Summary Report

Introduction

The region's local governments are committed to significantly reducing greenhouse gas (GHG) emissions in the metropolitan Washington region. In December 2014, the Metropolitan Washington Air Quality Committee (MWAQC) and the National Capital Transportation Planning Board (TPB) affirmed the Region's GHG reduction goals set out in the National Capital Region Climate Change Report and Region Forward; and committed staff and resources to support a multi-sector, multi-disciplinary professional working group to identify and analyze implementable local, regional and state actions in four sectors (Energy, the Built Environment, Land Use, and Transportation) that would support the region's GHG reduction goals.

This Multi-Sector Working Group (MSWG) was convened by the Metropolitan Washington Council of Governments (COG) in January 2015, and charged with:

- Identifying viable, implementable local, regional, and state actions to reduce GHG emissions in four sectors (Energy, the Built Environment, Land Use, and Transportation)
- Quantifying benefits, costs and implementation timeframes of these actions;
- Exploring specific GHG emission reduction targets in each of the four sectors; and
- Jointly developing an action plan for the region

In April 2015, ICF International (ICF) was retained to support the work of the MSWG. ICF worked with the members of the MSWG to identify and refine a list of proposed strategies in the Energy, the Built Environment, Land Use, and Transportation Land Use sectors that were deemed most promising for the their GHG reduction potential. A total of 22 strategies were identified and recommended for detailed quantitative analysis. Ten of these strategies were for the combined Energy and Built Environment sectors and 12 were for the combined Land Use and Transportation Sectors. In May through July 2015, ICF performed a detailed analysis of the 22 strategies and reviewed the results of this analysis with the MSWG. This report summarizes the results of this analysis and addresses the first two tasks of the Multi-Sector Working Group's charge.

Background on Region's GHG Reduction Goals

On November 12, 2008, the Metropolitan Washington Council of Governments (COG) Board adopted the *National Capital Region Climate Change Report* including voluntary goals to reduce GHG emissions. The goals were based on scientific evidence from the 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change. The adoption of these voluntary GHG reduction goals were also part of the broader work of COG, set out in the *Region Forward* report, to support a more accessible, sustainable, prosperous, and livable National Capital Region. The COG GHG reduction goals call for reducing GHG emissions by 10% below the business as usual forecast by 2012, by 20% below 2005 levels by 2020 and by 80% below 2005 levels by 2050. The adoption of these goals placed the region as a national leader in calling for aggressive action to address climate change.[1] These goals were subsequently confirmed in the 2010 Region Forward Compact that set out a vision for an accessible, sustainable, prosperous and livable National Capital Region[2].

The *National Capital Region Climate Change Report* recommended that regional leaders should periodically assess progress toward meeting the goals and consider how conditions have changed since the report was completed. The convening of the MSWG is consistent with this recommendation.

GHG Emissions in a Growing Region

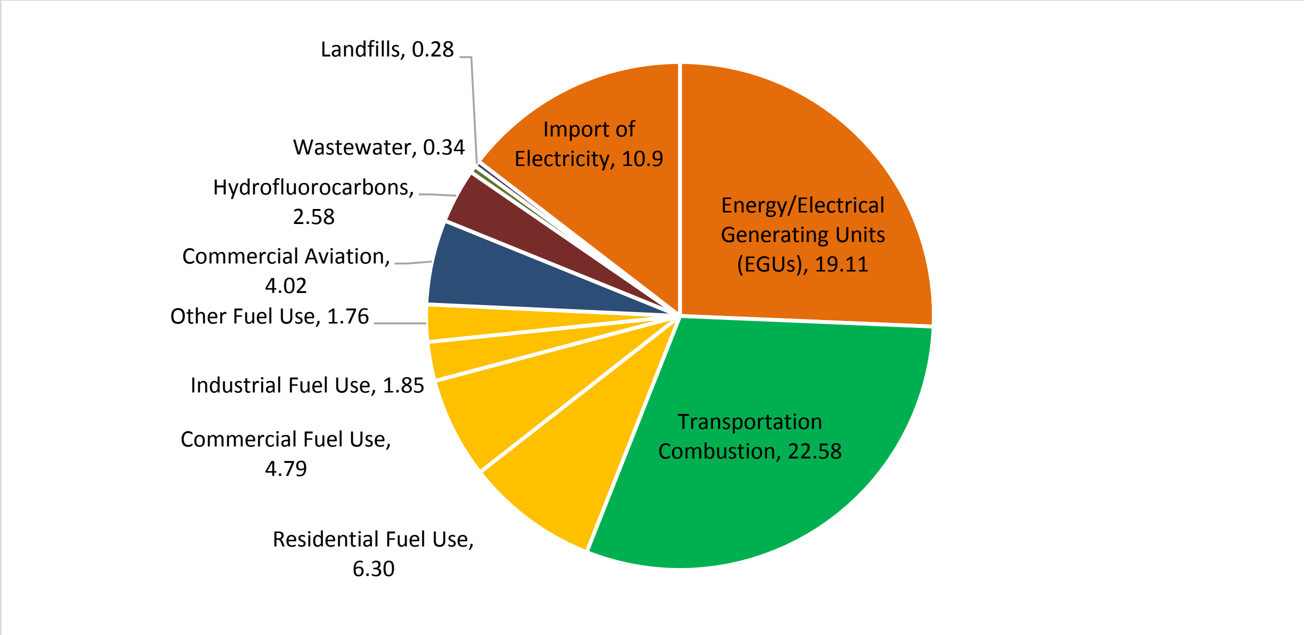
COG's 2005 regional GHG inventory and baseline forecasts – representing business as usual (BAU) conditions in 2005 – provide a starting point for measuring needed GHG reductions to meet the region's GHG goal. In the 2005 base year, GHG emissions in the metropolitan Washington region totaled 74.5 million metric tons of carbon dioxide equivalent ($MMTCO_2e$)[3]. As shown in Figure 1, this inventory breaks out emissions from electricity generation; on-road motor vehicle transportation; residential/commercial/industrial and non-road fuel use, commercial aviation fuel use; 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 combustion from on road motor vehicles contributed about 30% of regional GHG emissions.

[1] National Capital Region Climate Change Report, November 12, 2008. Executive Summary, page 9.

[2] Region Forward: A Comprehensive Guide for Regional Planning and Measuring Progress in the 21^{st} Century, January 13, 2010, page 30.

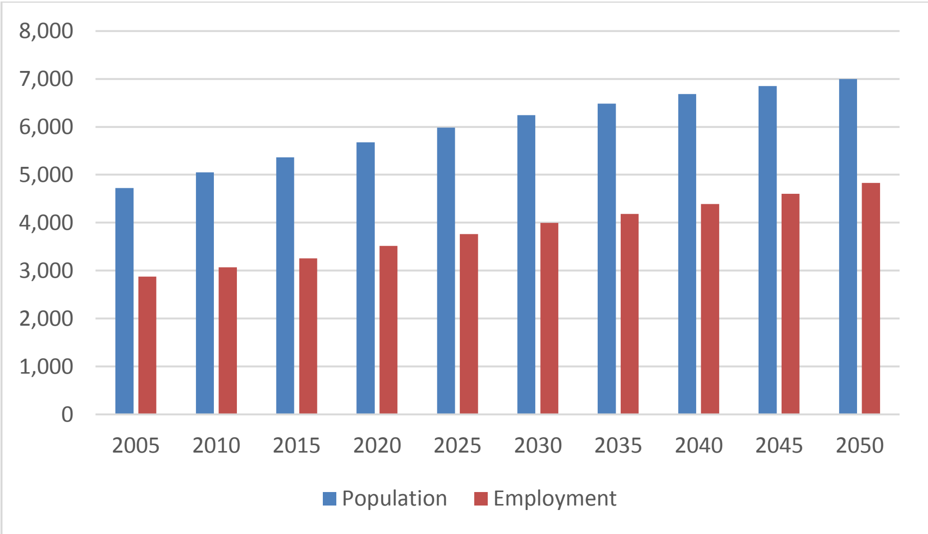
[3] COG is recalculating, or backcasting, the 2005 GHG inventory using the same methodology as used in the 2012 GHG inventory. This will provide for a more accurate basis to compare change over time. Based on this backcasting, 2005 GHG emissions are estimated to have been reduced to 70.76 MMTCO2e, or 14.93 metric tons per person.

Figure 1. 2005 Regional GHG Inventory Sources (MMTCO$_2$e)



Population and employment in the region has continued to grow in the past 10 years and both are projected to increase significantly through 2050, as shown in Figure 2. It is anticipated that by 2050 the residential population will have grown from approximately 4.7 million in 2005 to nearly 7 million, an increase of 48%. Employment is anticipated to grow even faster, by 68% – from 2.87 million jobs in 2005 to 4.83 million jobs in 2050. Together this growth will create increasing demands for land use development, electricity, heating and cooling, water and sewer, waste management and travel across the region.

