National Capital Region
Transportation Planning Board

October 30, 2015

To: TPB Technical Committee

From: Daivamani Sivasailam
Principal Transportation Engineer

Subject: Multi Sector Working Group (MSWG) Update

The MSWG met on October 27, 2015 and reviewed the technical analysis of the 22 strategies performed by the ICFI, discussed potential strategies for the COG board to consider as part of their action plan as well as goals and targets. The attached pdf file is made up of four documents that were reviewed by the group. They are:

1. The COG board resolution R59-2015
2. A summary document prepared by COG staff from the detailed ICFI prepared technical report.
3. National level strategy analysis to close the gap in reaching the greenhouse gas reduction goal of 80% below 2005 levels by 2050.
4. A power point presentation of the national level strategy analysis.

Attachment

Resolution R59-2015
October 14, 2015

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS
777 NORTH CAPITOL STREET, NE
WASHINGTON, DC 20002-4239

RESOLUTION DIRECTING THE COG STAFF TO PREPARE CONSENSUS RECOMMENDATIONS ON THE MULTI-SECTOR WORKING GROUP INTERIM TECHNICAL REPORT

WHEREAS, the Metropolitan Washington Council of Governments (COG) is comprised of the 22 jurisdictions of the National Capital Region's local governments and their governing officials, plus area members of the Maryland and Virginia legislatures and the U.S. Senate and House of Representatives, and COG provides a focus for action on issues of regional concern; and

WHEREAS, in January 2015 the COG Board of Directors, Transportation Planning Board, and the Metropolitan Washington Air Quality Committee supported creation of a Multi-Sector Greenhouse Gas Working Group; and

WHEREAS, the Multi-Sector Greenhouse Gas Working Group has convened many times throughout 2015 and presented progress reports to the COG Board in March 2015 and October 2015; and

WHEREAS, the Board would like COG staff to review all 22 proposed strategies and report back.

NOW, THEREFORE, BE IT RESOLVED BY THE BOARD OF DIRECTORS OF THE METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS THAT:

The Board provides the following direction to COG Staff regarding the Interim Technical Report recommendations from the Multi-Sector Working Group:

1) The Board acknowledges and formally expresses its gratitude to the members of the Multi-Sector Greenhouse Gas Working Group.

2) The Board directs the staff to prepare a consensus recommendation consisting of a package of greenhouse gas emission reduction strategies for incorporation into a regional action plan for consideration by the Board in January, 2016. The consensus recommendation would also address the exploration of goals and target that is part of the Multi-Sector workgroup mission.

3) The consensus recommendation shall be developed with the assistance of a policy level working group made up of elected official representatives drawn from the COG Board, TPB, MWAQC and CEEPC.

4) The final report shall include identification of the legal authority for any recommendation for mandatory actions or exclusions related to management of greenhouse gases.

I HEREBY CERTIFY THAT the foregoing resolution was adopted by the COG Board of Directors on October 14, 2015.

Monica Beyrouti
Clerk to the Board of Directors

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

Interim Summary Report

October 20, 2015

Introduction

The Metropolitan Washington Council of Governments (COG) Board, at the request of the Metropolitan Washington Air Quality Committee (MWAQC) and the National Capital Region Transportation Planning Board (TPB), convened a multi-sector, multi-disciplinary professional working group to identify and analyze implementable local, regional and state to reduce Greenhouse Gas (GHG) emissions in four sectors (Energy, the Built Environment, Land Use and Transportation). This study has been guided by input from a Multi-Sector Working Group (MSWG) made up of technical and policy staff from COG's member jurisdictions, states, and regional agencies with expertise in one or more of the sectors from which the region's GHG emissions come. The study also has incorporated input from COG policy committees including MWAQC, TPB, the Climate, Energy and Environment Policy Committee (CEEPC), and citizen advisory committees including the Air and Climate Public Advisory Committee and the Transportation Planning Board Citizen Advisory Committee.

The MSWG was convened by 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

The study represents a focused effort to examine broad sectors of the economy to identify potentially viable and stretch local, regional, and state actions to significantly reduce GHG emissions in accordance with the 2008 goals.

This Summary Report covers the first two phases of the work, identifying greenhouse gas emission reduction strategies in the four sectors, and evaluating their benefits, costs, and implementation challenges. It outlines the findings of this study, describes the process used to identify feasible scenarios, the methods used for analysis, and presents the results of the scenario analysis. It also provides background on past and projected future GHG emissions in the metropolitan Washington region.

Metropolitan Washington
Council of Governments

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 recommended for detailed quantitative analysis. Ten of these strategies addressed the combined Energy and Built Environment sectors and 12 addressed 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 Summary 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 COG Board adopted the *National Capital Region Climate Change Report* which established a set of 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 of what is needed to keep global temperatures within 2 ½ to 3 degrees Celsius.

