about 50% more carbon intensive than the regional average emission factor. To illustrate the magnitude of this change, three reduction scenarios are shown below that address all strategies where electricity emission factors are applied to determine reductions.

1. **Marginal Emission Factor (current):** In this scenario, all reductions that take place come from a marginal factor for the PJM region. This factor is reduced by 30% for 2040 and 2050, assuming a general decarbonization of the PJM region over time. It is assumed that since power is drawn from the PJM region, reductions in the carbon intensity of the power supply within the COG region will have little effect on the emission factor applied to demand side reductions. Both the high carbon intensity of the marginal factor and the static nature of this factor push reductions significantly higher than other scenarios.
2. **Average Emission Factor:** In this scenario, the average emission factor for the PJM region (which corresponds with the average emission factor for utilities in the COG region) is applied to all emission reductions. This is the same emission factor used in the power sector inventory projections. No layering is applied to account for a decarbonization of the power sector over time.
3. **Average Emission Factor – Layered:** In this scenario, the average emission factor for the PJM region is used, and then reductions from supply-side strategies are layered in to result in a lower emission factor to be applied to energy efficiency and electric vehicle strategies.

GHG Reduction Comparison (MMTCO$_2$e)	2020			2040			2050		
	Marginal Emission Factor	Avg Emission Factor	Avg Emission Factor - Layered	Marginal Emission Factor	Avg Emission Factor	Avg Emission Factor - Layered	Marginal Emission Factor	Avg Emission Factor	Avg Emission Factor - Layered
EBE-1	2.7	2.1	1.9	10.5	10.5	7.8	10.5	10.5	7.8
EBE-4	1.0	0.8	0.8	4.2	4.2	3.6	6.6	6.6	5.6
EBE-5	0.1	0.04	0.03	0.2	0.2	0.2	0.3	0.3	0.2
EBE-2	1.2	0.8	0.7	2.7	2.0	1.3	4.0	3.0	2.0
EBE-6 "On the books" - S10	2.9	2.0	2.0	4.7	3.5	3.5	4.7	3.5	3.5
EBE-6 Additional measures - S2	1.3	1.1	1.1	2.5	1.9	1.9	2.5	1.9	1.9
EBE-6 Additional measures - S3	0.0	0.0	0.0	6.1	4.2	4.2	6.1	4.2	4.2
EBE-6 Additional measures - S12	0.6	0.4	0.4	2.1	1.6	1.6	2.1	1.6	1.6
TLU-3	0.1	0.1	0.1	0.4	0.4	0.6	0.6	0.6	1.0
Total	**9.9**	**7.4**	**7.0**	**33.4**	**28.5**	**24.6**	**37.4**	**32.2**	**27.7**
Change from Marginal EF	**--**	**-2.6**	**-2.9**	**--**	**-4.9**	**-8.8**	**--**	**-5.2**	**-9.7**

Transportation and Land Use

Based on the discussions during the combined Transportation and Land Use Work Group meeting on April 17, 2015, and feedback from the public comment process, ICF edited the list of strategies discussed with the Working Group, shown below.

Transportation and Land Use GHG Reduction Strategies

Strategy Type/Focus	Measure Description (including possible Implementation Actions)
TLU-1: Increase urban tree canopy and land stewardship	Measures to maintain/increase open space, tree canopy, and green infrastructure through sustainable landscaping and land management practices: • Maximize urban canopy • Tree conservation ordinances • Conservation of open space • Regional mitigation bank • Shifting more new development into activity centers with smaller environmental footprint (through measures like TLU-2 below) and thus preserving existing undeveloped lands. • Commercial and residential landscaping should follow Climate, Community, and Biodiversity Standards • Reduce impervious surfaces to minimize water treatment energy needs to remove phosphorus, nitrogen, and sediment • Support soil and forest carbon sequestration
TLU-2: Sustainable development patterns & urban design (including enhancements for non-motorized modes)	Measures to encourage a higher share of new development in regional activity centers (RACs), together with associated sustainable urban design factors, such as: • Build near transit (transit-oriented development) and/or enhance existing transit service levels • Higher densities • Greater mix & balance of uses • Street network/walk friendly • Management of parking supply/cost • Greater mix of housing options RE size and affordability • School locations, design and access Recommend testing as a package of the above, in three different levels: • Constrained Long-Range Plan (CLRP) activity levels and networks (with assumed growth in RACs) • Maximum shift to RACs: assume entire 2014-2040 growth increment into RACs • Augmented: increase above current planned levels, rule-based targeting to centers by place type (transit service, location in major corridors) Efforts to foster greater jobs/housing balance, particularly