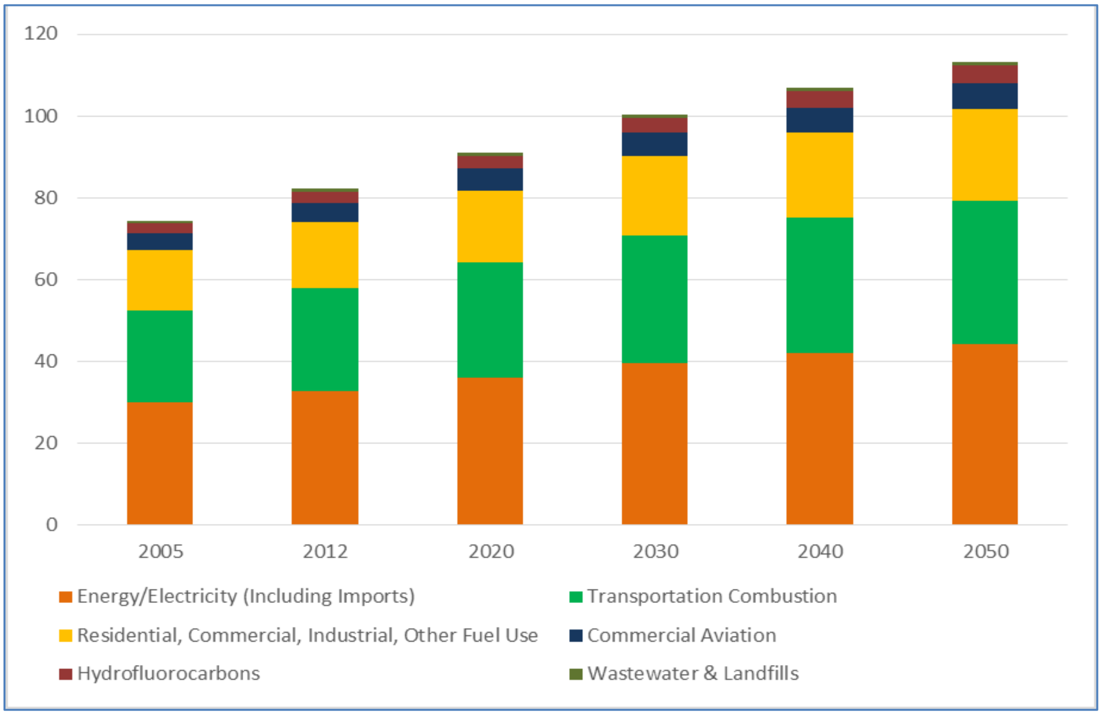
Figure 2. COG Planning Area Forecasts for Population and Employment



With no change in existing policy or practices from a 2005 baseline condition, the business as usual (BAU) scenario in the *2008 National Capital Region Climate Change Report,* it would expected that the region's projected future population and employment growth would result in a 33% increase in GHG emissions over 2005 levels by 2030 and a 43% increase over 2005 levels by 2050.

Consequently, the 2005 BAU scenario anticipated significant growth in GHG emissions across all key sectors, as shown in Figure 3 below, from 74.45 $MMTCO_2e$ to 113.35 $MMTCO_2e$.[4] 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 $MMTCO_2e$). Thus, to achieve the region's voluntary GHG reductions goals, GHG emissions per capita will need to decline by 86% from 15.76 Tonne CO_2e per person in 2005 to 2.13 Tonne CO_2e per person in 2050.

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



[4] 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 $MMTCO_2e$.

Existing Policies Are Making a Difference

Many local governments in the Washington region have become national leaders in adopting programs to reduce GHG emissions. 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 strategies for land use development.

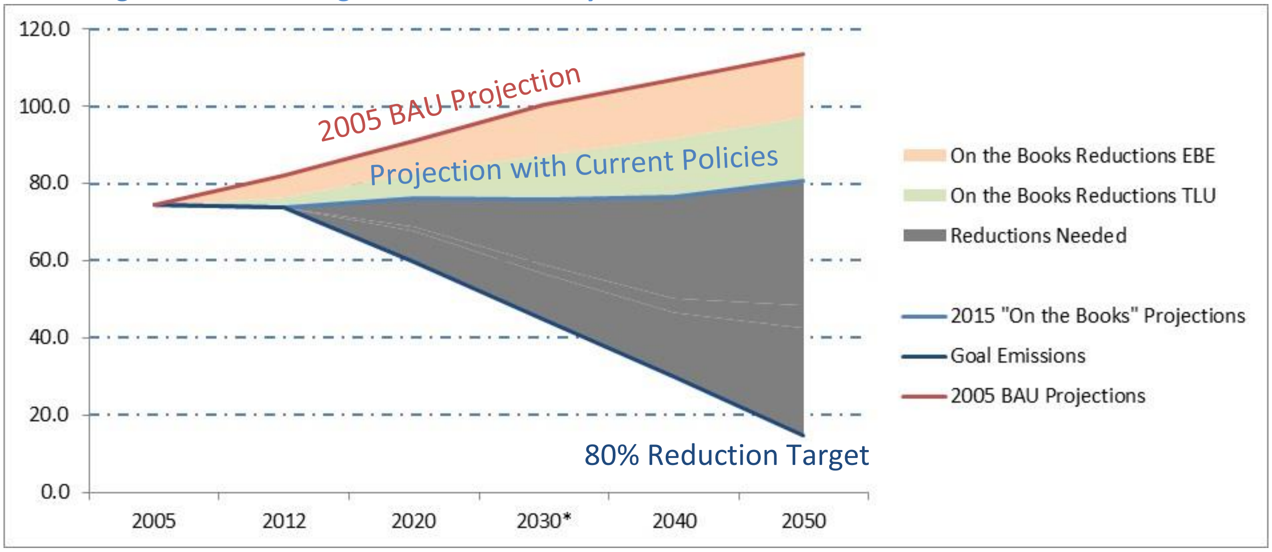
Local policies in place include adopting more stringent building codes for energy efficiency, supporting distributed solar system installations; developing net-zero energy buildings; implementing energy efficiency improvements in government facilities and operations; meeting the requirements to become an EPA Green Power Partners; land use plans focusing more of the region's future growth in walkable, mixed use, transit oriented centers; and transportation investments to support these land use plans and provide more multimodal travel options for traveling between these centers and within them. Communities have signed agreements such as Cities for Climate Protection, Cool Counties, and Green Power Communities. In addition to existing policies at the state, regional, and local levels, national policies, such as increased CAFÉ standards for light-duty vehicles, renewable energy production tax credits, and others have also helped the region reduce its GHG emissions.

COG has recently completed a GHG inventory for 2012 to assess whether the region had met its first GHG reduction goal. Analysis of this inventory compared to would have been expected with no change in existing policy or practices from a 2005 baseline condition shows a reduction of 8.4 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) or over a 10% reduction in total GHG emissions from a 2005 BAU projection based on growth in population in the region between 2005 and 2012.

Combined, these existing policies will continue to make a significant contribution to reducing GHG emissions in the Washington metropolitan region between 2012 and 2050.

Analysis of these current policies that are "on the books" show that these policies, if fully implemented, 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 as shown in Figure 4.

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



Significant reductions in emissions are anticipated 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 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 on vehicle travel.[5] 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 nearly flat (6% above 2005 levels, rather than 48% higher). 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[6] region. This reference case takes into account shifts

[5] 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.

[6] The 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.

in energy efficiency and generation fuel mix. Layered on top of these projections are assumptions locking in reductions from Maryland's Renewable Portfolio Standard (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. These projections in transportation and energy do not account for currently proposed new federal regulations.

Pathways for Further Greenhouse Gas Reductions

Even with the progress being made with current policies, additional actions will be needed to achieve the voluntary goals to reduce GHG emissions set out in the *2008 National Capital Region Climate Change Report.* These additional reductions will need to come from a variety of sources in the Energy, the Built Environment, Land Use, and Transportation sectors including:

Energy Efficiency

Reducing energy use through efficient technology investments and improved facility operations is a proven practice that has been successfully pursued by federal, state, and local governments for some four decades. GHG emission reductions can be achieved through energy efficiencies in energy and water use in existing buildings, the efficiency impacts of smaller buildings in higher-density activity centers, improved building codes and net-zero-energy policies for new buildings, and through 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. GHG emission reductions would be achieved through policy actions that reduce power sector emissions in the regional grid. Although some of these actions can be implemented within the region, some require federal-level policy action. Further reductions can be achieved through implementation of renewable energy development in existing buildings, primarily in terms of solar photovoltaic development at the building or facility level.