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 early action to address climate change.[1] These goals were subsequently confirmed in the 2010 Region Forward Compact as a key part of achieving the region's vision for an accessible, sustainable, prosperous and livable National Capital Region.[2]

The *National Capital Region Climate Change Report* recommended that regional leaders 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 that 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$_2$e).[3] As shown in Figure 1, this inventory breaks out emissions from electricity generation; on-road motor vehicle transportation;

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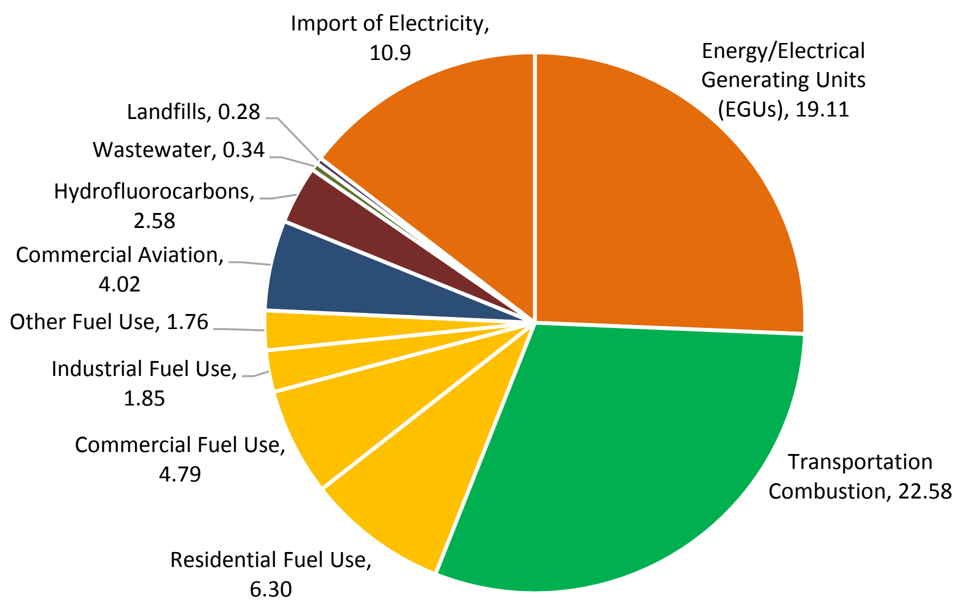
1 National Capital Region Climate Change Report, November 12, 2008. Executive Summary, page 9.

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

3 COG has recalculated, or backcasted, 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 69.2 MMTCO2e, or 14.6 metric tons per person.

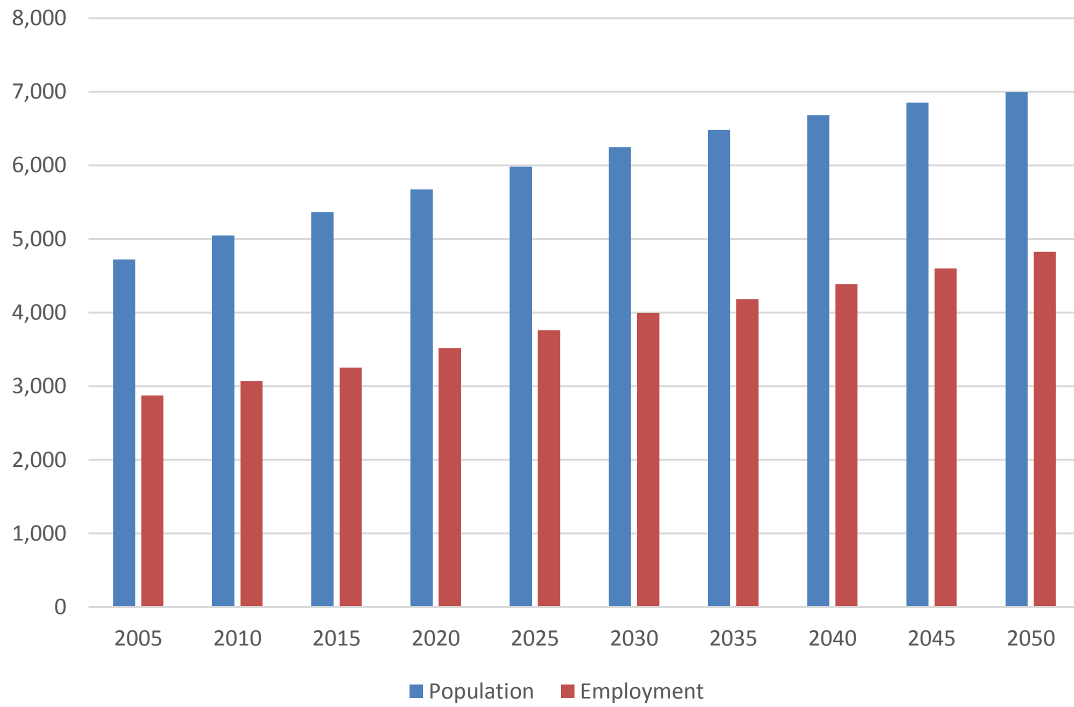
residential/commercial/industrial and non-road fuel use, commercial aviation fuel use; hydrofluorocarbons used as refrigerants and solvents, and methane from wastewater treatment plants and landfills. In 2005, electricity contributed about 40% of regional GHG emissions and combustion from on road motor vehicles contributed about 30% of regional GHG emissions.