	by targeting more residential opportunities to areas with high jobs/housing ratios. Key actions embodied in this strategy include • Housing affordability (especially in center city and inner suburban jurisdictions and areas near transit) • Live Near Your Work incentives • Balancing job opportunities between west and east region • Incentivize jobs in eastern region Ensure adequate pedestrian and bicycle infrastructure and connectivity in activity centers to support walking and biking as modes, as well as access to transit. Key actions embodied in this strategy include: • Local street networks meeting block size or intersection density criteria • Complete streets concepts • Traffic calming measures. • On & off-road bicycle networks and storage facilities Efforts to encourage local retail. Actions embodied in this strategy include: • Higher retail/service to households or employment ratios • Location incentives for retail • Easing/changing zoning to allow broader array of retail/service options, locations • Retail must be located strategically within centers Locate as much of new or relocated government employment near premium transit (Metro, commuter rail, LRT/BRT), including: • Federal agencies • State agencies • Regional, county and municipal agencies Measures designed to increase the share of bike/walk trips, such as: • Complete streets policies • Increased bike-sharing • Completion of bicycle/pedestrian enhancements • Increased connectivity of pedestrian network (especially in cul-de-sac developments), require sidewalks on all streets except freeways which should have parallel trails, connect communities to parks, and identify and complete trails with maximum potential • Supportive urban design and architectural guidelines. • Plan and build necessary transit infrastructure to support walkable development. Other supporting implementation actions:

	Update zoning to permit higher density development Plan and build necessary transportation infrastructure to support compact development, including transit, pedestrian, and bicycle facilitiesto create more opportunities for activity ceners with premium transit access. Update urban design requirements to promote a built environment oriented towards transit, walking, and biking
TLU-3: Improve fuel economy of light-duty vehicle fleet	Measures to incentivize more fuel efficient passenger vehicles: • Implement a "Cash for Clunkers" program to encourage replacement of older, less fuel efficient vehicles • Offer incentives for consumer/private sector purchase of electric vehicles and charging equipment • Offer incentives for purchases of fuel-efficient vehicles (fee-bates) • Provide disincentives for purchases of fuel-inefficient vehicles (gas guzzler tax/registration fees) • Adoption of CA Low-Emission Vehicle (LEV) Phase II program
TLU-4: Increase alternative fuels in public sector fleets	Measures to incentivize more fuel efficient passenger vehicles: • Implement a "Cash for Clunkers" program to encourage replacement of older, less fuel efficient vehicles • Offer incentives for consumer/private sector purchase of electric vehicles and charging equipment • Offer incentives for purchases of fuel-efficient vehicles (fee-bates) • Provide disincentives for purchases of fuel-inefficient vehicles (gas guzzler tax/registration fees) • Adoption of CA Low-Emission Vehicle (LEV) Phase II program
TLU-5: Truck stop electrification (and other clean freight technologies)	Adoption of truck stop electrification bays. Note other measures to reduce emissions associated with freight not addressed directly in this analysis include: • Engine and powertrain technologies to improve fuel efficiency (e.g., hybrids, plug-in electric, and alternative fuel vehicles) • Vehicle technologies to improve fuel efficiency (e.g., aerodynamic devices, low rolling resistance tires, tire pressure systems, idle reduction technologies) • Operational strategies (e.g., routing software, engine governors, efficient truck refrigeration units, off-peak delivery incentives) • Clean truck corridor infrastructure (e.g., overhead catenary systems, linear synchronous motors, in-

	road battery charging capabilities)
TLU-6: Low carbon fuel standard	Implement market-based program to reduce carbon intensity of on-road fuels through use of lower-carbon alternatives (e.g., natural gas, electricity, biofuels, hydrogen)
TLU-7: Enhancing system operations	Apply cost effective operational improvements to freeways and arterials/collectors, such as: • Integrated corridor management (ICM) on freeway and major arterial corridors • Implement ramp metering • Freeway operations patrols / faster incident management • Signal retiming • Roundabouts • Intersection efficiency improvements • Targeted bottleneck improvements (those that reduce GHG emissions) Promote driving patterns to reduce rapid acceleration/deceleration and extended idling System efficiency improvements through connected vehicles, such as vehicle-to-vehicle, vehicle-to-infrastructure, and autonomous vehicles
TLU-8: Reduce speeding on freeways	Enforce speed limits on freeways and include GHG surcharge as part of enforcement
TLU-9: Travel demand management	Measures to reduce the availability of free parking in activity centers, such as: • Parking impact fees • Parking caps • De-couple the costs of residential parking from rents Parking pricing for on and off-street parking Measures designed to incentives carpooling/ridesharing, non-motorized modes, and telecommuting, such as: • Expanding telecommuting • Carpool incentive programs • Vanpool incentive programs • Increased employer outreach Ordinances to require employers to offer parking cash out / transit benefits Park and ride facilities Additional incentives for employee commute options Mandatory employer trip reduction programs
TLU-10: Transit enhancements	Measures designed to increase the share of transit trips (and support more sustainable land use) through increased/improved services, such as: • More neighborhood circulator buses • Enhanced commuter bus services

	• Real-time bus scheduling information • Transit signal priority improvements / bus rapid transit • Expand Metrorail / Commuter rail • Bus stop improvements (benches, shelters) • Increase schedule coordination between transit agencies • Bus on Shoulder • Transit access improvements to eliminate drive access to bus • System of dedicated bus lanes • Bus infrastructure commitments
TLU-11: Transit incentives / Fare reductions	Measures designed to incentivize transit use through lower fares, such as: • Reduced price monthly transit passes • Free bus-rail transfers • Free off-peak bus service
TLU-12: Road pricing	Adding cordon roadway pricing for entering downtown Washington Pricing all road travel, such as through: • Conversion to full electronic tolling • VMT-based vehicle fees