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. Reductions can be achieved through changes in management of municipal solid waste to reduce landfilling of wastes.

Non-Road Engines

Construction, landscaping, and other non-road equipment generate GHGs as well as criteria pollutant emissions. Reductions can be achieved higher equipment efficiencies, tailpipe controls, idling reductions and electric alternatives.

Sustainable Land Use Patterns and Increasing Regional Tree Canopy

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. 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. Encouraging denser development multi-family housing and commercial development, rather than low-density development, also results in lower building energy consumption per dwelling unit due to energy efficiencies and typically smaller average dwelling sizes. Such 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.

Changes in the Composition of the Vehicle Fleet and Fuels Used

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 offset somewhat by increased emissions from the power sector in generating additional electricity to power these ZEVs. The size of this offset would depend on the composition of fuels used to generate this electricity and the diurnal pattern of the charging of these ZEVs.

Reduction in the Growth of 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.

Operational Efficiencies of Vehicles on the Region's Roadways

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.

Analysis of Greenhouse Gas Reductions Strategies

In examining the various pathways for further GHG reductions in the Washington region, the MSWG, consisting of technical and policy staff from COG's member jurisdictions, states, and regional agencies with expertise in one or more of the main sectors from which the region's GHG emissions come, identified and recommended 22 greenhouse reduction strategies for detailed quantitative analysis. Ten of these strategies were for the combined Energy and Built Environment sectors and 12 were for the combined Land Use and Transportation Sectors. Public comment from agencies, organizations, and individuals also informed the sets of strategies and policy strategies considered within this analysis.

Sketch planning methods – relying upon available literature, recent studies, and simple analysis tools – were used to analyze each of the 22 strategies for 2020, 2040, and 2050 analysis years. Analysis of each strategy contained two dimensions: temporal, considering the timeframe of implementation; and level of stringency or "stretch". Based on feedback from the Multi-Sector Working Group, the analysis presented what were considered generally "viable" strategy assumptions for 2020 and 2040 and "stretch" assumptions for 2050. Stretch assumptions were included to assess what might be possible under very stringent policy actions.

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

- These results do not account for additional federal policies, which could have a 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 may have an impact on GHG emissions 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 to estimate GHG impacts. The sketch planning methods address the 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. Similarly, while some interactive effects among strategies are taken into account, others could not be assessed. For instance, some transportation strategies might have indirect effects on land use (e.g., cordon pricing might encourage shifts of economic activity outside of the cordon area) that were not assessed.

The results of the 22 strategies analyzed are provided in

Table 1 and are followed by summary sections grouped into four broad categories for presentation purposes. The categories are (1) Energy and Built Environment Strategies, (2) Land Use Strategies, (3) Transportation Strategies and (4) Public and Community Engagement Strategies. This table presents the independent effects of individual strategies off of current forecast conditions.

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

Strategy	Strategy Name	GHG Reductions ($MMTCO_2e$)		
		2020	2040	2050
EBE-6	Achieve targeted reductions in power sector emissions	1.97	8.05	10.74
EBE-1	Achieve annual and cumulative reductions in 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 land stewardship	^0.19	^0.82	^0.98
TLU-3*	Improve fuel economy of light-duty vehicle fleet	*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 (TLU-2A)	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	0.056	0.06	0.08

Strategy	Strategy Name	GHG Reductions ($MMTCO_2e$)		
TLU-8	Reduce speeding on freeways	0.005	0.006	0.006
TLU-5	Truck stop electrification	<0.001	0.002	0.006

Note that the additive impact of individual strategies does not sum to the combined impact of implementing all strategies.

^ 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.

* 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)

Energy and Built Environment Strategies

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

Energy Efficiency Strategies

Reduce Energy and Water Consumption in Existing Buildings (EBE-1) – This strategy would reduce energy and water consumption in existing buildings and seek to achieve 2% annual reduction in energy and water use by leveraging utility ratepayer-funded programs for improvements, extending enforcement of building energy code provisions, water utility partnerships, challenge initiatives, expanding low-income housing and water saving programs and expanding financing options for energy and water efficiency improvements.

Strategy Greenhouse Gas Reduction Benefits

Table 2. Greenhouse Gas Reductions for EBE-1

Summary Metric	2020	2040	2050
GHG Reductions ($MMTCO_2e$)	2.73	14.02	14.02
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	82,642

Strategy Co-Benefits

Table 3. 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 emission 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 and Health	Buildings that perform efficiently are often more comfortable and healthier for workers and visitors.

Strategy Costs

Table 4. 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.		

Strategy Implementation Issues

This strategy is aggressive. No jurisdiction in the region has yet shown the ability to sustain 2% or better annual savings across the entire existing building stock over time period as long as the 15-year period. Yet several jurisdictions have already acted on commercial building benchmarking policies, utility energy efficiency programs, and related efforts aimed at upgrading building energy efficiency. Implementation considerations will include policy feasibility (e.g. will local policymakers and stakeholders ultimately support such initiatives), and cost issues (e.g. will utility commission policies or rate impacts of efficiency programs limit the scope of efficiency programs).

Improve New Building Energy and Water Efficiency Performance (EBE-4) – This strategy would reduce energy and water consumption in new buildings by 100% with most stringent building code/energy performance standards by 2020, 100% of new buildings use WaterSense fixtures by 2030, 50% of new buildings are designed to be net zero energy use by 2040, 100% of new buildings are designed to be net zero energy use by 2050.

Strategy Greenhouse Gas Reduction Benefits

Table 5. Greenhouse Gas Reductions for EBE-4

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	1.03	4.96	7.79

Electricity Reductions (MWh)	754,305	3,289,709	5,068,080
Natural Gas Reductions (MMBtu)	8,258,484	44,607,606	71,577,122
Water Reductions (Gallons)	0	196,932,718	323,257,485

Strategy Co-Benefits

Table 6. 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.

Strategy Costs

Table 7. Costs for EBE-4

Level	Public Sector Costs	Private Sector/Other Costs
Low	Building code compliance	Net Zero building requirements Water Sense fixture requirements
Cost Savings Efficiency is an investment that can realize substantial cost savings.		

Strategy Implementation Issues

Strategy would require updating of planning/zoning/building code policies and provisions. It would require greater building code compliance efforts, potentially including code-compliance-related utility programs. Implementation considerations revolve mainly around political feasibility: building industry stakeholders may resist more-stringent codes and related policies, and policymakers may face limits in moving past conventional approaches or stringency levels.

Improve Infrastructure Efficiency and Increase Renewable Energy Use (EBE-5) – This strategy is designed to reduce fossil fuel energy use through efficiency improvements and expanded renewable options in the COG region infrastructure institutions, including water and wastewater systems, the Washington Metropolitan Area Transit Authority (WMATA), and airports. This strategy would improve energy efficiency by reducing leaks in water and wastewater systems, fostering system efficiency process improvements, implementing outdoor lighting and end-use efficiency technologies, and installing on-site renewable power systems at facility locations.

Strategy Greenhouse Gas Reduction Benefits

Table 8. Greenhouse Gas Reductions for EBE-5

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	0.05	0.32	0.46
Electricity Reductions (MWh)	68,435	398,109	562,946
Natural Gas Reductions (MMBtu)	13,574	155,840	226,972

Strategy Co-Benefits

Table 9. 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.
Resilience to Weather	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.

Strategy Costs

Table 10. 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.		

Strategy Implementation Issues

Many of the region's infrastructure institutions are moving aggressively on energy efficiency, renewable energy, and other sustainability initiatives. Many efficiency and renewable improvements are currently planned or already in progress. 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.

Power Sector and Renewable Energy Strategies

<u>Targeted Reductions in Power Sector Emissions (EBE-6)</u> – This strategy would reduce total power sector emissions on a mass basis by phasing out the use of coal in regional power plants by 2030, installing additional units at existing regional nuclear plants, increasing to 40% renewable energy offsets in MD by 2040, and achieving 10% renewable offsets in DC and VA. These actions would be additional to the impacts of the EPA Clean Power Plan regulation, which would reduce the CO_2 emissions rate from existing powerplants in Virginia and Maryland about 37% by 2030 from a 2012 baseline.

Strategy Greenhouse Gas Reduction Benefits – A "Preferred Portfolio" consisting the actions is shown in Table 11 below. Focusing on these actions in would result in maximum impact on GHG emissions for the region. Specifically, the analysis forecasts the impact from action 2 (phase out local coal plant use) in parallel with actions 3, 11 and 12. These will drive regional policy (actions 11 and 12 raising RPS goals to 40% from 20% in MD, and increasing the share of renewables in DC and VA) and replace coal–fired power with broader availability of natural gas infrastructure and plants; and the potential for an additional nuclear reactor at Calvert Cliffs or North Anna (action 3). The 2040 reduction figure represented here results in emissions levels that are 30% lower than 2012 and takes into account projected emissions growth to 2040.