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



Population and employment in the region was projected to increase significantly through 2050, as shown in. It was 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 was anticipated to grow even faster, by 68%, from 2.87 million jobs in 2005 to 4.83 million in 2050. Together this growth would 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



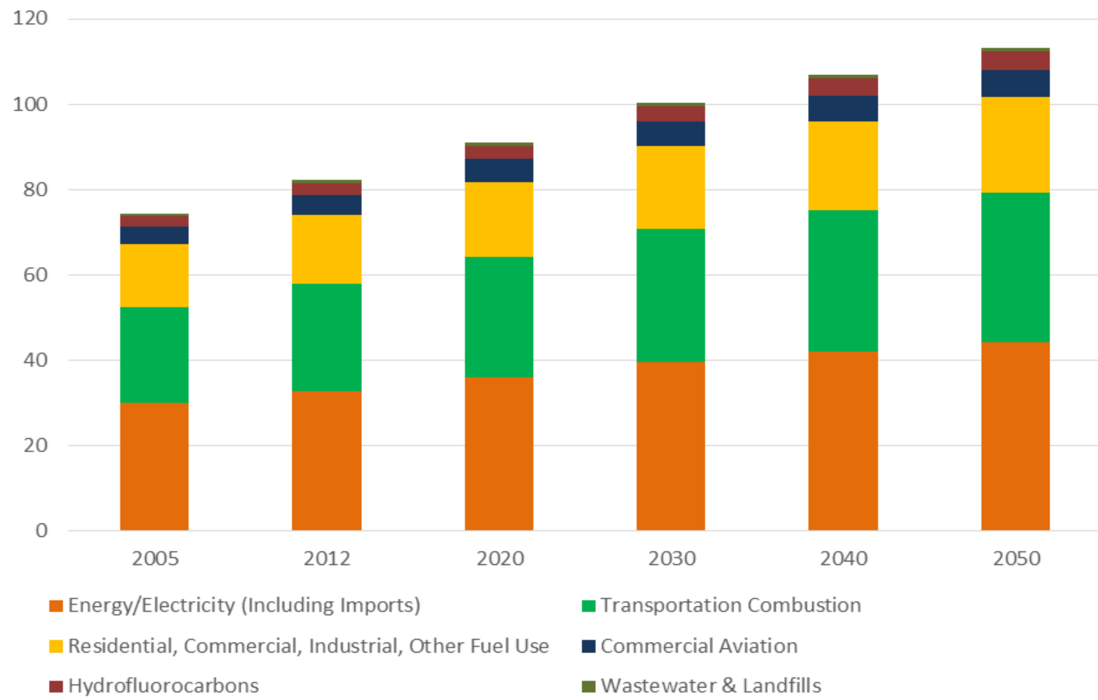
With no change in existing policy or practices from a 2005 baseline condition, the business as usual (BAU) scenario in the *2008 National Capital Region Climate Change Report* estimates that the region's projected future population and employment growth would result in a 23% increase in GHG emissions by 2020 over 2005 levels, a 33% increase over 2005 levels by 2030, and a 52% 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] 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 would need to decline by 86% from 15.76 MTCO_2e per person in 2005 to 2.13 MTCO_2e per person in 2050.

[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.

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



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 that the region's localities and states could take and is tracking progress toward these actions. COG also conducted focused analyses of transportation-related GHG reduction strategies through its *What Would It Take?* scenario study, and has explored various strategies that would reduce GHG emissions related to land use development.

Local policies in place include actions such as:

- 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 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 and Cool Counties, and have become Green Power Communities. In addition to these 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.

A significant reduction in emissions is also attributable to decreases in the emissions rate from generation of electricity. Electricity generators switched to fuel sources that produce fewer GHG emissions and increased the efficiency of their generating plants. The emission rate for the SERC Reliability Corporation-VACAR subzone covering Virginia dropped nearly 10% from 1153 lbs CO_2e/MWh to 1042 lbs CO_2e/MWh. Similarly, the emission rate for the Reliability First-East subzone covering the District of Columbia and Maryland, dropped approximately 13.5% from 1101 lbs CO_2e/MWh to 952 lbs CO_2e/MWh.

Looking forward, the electricity sector is forecast to continue to see reductions in GHG emissions compared to, with 2050 emissions projected to be 42% lower in 2050 than 2005 BAU projections. This results in electricity sector emissions being nearly flat (6% above 2005 levels, rather than 48% higher). Power sector projections were calculated using the 2012 COG regional emissions inventory, projected based on the percent change in power sector emissions in the Annual Energy Outlook (AEO) 2015 reference case GHG projections for the PJM[5] region. This reference case takes into account shifts 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.

Changes in other emission source categories, such as residential fuel use, commercial aviation, and landfills, were projected from 2012 levels using regional population and employment projections.

Further 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, changes in regional land use patterns, transportation investments, and policies in the Constrained Long Range Plan (CLRP) will reduce the rate of growth of vehicle travel.[6]

Based on these improvements, GHG emissions from transportation combustion are projected to be 17% lower in 2050 than in 2005 based on currently implemented policies and plans. This "on-the-books" 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 then are calculated to

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[5] 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.