Table 11. Greenhouse Gas Reductions for EBE-9

Action	Description	2020	2040	2050
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% Renewables Offset VA & DC	0.64	1.46	1.46
	"Preferred Portfolio" Total GHG Reductions ($MMTCO_2e$)	**1.97**	**10.74**	**10.74**

Strategy Co-Benefits

Table 12. Co-Benefit Results for EBE-6

Co-Benefit	Description of Co-Benefit
Air quality benefits	Retiring coal plants regionally will benefit MWCOG jurisdictions and the wider region by reducing criteria air pollutant as well as GHG emissions from these facilities.
Regional job creation	Building additional power generation will generate new jobs within regional communities and provide economic stimulus via private and public sector investments. Exact locations of new facilities, however, cannot be pinpointed at this stage.

Strategy Costs

Table 13. Costs for EBE-6

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium	MWCOG member costs would be relatively low, as costs would largely be borne by power sector generation owners and developers.	Private sector costs will depend in part on how federal and state policies implement Clean Air Act regulations. EPA provides broad flexibility in its compliance guidance, and private sector impacts will depend on the details of state compliance plans and private sector responses.

Strategy Implementation Issues

These potential actions outlined in this strategy are for the most part out of the direct control of COG members and in the hands of state and federal regulators and power sector generation owners and developers. MWCOG members can, however, engage with regulators and stakeholders in Maryland and Virginia to express their views on these issues. In particular, Clean Power Plan compliance plans are due to be completed by 2018 (though litigation may extend this timeframe or modify or vacate the rule), and MWCOG members may want to become active in these processes.

Renewable Energy for Existing Buildings (EBE- 2) – This strategy would increase the use of renewable energy in existing buildings through supporting and providing incentives for the distributed deployment of renewable energy sources including solar PV, wind and other technologies that may become viable in the 2020 to 2050 time frame.

Strategy Greenhouse Gas Reduction Benefits

Table 14. Greenhouse Gas Reductions for EBE-2

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	1.15	1.86	2.78
Electricity Reductions (MWh)	1,582,167	3,654,453	5,468,655

Strategy Co-Benefits

Table 15. 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.

Strategy Costs

Table 16. Costs for EBE-9

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium	Actions contemplated under EBE-2 generally have low program and implementation costs, though EBE-2.4 costs may be higher depending on the planned incentive levels.	Private sector costs can be medium to high depending on the technology chosen and the specific installation. Individuals and organizations willing to pay for “green” may incur higher costs; but PV and other renewable cost trends show rapid declines, and business models for some technologies such as solar PV are proving financially attractive.

Strategy Implementation Issues

Solar PV and other renewable energy initiatives can range greatly in scope and cost, from the relatively simple Solarize campaigns that have sprung up in the region, to sophisticated community solar projects and large facility installations. Implementation issues include: defining MWCOG roles in promotion, regulatory support, and financial incentives; defining utility roles in supporting renewable installations on customer sites, which can range from net metering to feed-in tariffs to owning and installing equipment; and the future of federal and state policies and programs, from the federal renewable tax credits to state RPS policies and utility interconnection rules.

<u>Targeted Reductions in Natural Gas Pipeline Emission (EBE- 7)</u> – This strategy would reduce emissions from natural gas leaks in the COG region by encouraging gas utility company investments to reduce pipeline emissions and supporting their cost recovery requests for these investment at regional utility commission meetings.

Strategy Greenhouse Gas Reduction Benefits

Table 17. Greenhouse Gas Reductions for EBE-7

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO_2e)	0.02	0.11	0.11
Methane (CH_4) emissions (MT)	601	4,205	4,205

Strategy Co-Benefits

Table 18. Co-Benefit Results for EBE-7

Co-Benefit	Description of Co-Benefit
Safety improvement	By reducing fugitive emissions, this strategy will also reduce the potential for fires, explosions, and other health risks.
Local Job Growth	Leakage reduction investments will support jobs in the gas utility, pipe and materials manufacturing, engineering, and construction sectors

Strategy Costs

Table 19. 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.
Cost Savings Reductions in gas distribution system emissions will reduce utility losses. The resulting loss reductions will reduce utility fuel costs, which will offset capital investments in leak reductions.		

Strategy Implementation Issues

This strategy is relatively straightforward from a MWCOG member perspective. The primary implementers will be the region's gas companies; MWCOG members can best support their efforts by expressing support for approval and cost recovery at the region's utility commissions. There may also be steps that MWCOG members can take to support local construction activities at specific pipe locations.

Waste Reduction Strategies

Targeted Reductions in Municipal Solid Waste (EBE-8) – This strategy would reduce emissions from municipal solid waste by increasing the recycling rate to 75%, increasing reuse of construction and demolition waste by 15% by 2020 and by 100% by 2050, diverting 100% of organic waste from landfills by 2040, implementing green purchasing programs; and increasing use of waste to energy and landfill gas projects.

Strategy Greenhouse Gas Reduction Benefits

Table 20. 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

Strategy Co-Benefits

Table 21. Co-Benefit Results for EBE-8

Co-Benefit	Description of Co-Benefit
Local Job Growth	Many of the jobs for improving recycling and C&D reuse rates require local staff to perform on-site work.

Strategy Costs

Table 22. Costs for EBE-8

Level	Public Sector Costs	Private Sector/Other Costs
Low	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. MWCOG members may also experience decrease in their waste management costs.		

Strategy Implementation Issues

MWCOG members will be the driving agents in this strategy to the extent their waste management policies, contracts, and facilities are the focus of policy and program actions. Many members are already pursuing the goals outlined in this strategy, and can contribute to the strategy's target by coordinating and ramping up their efforts. Specific implementation issues may vary widely, from raising and restructuring waste collection fees, ramping up recycling programs, modifying tipping fees and other elements of managing construction and demolition wastes, expanding composting efforts, constructing waste-to-energy facilities, and revising purchasing procedures to minimize the impact on the waste stream.

Non-Road Engine Strategies

Reduce Emissions from Non-Road Engines (EBE-9) – This strategy would reduce CO_2 emissions from non-road engines by increasing the market penetration of energy-efficient back-up generators, construction equipment, agriculture, lawn and garden equipment, construction equipment, commercial and industrial equipment, recreational equipment and other non-road engine equipment listed in the COG Gold Book. Also, idling reductions and electric alternatives will reduce non-road engine emissions.

Strategy Greenhouse Gas Reduction Benefits

Table 23. Greenhouse Gas Reductions for EBE-9

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

Strategy Co-Benefits

Table 24. 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.

Strategy Costs

Table 25. 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 Higher-efficiency technologies will reduce fuel use and operating costs.		

Strategy Implementation Issues

Electrification of some non-road engine equipment has been supported by the electricity utility industry and other stakeholders. If such efforts ramped up in the region, this would reduce direct CO_2 emissions from the equipment that is electrified, but this would also increase electricity demand on the regional grid and thus generate increases in power sector emissions. On balance, it is expected that net emissions would decrease, but this depends on the efficiency of the electric-powered equipment, and on the future marginal emissions rates in the power sector.

Implementation issues may also interact with criteria air pollutant policy implementation. For example, if reducing non-road emissions becomes a major element of regional NOx or other air quality compliance efforts, that could drive electrification and other off-road emission reductions that would also provide GHG emission benefits.

Land Use Strategies

Land Use Strategies – Impacts on Reducing Growth in VMT

Sustainable Development Patterns and Urban Design (TLU-2) -This strategy would reduce the growth in emissions from passenger vehicles by directing more of the region's anticipated growth and redevelopment to locations that are currently or will be, in the future, less reliant on autos for daily travel. This strategy would be implemented by focusing almost all of the region's new development in walkable, mixed use activity centers served by premium transit (Metrorail, Commuter rail, LRT and BRT), and also by trying to lessen regional imbalances in population and employment toward more balanced jobs/housing ratios.