[6] 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.

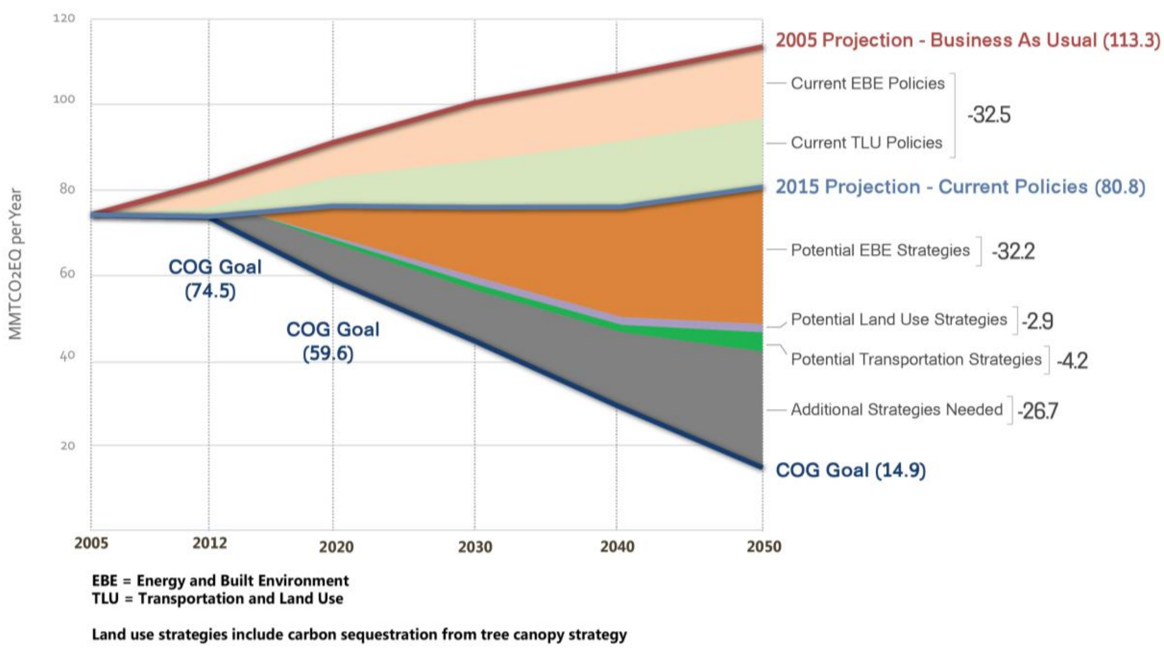
rise to 18.6 $MMTCO_2e$ in 2050, driven by increasing population and VMT and no further fuel economy improvements beyond 2040.

These projections in energy and transportation do not account for new federal regulations such as implementation of the federal Clean Power Plan, fuel efficiency standards for medium and heavy-duty vehicles and engines, and natural gas pipeline leakage reduction rules that are not yet final.

COG has recently completed a regional GHG inventory for 2012 to assess whether the region had met its first GHG reduction goal. The 2012 regional GHG inventory found that the region's emissions totaled to 68.7 $MMTCO_2e$, or 13.1 metric tons per person. The 2012 inventory shows that the region reduced GHG emissions by over 10% below the 2005 business as usual (BAU) baseline projections between 2005 and 2012—meeting COG's first GHG emission reduction goal

Combined, these multi-sector "on-the-books" policies will make a significant contribution to reducing GHG emissions in the Washington metropolitan region between 2012 and 2050. ICF analysis of these policies show that, if fully implemented, the policies are anticipated to result in 2050 GHG emissions of 80.8 $MMTCO_2e$, a reduction of about 32.5 $MMTCO_2e$ from the 2005 BAU scenario, as shown in Figure 4.

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



Pathways for Further Greenhouse Gas Reductions

While good progress is being made under current policies, significant additional actions will be needed to achieve the voluntary GHG emission reduction goals 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.

Through this study, COG's contractor, ICF International, has evaluated strategies identified by the Multi-Sector Working Group to reduce GHG emissions. The Multi-Sector Working Group originally identified 75 ideas for action. These initial ideas were screened for their potential emission reduction potential, implementation time frame, relative cost, viability, sector affected and co-benefits. This screening, together with grouping similar strategies together, resulted in a list of 38 individual strategies. This smaller set of strategies were further screened based on input from the MSWG and public comment, resulting in 22 strategies being selected for technical review.

The 22 strategies do not account for additional Federal policies which could have a significant effect on GHG emissions. The analysis focused on strategies that might be applied at the local, regional or state levels.

Strategies have been evaluated in eight groupings to account for the similarities and interactions among actions. Due to the interactions, the sum of individual strategies will not total to the combined GHG reductions. For example, increasing the CAFE fleet average miles per gallon would reduce the total GHG reductions from reducing vehicle miles traveled.

Energy Efficiency

Reducing energy use through efficient technology investments and improved facility operations is a proven practice that has been successfully pursued by businesses, homeowners, institutions, and federal, state, and local governments for decades. However, substantial additional savings are available through energy efficiency. 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, transportation and similar systems.

Power Sector and Renewables

Use of electricity in the region is one of the largest causes of GHG emissions, 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 from generation and delivery across the regional grid. Although some of these actions can be implemented within the region, some require federal-level policy action. Reductions can be achieved through implementation of the federal Clean Power Rule and renewable energy development, such as solar photovoltaic development.

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 that reduce landfill-based emissions.

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 result in fewer vehicle trips, shorter trip lengths, and more trips by transit, walking and biking. This would reduce GHG emissions from decreased daily vehicle miles traveled (VMT) in the region that would otherwise result from future population and employment growth.

Encouraging denser multi-family housing and commercial development also results in lower building energy consumption per dwelling unit or employee due to energy efficiencies and typically smaller average dwelling and office sizes.

Such development patterns are also more efficient in terms of land consumption, commanding less of a footprint on undeveloped land. 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 actions that would improve the fuel economy of the light-duty vehicle fleet, implementing a low carbon fuel standard, increasing use of lower emission alternative transportation fuels in public sector fleets, and implementing 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 in the passenger vehicle fleet could have a significant impact on reducing GHG emissions from on-road mobile sources, but these reductions would be partially offset by increased emissions from the power sector in generating additional electricity to power electric vehicles. 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 electric vehicles.

Reduction in the Growth of Vehicle Miles of Travel (VMT)

Daily travel by vehicles that burn fossil fuels are the main source of GHG emissions in the transportation sector. Currently, daily passenger vehicle miles of travel (VMT) in the region (not including heavy-duty vehicles, such as freight trucks) total more than 100 million miles. Even with local land use plans to concentrate more future growth in activity centers, daily passenger VMT is still anticipated to grow by over 25% by 2040 (31% when projected through 2050) with the region's overall expected increases in population and jobs, Reductions in this growth of VMT can reduce the growth of GHG emissions. These reductions can be achieved through transportation investments, policies, and strategies that encourage shifts from vehicle travel to options such as transit, ridesharing, biking, walking, and telecommuting. Travel demand management strategies that promote alternative modes of travel for commuting trips, enhance transit services, reduce the price of transit, manage parking, increase the price of vehicle travel and parking, and expand teleworking opportunities have the potential to reduce both the growth in VMT and GHG emissions.

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) affect fuel economy and emissions 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. Eco-driving can be furthered through public education and the use of in-vehicle technology, 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 has the potential of greatly improving the operational efficiency of vehicles operating on the region's roadways.

Analysis of Greenhouse Gas Reductions Strategies

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 sectors from which the region's GHG emissions come, identified 22 greenhouse reduction strategies for detailed quantitative analysis. Nine of these strategies addressed the combined Energy and Built Environment sectors and 12 addressed the combined Land Use and Transportation Sectors.

The twenty-second strategy is an overarching strategy addressing public education and engagement, critical to implement the other 21 strategies evaluated in this report. This report did not separately calculate greenhouse gas emission reductions from the public engagement strategies as the reductions are already encompassed in the calculations of the individual strategies.

Sketch planning methods were used to analyze the 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. Viable strategies were ones that were included in local plans in at least some localities across the region and that could be implemented by 2040. Stretch strategies go beyond current local plans, often requiring far-reaching policy actions, and would not likely be implementable until after 2040.

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 local and state strategies explored here also might be implemented in part through future federal actions. For example, increased adoption of electric vehicles can be encouraged regionally but also might be expanded 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, it is 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. The sketch planning methods address the direct impacts of strategies, but do not account for the indirect impacts of most strategies which would require more detailed travel modeling to assess. 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.

  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 analysis are provided in Table 1. This is followed by descriptions of the strategies 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, in descending order of GHG emission reduction benefits.

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
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.
* 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 and the built environment sectors come from a variety of strategies, implemented through multiple policy and program actions. The nine 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 through achieving a 2% annual reduction in energy and water use. The reductions would be achieved through 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.

Table 2. Greenhouse Gas Reductions for EBE-1

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO_2e)	2.73	10.55	10.55
Electricity Reductions (MWh)	2,406,764	14,671,915	14,671,915
Natural Gas Reductions (MMBtu)	15,843,725	44,920,334	44,920,334
Water Reductions (Gallons)	23,943	82,642	91,484

Table 3. Co-Benefit Results for EBE-1

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

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	Building benchmarking Private sector portion of efficiency investments First cost of compliance with building code policies
Cost Savings	Efficiency encompasses cost-effective measures that typically yield positive net present value over the study period. Numerous analyses show that a range of efficiency measures cost less than available energy supply options.	

Implementation Considerations

This strategy sets out an aggressive schedule to implement existing building energy efficiency improvements. No jurisdiction in the region has yet sustained 2% or better annual savings across the entire existing building stock over a 15-year period. However, most jurisdictions have already enacted policies such as commercial building benchmarking, supporting utility energy efficiency programs, strengthened building energy codes, 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 through implementing stringent building code/energy performance standards by 2020, providing that 100% of new buildings to use WaterSense fixtures by 2030, providing that 50% of new buildings be designed to be net zero energy use by 2040, and 100% of new buildings be designed to be net zero energy use by 2050.