Strategy Greenhouse Gas Reduction Benefits

Table 26. Greenhouse Gas Reductions for TLU-2

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (strategy alone)	0.34	1.32	1.67

Strategy Co-Benefits

Table 27. Co-Benefit Results for TLU-2

Co-Benefit	Description of Co-Benefit
Safety	Compact development should lead to less auto use, VMT and congestion, which should reduce both exposure to and rates of incidents
Congestion Reduction	Compact development should lead to less auto use , VMT and congestion; however, congestion results may be mixed due to more compact, denser development.
Reliability	Lower congestion should mean fewer breakdowns of level of service and greater predictability of travel time; shorter trips should be less

Co-Benefit	Description of Co-Benefit
	prone to unpredictability
Air Quality (Criteria Pollutants)	Fewer vehicle trips, reduced VMT and more stable speeds should be helpful in reducing other 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
Accessibility	There should be more travel options (shorter trips, more destinations, other modes)
Weather resiliency	Preservation of natural ground cover by reducing development impact on land consumption; travel in compact multimodal environments is 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.

Strategy Costs

Table 28. Costs for TLU-2

Level	Public Sector Costs	Private Sector/Other Costs
Low direct cost – within existing planning functions.	Tradeoffs between costs and savings are complex, but compact development should be cheaper to provide infrastructure to sustain.	Should reduce housing and transportation costs for households, improve access for employers and commercial establishments

Strategy Implementation Issues

This is an aggressive strategy. About 60% of the region's projected future residential development and 75% of its projected commercial development is already forecast to occur in activity centers that comprise less than 10% of region's land area. Directing 100% of the region's future residential and commercial development to less auto-reliant locations currently planned to be served by premium transit services may be difficult given existing lifestyle preferences and market forces. Significant additional investments in transit capacity and service would be required to support this sustainable development pattern.

Land Use Strategies – Impacts on Building Energy Efficiency

Encourage Development in Activity Centers (EBE-3/TLU-2A) -More compact development in activity centers should reduce the growth in emissions from residential and commercial energy use. This strategy would be accomplished in part by reducing average dwelling unit sizes and the commercial firm floor space usage.

Strategy Greenhouse Gas Reduction Benefits

Table 29. 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 ($MMTCO_2e$)	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

Strategy Co-Benefits

Table 30. Co-Benefit Results for EBE-3

Co-Benefit	Description of Co-Benefit
Criteria Air Pollutants	Fewer vehicle trips, reduced VMT and more stable speeds should be helpful in reducing other criteria pollutants.
Energy savings	Lower consumption of fossil fuels for vehicle travel, possibly more efficient buildings in higher density locations.

Strategy Costs

Table 31. Costs for EBE-3

Level	Public Sector Costs	Private Sector/Other Costs
Unknown	Investment in transit and city infrastructure, counterbalanced against reduced cost for highway expansion and maintenance, plus other infrastructure	Potentially higher costs for building in infill and higher density areas, but counterbalanced by higher sales prices Employers should see reduced costs for employee travel

Strategy Implementation Issues

Currently, about 60% of the region's projected future residential development and 75% of its projected commercial development is forecast to occur in activity centers. Directing 100% of the region's future residential and commercial development to activity centers may not completely match with some desired lifestyle preferences for larger housing units and business establishment floor space needs.

Land Use Strategies to Increase Carbon Sequestration

Reduce Loss of Vegetation due to Sustainable Development Patterns and Programs to Increase Tree Canopy (TLU-1)

The land consumption associated with the planned growth between 2012 and 2040 is estimated to consume 48,465 of the region's current 949,891 acres of forest, and 86,935 of the 599,179 acres of undeveloped grassland. The carbon sequestration provided by the current forest and natural ground cover is estimated at 9.06 million annual metric tons; the losses due to development would reduce total sequestration in 2040 to 8.41 $MMTCO_2e$, a reduction of 0.65.

Under the TLU-2 alternative land use scenarios, the consumption of undeveloped lands would be less. Forested acreage loss would be reduced to 39,053 and grassland loss to 76,719.
In addition, a proactive strategy can be undertaken to expand region's capacity to sequester CO_2 emissions by expanding the region's tree canopy. The policy studied focused on an increase in canopy by 5% by the year 2040.

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 $MMTCO_2e$ of annual sequestration. The analysis 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 GHG benefits.

Strategy Greenhouse Gas Reduction Benefits

Table 32. Greenhouse Gas Reductions for TLU-1: Increase Urban Tree Canopy and Land Stewardship

Summary Metric	2020	2040	2050
GHG Sequestration – Avoided Less due to more compact development ($MMTCO_2e$)	0.10	0.50	0.54
GHG Sequestration – Increase due to expanding tree canopy ($MMTCO_2e$)	0.09	0.32	0.44
Total GHG Sequestration benefits ($MMTCO_2e$)	0.19	0.82	0.98

Strategy Co-Benefits

Table 33. Potential Co-Benefits from Retention of Tree Canopy

Co-Benefit	Description of Co-Benefit
Air Quality (Criteria Pollutants)	Leaves and needles have surface area that can allow for removal (deposition) of ozone, nitrogen dioxide, and to a lesser extent particulate matter. However, trees can also have adverse effects on air quality by releasing compounds which can react to form ozone and particulates, and by the release of allergens such as pollen. Also, forested areas do not require landscaping and other activities that use high-emitting appliances like lawnmowers and leaf blowers
Economic Vitality	Forests and urban trees add to an area's livability and serves as an amenity that can attract businesses and employees
Weather resiliency	Trees and natural cover are an important buffer against global warming and severe weather events, although trees can also cause damage during storm 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	Trees add important natural beauty to inhabited areas, as do forests and rural/agricultural lands to metropolitan areas.

Strategy Costs

Table 34. Costs for TLU-1

Level	Public Sector Costs	Private Sector/Other Costs
Estimated to cost approximately $245 million for tree reforestation (56,350 acres). This investment would be made gradually over time, however, at an average cost of $6.5 million per year.	Direct expenditures for tree planting. Indirect: potential loss of land area for economic development	Private developers would likely be required to plant trees or pay toward reforestation.

Strategy Implementation Issues

This policy could be implemented by either a public sector planting program or through voluntary or required planting by development entities in exchange for project approvals.

Transportation Strategies

Vehicle and Fuels Strategies

<u>Improve Fuel Economy of Light Duty Fleet (TLU-3)</u> – This strategy would reduce emissions by incentivizing the replacement of older less fuel efficient vehicles and the purchase of electric vehicles and charging equipment, implementing disincentives for the purchase of inefficient fuel vehicles (feebates) and adopting stricter low emission vehicle standards for the light duty fleet. This strategy would also promote and support the purchase of light-duty zero emission vehicles (ZEVs) by 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 offering tax credits for ZEV vehicle purchases. The analysis scenario assumed that ZEVs increase to 2% of the passenger vehicle population by 2020, 15% by 2040, and 25% by 2050 (beyond business as usual conditions).

Strategy Greenhouse Gas Reduction Benefits

Table 35. Greenhouse Gas Reductions for TLU-3: Improve Fuel Economy of LD Vehicle Fleet

Summary Metric (MMTCO$_2$e)	2020	2040	2050
Strategy Alone			
GHG Reductions: Fuel Consumption (strategy alone)	0.22	1.23	2.14
GHG Increase: Electricity Offset (strategy alone)*	(0.13)	(0.72)	(1.26)
Net GHG Reductions (strategy alone)	0.09	0.50	0.88

Note that the amount of electricity use associated with ZEVs is highly dependent upon power sector strategies, and this offset could be considerably lower with the implementation of energy sector strategies.

Strategy Co-Benefits

Table 36. 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.

Strategy Costs

Table 37. 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	Cost savings from driving a PEV can be up to $950/year due to reduced fuel costs

	implementation costs	

Strategy Implementation Issues

The emission reduction benefits of ZEVs are offset somewhat by increased emissions from electric utilities that would need to generate additional electricity to power these ZEVs. The size of this offset would depend on the composition of fuels used to generate this electricity and the diurnal pattern of the charging of these ZEVs. The extent to which charging infrastructure incentives accelerate the purchase of ZEVs is also currently unclear. ZEV incentives can be expensive and generally would require program administration at state/multi-state level. Feebate programs would also entail program admiration.

Increase Alternative Fuels in Public Sector Fleets (TLU-4) – This strategy would reduce emissions by increasing the number of alternative fuel vehicles, including ZEVs, in public sector fleets. This strategy would implemented through programs that fund purchases of alternative fuel school buses and transit bus fleets, convert existing garages and share alternative fuel facilities for school bus fleets, and increase the share of electric vehicles in light-duty public sector fleets (e.g., police cars, government vehicles, etc).

Strategy Greenhouse Gas Reduction Benefits

Table 38. 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

Strategy Co-Benefits

Table 39. 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

Strategy Costs

Table 40. Costs for TLU-4: Increase Alternative Fuels in Public Sector Fleets

Level	Public Sector Costs	Private Sector/Other Costs
Low (under $50 million)	Incremental costs of purchasing	-

*considering incremental costs of vehicle replacements	alternative fuel vehicles Costs associated with fueling stations	

Strategy Implementation Issues

This strategy results in relatively low GHG emissions reductions, given that public sector fleets comprise a small share of the total vehicles in the metropolitan area, but this strategy is very actionable and would show leadership and commitment of governments to climate action goals. 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. Deployment of ZEVs into the light-duty municipal fleet would entail significant upfront cost, there be total cost savings over the life cycle of these vehicles.