Table 5. Greenhouse Gas Reductions for EBE-4

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	1.03	4.18	6.59
Electricity Reductions (MWh)	754,305	3,290,694	5,069,696
Natural Gas Reductions (MMBtu)	8,258,484	44,607,606	71,577,122
Water Reductions (Gallons)	0	196,932,718	323,257,485

Table 6. Co-Benefit Results for EBE-4

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	Energy efficiency lessens the demand for electricity and natural gas, resulting in fewer emissions 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.

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.	

Implementation Considerations

Implementation of EBE 4 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's infrastructure institutions. This would include 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.

Table 8. Greenhouse Gas Reductions for EBE-5

Summary Metric	2020	2040	2050
GHG Reductions (MMTCO$_2$e)	0.05	0.23	0.32
Electricity Reductions (MWh)	68,435	398,109	562,946
Natural Gas Reductions (MMBtu)	13,574	155,840	226,972

Table 9. Co-Benefit Results for EBE-5

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	Energy efficiency and renewable energy lessen the demand for electricity and natural gas, and also reduce direct facility emissions, resulting in fewer emissions from facilities and power plants.
Job Creation	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.
Resiliency	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.

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 show that a range of efficiency measures cost less than available energy supply options. Use of on-site renewables also reduces purchased energy costs.	

Implementation Considerations

Many of the region's infrastructure institutions are moving aggressively on energy efficiency, renewable energy, and other sustainability initiatives, with many efficiency and renewable improvements planned or in progress. These will need to be continued, and expanded, into the future. Costs would be borne through institutions' capital cost budgets, 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

Targeted Reductions in Power Sector Emissions (EBE-6)

This strategy would reduce total power sector emissions on a mass basis through implementation of the Clean Power Plan by Virginia and Maryland. A preferred portfolio of stretch strategies (out of 12 actions analyzed) would provide for additional to CO_2 emissions reductions from actions such as phasing out the use of coal in regional power plants by 2030 and installing additional units at existing regional nuclear plants or as an alternate building out offshore wind capacity in Virginia or Maryland waters, as well as adding an additional 20% renewable energy offsets in Maryland and an additional 10% renewable offsets in each of the District of Columbia and Virginia.

This preferred portfolio, shown in Table 11 below, focuses on those actions that would result in maximum impact on GHG emissions for the region. These would drive regional policy (actions 11 and 12 call for 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 or offshore wind (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-6

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 or offshore wind	0	4.28	4.28
11	Increase Renewables Offset by 40% by 2040 in MD	0	3.28	3.28
12	Increase Renewables Offset by 10% in VA & DC	0.64	1.46	1.46
	"Preferred Portfolio" Total GHG Reductions (MMTCO_2e)	**1.97**	**10.74**	**10.74**

Table 12. Co-Benefit Results for EBE-6

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	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.
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.

Table 13. Costs for EBE-6

Level	Public Sector Costs	Private Sector/Other Costs
Medium to high	COG 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 Power Plan. 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.

Implementation Considerations

The 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 at the state and federal levels, to support the recommended action. 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.

Table 14. Greenhouse Gas Reductions for EBE-2

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

Table 15. Co-Benefit Results for EBE-2

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	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.
Electric Reliability	Well planned use of distributed power and use of a broad portfolio of generation sources can increase electric system reliability.
Job Creation	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.

Table 16. Costs for EBE-2

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 depend 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.

Implementation Considerations

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 COG and local government roles in promotion, regulatory support, 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 whether or not there are ongoing, stable federal and state policies and programs such as federal renewable tax credits and state RPS policies and utility interconnection rules.

Targeted Reductions in Natural Gas Pipeline Emission (EBE- 7)

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 investments before regional utility commissions.

Table 17. Greenhouse Gas Reductions for EBE-7

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

Table 18. Co-Benefit Results for EBE-7

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	By reducing fugitive emissions, this strategy reduces the emissions of criteria pollutant ozone precursors.
Job Creation	Leakage reduction investments supports jobs in the gas utility, pipe and materials manufacturing, engineering, and construction sectors

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 have not been quantified.
Cost Savings	Reductions in gas distribution system emissions will reduce utility losses. The resulting loss reductions will reduce utility fuel costs, which helps offset capital investments in leak reductions.	

Implementation Considerations

This strategy is relatively straightforward with the primary implementers being 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. MWCOG members can also facilitate local permitting, access to street right-of-way, and coordinate other activities such as road resurfacing and other infrastructure improvements with the local gas utilities.

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.

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

Table 21. Co-Benefit Results for EBE-8

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

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 can realize cost savings through producing energy directly from waste or through landfill gas generation, or through production of new materials from recycled and composted waste. Materials reuse allows companies and individuals to avoid spending on new products. COG members may also experience decrease in their waste management costs.	

Implementation Considerations

COG members can 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 modifying waste collection and tipping fees, ramping up recycling programs, and other elements of managing construction and demolition wastes, expanding composting efforts, optimizing operation of 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 or lower emission back-up generators, and construction, agriculture, lawn and garden and commercial and industrial equipment, as well as recreational and other non-road engine equipment. Also, idling reductions and electric alternatives would reduce non-road engine emissions.