Low Carbon Fuel Standard (TLU-6) – This strategy would reduce emissions by implementing market-based programs to reduce the carbon intensity of on-road vehicle fuels through the use of lower-carbon alternatives (e.g. natural gas, electricity, biofuels, and hydrogen). This strategy would be accomplished through the adoption of a Low Carbon Fuel Standard (LCFS) within the COG region. The analysis scenario assumed a standard that reduces on-road fuel emissions by 10% by 2040 and by 15% by 2050, with implementation assumed to occur after 2020.

Strategy Greenhouse Gas Reduction Benefits

Table 41. Greenhouse Gas Reductions for TLU-6: Low Carbon Fuel Standard

Summary Metric (MMTCO$_2$e)	2020	2040	2050
GHG Reductions (strategy alone)	0	1.02	1.29

Strategy Co-Benefits

Table 42. Co-Benefit Results for TLU-6: Low Carbon Fuel Standard

Co-Benefit	Description of Co-Benefit
Criteria Air Pollution	Increased use of biofuels lower the carbon content of the overall motor vehicle fuel supply, which generally also results in improvements in criteria pollutant emissions.
Economic Vitality, Jobs, Equity	There may be some economic benefits associated with increased local production and distribution of alternative fuels.

Strategy Costs

Table 43. Costs for TLU-6: Low Carbon Fuel Standard

Level	Public Sector Costs	Private Sector/Other Costs

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).

Strategy Implementation Issues

A low carbon fuel standard requires legislative action, likely at the state level. Implementation issues associated with low carbon fuel standards in California, Oregon, and Washington suggests that there will likely be legislative hurdles, regardless of the jurisdiction that implements a low carbon fuel standard. And it is likely that the success or failure of the programs in other jurisdictions will have an impact if/when a low carbon fuel standard is pursued for the MWCOG region. Implementation of a low carbon fuel standard will require an agency to oversee and regulate the program. Oregon's program, for instance, requires the implementation of an online reporting tool for regulated parties, a mechanism to submit and the review of new lifecycle analyses of fuel pathway documents, and a mechanism for market participants to buy/sell/exchange credits. Moreover, a more comprehensive review of the supply and availability of alternative transportation fuels to the region will be needed to ensure the viability of such a program. This includes the consideration of the availability of low carbon liquid biofuels (like ethanol, biodiesel, and renewable diesel), natural gas (from fossil and renewable sources), electricity, propane, and hydrogen.

Truck Stop Electrification (TLU-5) – This strategy would reduce emissions by reducing idling by heavy-duty vehicles through the installation of truck-stop electrification (TSE) sites in the COG region. The scenario assumed one TSE location with 20 bays by 2020; six locations by 2040; and 14 locations by 2050.

Strategy Greenhouse Gas Reduction Benefits

Table 44. Greenhouse Gas Reductions for TLU-5: Truck Stop Electrification

Summary Metric (MMTCO$_2$e)	2020	2040	2050
GHG Reductions (Strategy alone)	<0.001	0.002	0.006

Strategy Co-Benefits

Table 45. 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.

Strategy Costs

Table 46. 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

Strategy Implementation Issues

Installation of TSEs would require public sector expenditures for the infrastructure, as well as on-going operating and maintenance (O&M) costs.

VMT Reduction Strategies

Travel Demand Management (TLU-9) – This strategy would reduce the growth in VMT and emissions from on-road vehicles by shifting more single driver commuters to carpools and vanpools, public transit, walking, and bicycling, as well encouraging more telecommuting. This strategy would be primarily accomplished by expanding employer-based incentives to more workers and substantially increasing the daily cost of parking for workers working in the region's higher density activity centers. By 2050, the scenario assumes mandatory employer-based incentives (subsidies for alternative modes provided by 100% of employers).

Strategy Greenhouse Gas Reduction Benefits

Table 47. Greenhouse Gas Reductions and Travel Impacts 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
GHG Reductions (MMTCO$_2$e)	0.13	0.24	0.54

Strategy Co-Benefits

Table 48. 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

Co-Benefit	Description of Co-Benefit
	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.

Strategy Costs

Table 49. 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	Parking pricing will increase costs on drivers. Employer incentives low costs of using transit or other options.

Strategy Implementation Issues

This strategy would need to be implemented on a consistent region-wide basis so not to influence the locational decisions of commercial establishments because of large disparities in daily parking costs.

Transit Enhancements (TLU-10) – This strategy would reduce the growth in VMT and emissions from on-road vehicles by shifting more daily travel from autos to transit through the reduction of transit travel times and waiting times. This strategy would be accomplished by increased circulator buses, enhanced commuter bus services, real-time bus schedule information, transit signal priority improvements, bus rapid transit improvements, expanded Metrorail/Commuter Rail, bus stop improvements, schedule coordination between transit agencies, permitting buses on highway shoulders establishing dedicated bus lanes, bus infrastructure improvements and transit access improvements. The scenario analyzed assumed a reduction of transit travel and wait times of 20% on average across the region.

Strategy Greenhouse Gas Reduction Benefits

Table 50. Greenhouse Gas Reductions and Travel Impacts for TLU-10: Transit Enhancements

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

Strategy Co-Benefits

Table 51. 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 provides for a more equitable and appealing community.

Strategy Costs

Table 52. Costs for TLU-10: Transit Enhancements

Level	Public Sector Costs	Private Sector/Other Costs
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. While many lower-cost transit enhancement strategies can be applied, achieving significant improvements in transit time regionally is assumed to require many investments regionally.	--

Strategy Implementation Issues

Significant new funding for increased transit capital and operating expenses would be required to implement this strategy.

Transit Fare Reductions (TLU-11) – This strategy would reduce the growth in VMT and emissions from on-road vehicles by shifting more daily travel from autos through transit reduction in the fares. This strategy would reduce transit fares by offering reduced price monthly transit passes, free bus-rail transfers and free off-peak bus service. The strategy analyzed assumed an average regional transit fare reduction of 20% by 2020, 25% by 2040, and 40% by 2050, likely partially funded through road pricing strategies.

Strategy Greenhouse Gas Reduction Benefits

Table 53. Greenhouse Gas Reductions and Travel Impacts for TLU-11: Transit Incentives/Fare Reduction

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

Strategy Co-Benefits

Table 54. 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

Co-Benefit	Description of Co-Benefit
	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.
Mobility	The reduction in transit fare makes transit 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 rider transit more accessible.

Strategy Costs

Table 55. Costs for TLU-11: Transit Incentives/Fare Reduction

Level	Public Sector Costs	Private Sector/Other Costs
High	Estimated at \$60 million - \$140 million for the period 2010-2020 in the Maryland Climate Action Plan; regionally, costs are significant	Savings for the consumer

Strategy Implementation Issues

Lower transit fares would require increased operating costs subsidies and may require some increase in transit capacity to serve increased demand.

Road Pricing (TLU-12) – This strategy would reduce the growth in VMT and emissions from on-road vehicles by implementing roadway pricing measures to discourage vehicle travel in the region. This strategy would be accomplished by implementing a \$5 per trip cordon charge to enter downtown DC (assumed implemented after 2020) and a \$0.10 per mile VMT-based charge on the region's road network (assumed for implementation by 2050).

Strategy Greenhouse Gas Reduction Benefits

Table 56. Greenhouse Gas Reductions for TLU-12: Road Pricing

Summary Metric	2020	2040	2050
Vehicle Miles Traveled percent change (passenger vehicles)	0	-0.3%	-7.8%
Vehicle Miles Traveled reduced (millions annually)	0	104	3,211
GHG Reductions ($MMTCO_2e$) – strategy alone	0	0.03	0.79

Strategy Co-Benefits

Table 57. 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.
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 air pollutant emissions.

Strategy Costs

Table 58. Costs for TLU-12: Road Pricing

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium direct costs for implementing pricing scheme.	Road/congestion and cordon pricing will generate significant 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

Strategy Implementation Issues

A cordon charge for trips entering downtown DC is in the District's MoveDC long range transportation plan, but is likely not to be implemented in the short-term. VMT-based road pricing is a relatively new concept and has only been tried out on a limited experimental basis. Because of the somewhat controversial nature of VMT-based road pricing and because it would require enabling legislation at the state level, this element of road pricing strategy was only considered a stretch strategy for 2050.