Table 23. Greenhouse Gas Reductions for EBE-9

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

Table 24. Co-Benefit Results for EBE-9

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	Many alternative technologies will have lower criteria air pollutant emissions as well as lower CO_2 emissions.

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.	

Implementation Considerations

Electrification of some non-road engine equipment has been supported by the electricity utility industry and other stakeholders. If such efforts are ramped up in the region, this would reduce direct CO_2 emissions from the equipment that is electrified, but would 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 and Building Energy Efficiency

<u>Sustainable Development Patterns and Urban Design (TLU-2)</u>
<u>Encourage Development in Activity Centers (EBE-3)</u>

These strategies jointly 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 lessening regional imbalances in population and employment toward a more balanced jobs/housing ratios.

More compact development in activity centers should also 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 and from use of more efficient building forms. Development in more dense activity centers also provides increased opportunities for use of more efficient distributed energy systems.

Table 26. Greenhouse Gas Reductions for TLU-2

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions – TLU-2 strategy alone ($MMTCO_2e$)	0.34	1.32	1.67

Table 27. 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

Table 28. Co-Benefit Results for TLU-2/EBE3

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 prone to unpredictability
Air Quality/Reduced Air Pollution	Fewer vehicle trips, reduced VMT and more stable speeds should be helpful in reducing criteria pollutants
Energy Savings	Lower consumption of fossil fuels for vehicle travel and building conditioning.
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)
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.
Stormwater	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.

Table 29. Costs for TLU-2/EBE3

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 and sustain infrastructure.	Potentially higher costs for building in infill and higher density areas, but counterbalanced by higher sales prices. Should reduce transportation costs for households and improve access for employers and commercial establishments

Implementation Considerations

About 60% of the region's projected future residential development and 75% of its projected commercial development are already forecast to occur in activity centers. Directing 100% of the region's future residential and commercial development to less auto-reliant locations currently or planned to be served by premium transit services could be challenging given currently adopted local land use plans, lifestyle preferences, market forces and the difficulties local jurisdictions would face in down-zoning existing development rights.

Significant additional investments in transit capacity and service would also be required to support this significant additional development in locations that currently or are planned to be served by premium transit services.

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 projected growth from 2012 to 2040 would 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$_2$e, a reduction of 0.54 MMTCO$_2$e.

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. 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.

Table 30. Greenhouse Gas Reductions for TLU-1

Summary Metric	2020	2040	2050
GHG Sequestration – Avoided Less due to more compact development (MMTCO$_2$e)	0.10	0.50	0.54
GHG Sequestration – Increase due to expanding tree canopy (MMTCO$_2$e)	0.09	0.32	0.44
Total GHG Sequestration benefits (MMTCO$_2$e)	0.19	0.82	0.98

Table 31. Potential Co-Benefits from Retention of Tree Canopy

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	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 regular 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.
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.
Stormwater	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.
Heat Island Effect	Adding additional green space reduces the heat island effects in urban areas.

Table 32. Costs for TLU-1

Level	Public Sector Costs	Private Sector/Other Costs
Low to medium Estimated to cost approximately $245 million for tree reforestation (56,350 acres). This investment would be made gradually over time, at an average cost of $6.5 million per year, and could be partially offset by timber harvesting in less developed parts of the region.	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.

Implementation Considerations

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, creation of silvicultural districts, or similar local policies.

Transportation Strategies

Vehicle and Fuels Strategies

Improve Fuel Economy of Light Duty Fleet (TLU-3)

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.

Table 33. Greenhouse Gas Reductions for TLU-3

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. The offset could be lower with the implementation of EBE-6 power sector strategies.

Table 34. Co-Benefit Results for TLU-3

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced 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.

Table 35. Costs for TLU-3

Level	Public Sector Costs	Private Sector/Other Costs
Medium ($50 million to $500 million)	Infrastructure improvements for widespread plug-in electric vehicles use ZEV incentive costs, and program implementation costs	ZEVs may have a higher first cost than conventionally fueled vehicles. However, cost savings from driving a ZEV can be up to $950/year due to reduced fuel costs

Implementation Considerations

The emission reduction benefits of electric vehicles are offset somewhat by increased emissions from electric utilities needed to generate additional electricity to power the 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 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 purchases of alternative fuel school buses and transit bus fleets, conversions of existing service facilities, development of additional shared alternative fueling facilities, and increases of the share of electric vehicles in light-duty public sector fleets (e.g., police cars, fleet vehicles, etc).

Table 36. Greenhouse Gas Reductions for TLU-4

Summary Metric (MMTCO$_2$e)	2020	2040	2050
GHG Reductions (strategy alone)	0.007	0.050	0.093

Table 37. Co-Benefit Results for TLU-4

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced 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

Table 38. Costs for TLU-4

Level	Public Sector Costs	Private Sector/Other Costs
Low (under $50 million), considering the incremental costs of vehicle replacements	Incremental costs of purchasing alternative fuel vehicles Costs associated with service facility updates and installing fueling stations	

Implementation Considerations

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 could 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.