Operational Efficiency Strategies

Enhance System Operations (TLU-7) – This strategy would reduce emissions through includes a wide array of measures to improve the operating efficiencies of all vehicles traveling on the region's roadways. This strategy would be achieved through increased adoption of eco-driving practices by drivers, integrated corridor management on freeway and major arterial corridors, ramp metering, signal retiming, the use of roundabouts, intersection efficiency improvements, elimination of roadway bottleneck and the introduction and use of connected and autonomous vehicles in the region.

Strategy Greenhouse Gas Reduction Benefits

Table 59. 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

Strategy Co-Benefits

Table 60. 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.
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.

Strategy Costs

Table 61. 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;	Savings due to reduced fuel consumption and vehicle operating costs

	costs associated with outreach to promote ecodriving; costs associated with installing, operating, and maintaining V21 infrastructure.	

Strategy Implementation Issues

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 the relationship between vehicle operations improvements and potential induced vehicle travel. Eco-driving campaigns could be implemented at a cost comparable in cost to other mass marketing campaigns under the Commuter Connections program. As more vehicles directly incorporate eco-driving displays and autonomous vehicles enter the fleet these eco-driving campaigns can be phased out over the longer-term, but the widespread introduction of semi-autonomous or autonomous vehicles may not occur for another 15 years and there is a high level of uncertainty regarding the implications of semi-autonomous/autonomous vehicles on travel demand.

Reduce Speeding on Freeways (TLU-8) – This strategy would reduce emissions through greater enforcements of speed limits on freeways in the region.

Strategy Greenhouse Gas Reduction Benefits

Table 62. 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

Strategy Co-Benefits

Table 63. 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.

Strategy Costs

Table 64. 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

Strategy Implementation Issues

Despite the significant safety co-benefits, motorist compliance with posted speed limits may be difficult to achieve. Reducing speeding will require additional highway speed enforcement through deployment of additional law enforcement officers and electronic monitoring.

Public and Community Engagement Strategies

Most if not all of the Energy and Built Environment, Land Use and Transportation strategies analyzed as part of the MSWG work will require extensive and sustained education and community engagement efforts on the part of COG members. In recognition this report recommends that the community engagement efforts be implemented. While originally identified as an Energy and Built Environment Strategy (EBE-10), at the recommendation of the MSWG this Public and Community Engagement Strategy was expanded to be an integral part of the Land Use and Transportation Strategies. Specific GHG reductions for the Public and Community Engagement Strategy are not separately calculated because the outcomes of the public education and community engagement efforts are already encompassed in the calculation of GHG reduction benefits of the other strategies. Rather, the Public and Community Engagement Strategy is seen as an important and essential enabling mechanism to implement the other strategies.

The Maryland Department of the Environment (MDE) proposed two additional strategies for open and transparent communication in transportation planning (TLU-13) and in land development (TLU-14) which MDE considers vitally necessary to build the public and political support for investment in the sustainable development patterns envisioned in TLU-2 and reflected in the TPB's Constrained Long Range Transportation Plan (CLRP) and Transportation Improvement Plans (TIP). The full description of MDE's proposed TLU-13 and TLU-14 strategies are included in the Summary Report Appendices.

Combining GHG Reduction Strategies

It is important to note that the Energy and Built Environment, Land Use and Transportation strategies analyzed 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, 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 and reduce GHGs emitted per vehicle mile traveled. While combining these strategies together will maximize overall GHG reduction, each higher efficiency vehicle mile removed from the road would save fewer emissions (or considered alternatively, the improvement in vehicle fuel economy will be affecting fewer vehicles). Some of these impacts are substantial - For instance, land use and VMT reduction strategies will be about 25% less effective when implemented in combination with a strategy to increase the passenger vehicle fleet to 25% ZEVs. Similarly, the GHG effects of a strategy to reduce energy consumption in buildings will be affected by strategies that affect the GHG emissions from the power supply. 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.

Some strategies affect emissions across multiple GHG source categories. For instance, land use strategies will reduce on-road mobile sources (transportation combustion) emissions, as well as reduce building energy consumption. Similarly, ZEV strategies will reduce transportation combustion emission but increase electricity emissions. As a result, it is useful to look at the overall impacts of strategies by **emissions source,** particularly when considering future tracking and reporting of GHG emissions, or considering the feasibility of setting targets by source category.

The interactive overall effects of the strategies on electricity, other fuel use, and waste emissions are showing below. This table shows that the majority of emission reductions come from energy efficiency and power supply and renewable energy strategies. Overall, emissions among these source categories are estimated to be about 41% below 2005 levels with the implementation of all strategies.

Table 65: Electricity, Other Fuel Use, and Waste Emissions (MMTCO2e)

Electricity, Other Fuel Use, and Waste Emissions	GHGs (MMTCO2e)					
	2005	2012	2020	2030*	2040	2050
2005 BAU Projections	**51.87**	**57.00**	**62.86**	**69.15**	**73.75**	**78.35**
2015 "On the Books" Projections	**51.87**	**51.10**	**54.56**	**56.04**	**58.59**	**62.18**
Energy Efficiency			-3.82	-9.31	-14.96	-17.46
Power Supply			-3.14	-6.58	-10.02	-13.63
Non-Road Engines			-0.28	-0.57	-0.85	-0.85
Waste			-0.08	-0.12	-0.15	-0.27
Land Use			-0.01	-0.09	-0.16	-0.19
Increased Electricity from ZEVs			0.12	0.43	0.61	0.92
Total Impact from All Strategies	0.00	0.00	-7.21	-16.24	-25.53	-31.48
Net Projected Emissions	**51.87**	**51.10**	**47.35**	**39.80**	**33.06**	**30.69**
Projected Reductions from 2005 levels (%)		1%	9%	23%	36%	41%

Projected Reductions from 2005 BAU Projections (%)		10%	25%	42%	55%	61%

Table 66 summarizes the GHG effects for on-road mobile sources/transportation combustion.

Table 66: On-Road Mobile Combustion GHG Emissions

Transportation Combustion Emissions	GHGs (MMTCO2e)					
	2005	2012	2020	2030*	2040	2050
2005 BAU Projections	**22.58**	**25.17**	**28.14**	**31.25**	**33.13**	**35.00**
2015 "On the Books" Projections	**22.58**	**22.63**	**21.54**	**19.67**	**17.80**	**18.64**
VMT Reduction - Sustainable Development	0.00	0.00	-0.34	-0.83	-1.32	-1.67
VMT Reduction - Transportation Strategies	0.00	0.00	-0.30	-0.37	-0.43	-1.60
Vehicle / Fuels Strategies	0.00	0.00	-0.23	-1.26	-2.30	-3.53
Operational Efficiency Strategies	0.00	0.00	-0.34	-0.46	-0.57	-0.86
Total On Road GHG Impacts	***0.00***	***0.00***	***-1.19***	***-2.74***	***-4.30***	***-6.77***
Net Projected Emissions	**22.58**	**22.63**	**20.35**	**16.92**	**13.50**	**11.86**
Projected Reductions from 2005 levels (%)			10%	25%	40%	47%
Projected Reductions from 2005 BAU Projections (%)			28%	46%	59%	66%

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

The following table also summarizes the carbon sequestration benefits of these strategies. These are important benefits but not directly comparable to the 80% GHG reduction goal.

Table 67: Carbon Sequestration Benefits

	GHGs (MMTCO2e)					
	2005	2012	2020	2030*	2040	2050
Tree canopy increase			0.09	0.21	0.32	0.44
Reduced vegetation loss - Land Use Strategies			0.10	0.30	0.50	0.54
Total carbon sequestration benefits			***0.19***	***0.51***	***0.82***	***0.98***

Key Findings from Strategy Analysis

The results of the strategy analysis shown in **Error! Reference source not found.** and Table 66 show that the Energy Efficiency Strategies, especially those designed to reduce energy and water consumption in existing and new buildings, have the greatest potential to reduce GHG emissions by 2050 and could reduce the region's total GHG emissions by 17.7 MMTCO$_2$e. Most of these reductions would come from

2% annual energy and water use reductions in existing buildings through 2030 and achieving net zero energy use in new buildings by 2040 and 100% net zero energy use in new buildings by 2050.

Power Sector and Renewable Energy Strategies, especially targeted reductions in power sector emissions and increased deployment of distributed renewable energy sources for and in existing buildings, have the second largest potential for reducing GHG emissions by 2050 and could reduce the region's total GHG emissions by 13.6 $MMTCO_2e$. The greatest amount of these reductions would phasing out of coal in regional power plants by 2030, and achieving larger renewable energy offsets in MD, DC and VA.

More aggressive Land Use Strategies, especially those focused on directing more of the region's anticipated growth and redevelopment to walkable, mixed-use activity centers served by premium transit, also have significant potential for GHG reduction and could reduce the region's total GHG emissions in 2050 by 1.86 $MMTCO_2e$. Such land use strategies would achieve these reductions through reductions in the growth of daily vehicle travel, reductions in energy use resulting from smaller average dwelling unit sizes and more compact commercial floor space usage, plus yield a benefit of 0.98 $MMTCO_2e$ in carbon sequestration benefits by reducing the loss of trees and natural land cover and efforts aimed at expanding the region's tree canopy. These strategies also yield multiple additional co-benefits including increased accessibility for shorter walk and bike trips, more pedestrian oriented community amenities, and reduced runoff to the Chesapeake Bay from reduced impervious surfaces.

It is important to note that implementing the Land Use Strategies aimed achieving a sustainable development pattern will also require some complementary transportation investments. Significant investments in transit capacity and service will be required to support the sustainable development pattern envisioned. Additional investments in pedestrian, bike and other types of transportation amenities and services also be needed to facilitate circulation and movement within the mixed-use centers are an integral part of the Land Use Strategies.

Transportation Strategies also have significant potential for GHG reduction and could reduce the region's total GHG emissions in 2050 by 4.18 MMTCO2e, after accounting for offsetting increases associated with electricity emissions. Particularly important are changes in the vehicle fleet to include more fuel efficient vehicles and the adoption of stricter standards for reducing the carbon intensity of vehicle fuels. Incentivizing the purchase of light duty zero emission vehicles (ZEVs) and investing in a system of public access recharging stations can be an effective strategy in reducing on-road mobile source GHG emissions. Although these emissions reductions are offset somewhat by the increased emission from electric utilities that would need to generate additional electricity to power ZEVs, the power section GHG reduction strategies noted above can significantly reduce the size of this offset.

Travel demand management, transit service enhancement and travel pricing strategies also have the potential to make measureable reductions in transportation sector GHG emissions. Increasing the cost of auto travel through increased parking costs and implementing cordon and VMT-based charges and reducing costs for travel by transit, carpooling, walking and bicycling through employer-based incentives and reductions in transit fares would result in some shifts in daily auto travel to other modes and also somewhat dampen the overall level of daily trip-making by auto. The reduction in the relative level of vehicle travel from the combined effects of these measures would thus also lead to some additional GHG reductions.

Transportation strategies that enhancing system operations through improved roadside and vehicle technology, including the introduction of semi-autonomous and autonomous vehicles on the region's roadways, can also be an effective strategy for further reducing GHG emissions in the transportation sector, but in may be another 15 years or more before some of this new technology becomes widespread. In the shorter-term, mass marketing campaigns to promote the adoption of eco-driving practices by drivers can also have an immediate impact on reducing transportation sector GHG emissions.

Public and Community Engagement Strategies will an important and essential component of the region's effort to achieve its GHG reduction goals. To achieve the region's GHG reduction goals, individuals will need to better understand the size of this challenge and be motivated to change some of the ways that they live, work and travel in the region. The Public Community Engagement Strategies will need to include education via school curricula and public information campaigns on the benefits and costs of GHG reduction strategies in all sectors, energy and built environment, land use and transportation. Only though greater public and community engagement will the region find the support needed to implement the strategies that will move it closer to its desired GHG reduction goal.

GHG Reduction Strategies and the 2050 Goal

Table 68 below presents the estimated overall GHG emission reductions from implementing all considered Energy and Built Environment, Land Use and Transportation strategies in combination in relation to the region's 2050. It shows that beyond the reductions already anticipated from implementation of policies that are currently "on the books", significant additional reductions might be achieved from the Energy and Built Environment, Land Use, and Transportation strategies analyzed in this effort.

It is important to note that the 2050 reductions shown are based on very aggressive stretch strategies, which may not be 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 eco-driving mode) can be supported through regional and location actions, but will likely be driven by federal actions.

Despite the aggressive nature of the Energy and Built Environment, Land Use and Transportation strategies considered, implementation of all of these strategies would take the region about half the way toward achievement of its voluntary GHG reductions goal for 2050. With a projected 48% increase in population and a 68% increase in employment between 2005 and 2050, continued implementation of GHG reduction policies and actions that have already been put in place, or "On the Books," will keep the growth total regional GHG emission in 2050 to just 8% above 2005 levels and will reduce per capita GHG emissions by XX% from 2005 levels. With continuation of current policies and full implementation of the aggressive Energy and Built Environment, Land Use and Transportation strategies considered by the MSWG in this analysis, total GHG emissions in 2050 could be reduced to 43% of 2005 levels and per capita GHG emissions reduced by 87% from 2005.

Table 68: 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	32.2
Reductions from additional TLU Strategies	--	--	1.1	3.7	6.0
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%

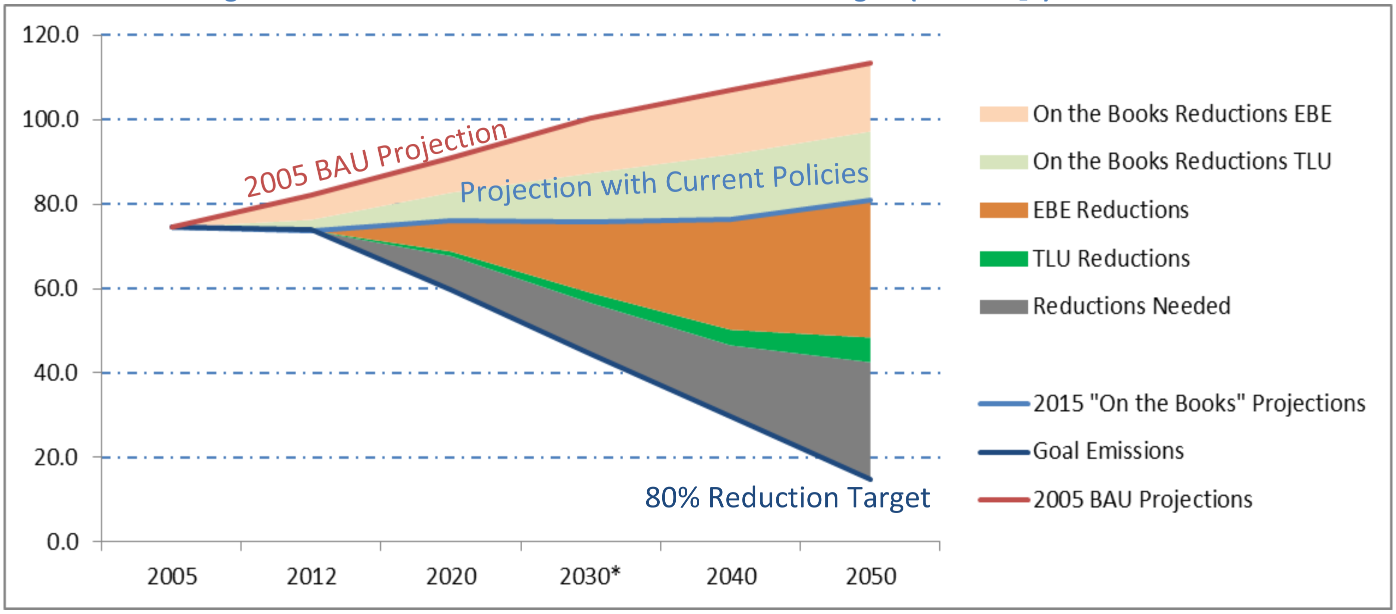
*The goal emissions were determined by using the goal of reducing GHGs to 20% below 2005 levels by 2020 and to 80% below 2005 levels by 2050. The interim years were linearly interpolated based on these data points. Carbon sequestration from TLU-1 was not included in the overall reductions.

Note that totals may not equal the sum of parts due to rounding.

Closing the GAP

After accounting for GHG reductions from current policies that are already "On the Books" and the Energy and Built Environment, Land Use and Transportation Strategies identified by the MSWG, there is still a 27.7 $MMTCO_2e$ gap in GHG emissions between the total potential GHG identified and the region's adopted voluntary 80% reduction goal for 2050.

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.

Further GHG reductions will be needed to close this gap. Potential additional strategies for closing this gap include:

- Clean Power Plan / More Nuclear Power
- New Fuel Economy / GHG Standards for Medium and Heavy Duty Vehicles and Engines
- New Natural Gas Pipeline Rule
- DOE Energy Efficiency Standards
- Life Cycle GHG reductions from products
- Higher light-duty vehicle fuel economy standards
- Expansion of Biofuels/ Fuel Cells/Battery Technology
- Improvements in Solar and Wind Technology
- Higher fuel taxes or carbon taxes