Table 39. Greenhouse Gas Reductions for TLU-6

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

Table 40 Co-Benefit Results for TLU-6

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced 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 local economic benefits associated with increased local production and distribution of alternative fuels.

Table 41. Costs for TLU-6

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

Implementation Considerations

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 for such a standard to be put in place. It is likely that the success or failure of the programs in other jurisdictions will have an impact on if or 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 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.

Table 42. Greenhouse Gas Reductions for TLU-5

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

Table 43. Co-Benefit Results for TLU-5

Co-Benefit	Description of Co-Benefit
Air Quality/Reduced Air Pollution	Reducing heavy-truck idle time reduces vehicle emissions, notably oxides of nitrogen and particulate matter emissions from diesel trucks.

Table 44. Costs for TLU-5

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

Implementation Considerations

Installation of TSEs could require public sector support for capital costs of infrastructure, as well as on-going operating and maintenance 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).

Table 45. Greenhouse Gas Reductions and Travel Impacts for TLU-9

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_2e)	0.13	0.24	0.54

Table 46. Co-Benefit Results for TLU-9

Co-Benefit	Description of Co-Benefit
Congestion Reduction	Demand management is designed to reduce VMT, and thereby reduce traffic congestion; strategies that encourage telecommuting, transit, and other alternatives to driving will help in managing congestion
Air Quality/Reduced 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.

Table 47. Costs for TLU-9

Level	Public Sector Costs	Private Sector/Other Costs
Low (less than $50 million)	Incentive costs for TDM strategies 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.

Implementation Considerations

Some jurisdictions in the region would need enabling legislation from their state to mandate that employers in their jurisdiction offer parking cash out and/or transit benefits to their employees. Also, there is typically strong resistance and political opposition by businesses and residents in local communities to proposed parking caps and parking impact fees. Because the density of residential and commercial development varies considerably across different types of activity centers in the region, these differences would need to be taken into consideration in implementing parking caps and parking impact fees for these different types of centers.

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 use of 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.

Table 48. Greenhouse Gas Reductions and Travel Impacts for TLU-10

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$_2$e) - strategy alone	0.06	0.06	0.08

Table 49. Co-Benefit Results for TLU-10

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 lead to 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.
Air Quality/Reduced Air Pollution	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.

Table 50. Costs for TLU-10

Level	Public Sector Costs	Private Sector/Other Costs
High (Over $500 million)	Costs for significant transit enhancements were estimated in the Maryland Climate Action Plan at $1.55 billion to $1.74 billion for 2010-2020. Achieving significant improvements in transit time regionally is assumed to require significant investments regionally.	--

Implementation Considerations

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.

Table 51. Greenhouse Gas Reductions and Travel Impacts for TLU-11

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$_2$e)	0.12	0.10	0.19

Table 52. Co-Benefit Results for TLU-11

Co-Benefit	Description of Co-Benefit
Congestion Reduction	The reduction in VMT means that there will be fewer single occupancy vehicles on the road, which will reduce congestion, especially at peak times.
Air Quality/Reduced Air Pollution	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.

Table 53. Costs for TLU-11

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

Implementation Considerations

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).

Table 54. Greenhouse Gas Reductions for TLU-12

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

Table 55. Co-Benefit Results for TLU-12

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.
Air Quality/Reduced Air Pollution	Fewer cars on the road result in fewer vehicle miles traveled, thus reducing air pollutant emissions.

Table 56. Costs for TLU-12

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

Implementation Considerations

A cordon charge for trips entering downtown DC is in the District's MoveDC long range transportation plan, but would likely become controversial as efforts to implement this charge moved forward. Some are likely to question the fairness of this charge because it would have a more significant impact on middle- and lower-income workers who work in downtown DC, but may not have a good transit option. Also, some suburban commuters are likely to view this charge as DC "commuter tax".

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 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, the introduction and use of connected and autonomous vehicles in the region, and additional integrated corridor management on freeway and major arterial corridors, ramp metering, signal retiming, the use of roundabouts, intersection efficiency improvements, and elimination of roadway bottleneck.

Table 57. Greenhouse Gas Reductions for TLU-7

Summary Metric ($MMTCO_2e$)	2020	2040	2050
GHG Reductions (strategy alone)	0.34	0.56	0.85

Table 58. Co-Benefit Results for TLU-7

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.
Air Quality/Reduced 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. These operational parameters 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 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.

Table 59. Costs for TLU-7

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

Implementation Considerations

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 to other mass marketing campaigns under the Commuter Connections program. These eco-driving campaigns can be phased out over the longer-term as more vehicles directly incorporate eco-driving displays and autonomous vehicles enter the fleet. However, 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.

Table 60. Greenhouse Gas Reductions for TLU-8

Summary Metric (MMTCO2e)	2020	2040	2050
GHG Reductions (strategy alone)	0.005	0.006	0.006

Table 61. Co-Benefit Results for TLU-8

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

Table 62. 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

Implementation Considerations

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 will require extensive and sustained public education and community engagement efforts to be successful. In recognition, this report recommends that the community engagement efforts be implemented as part of the strategies.

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 also 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 essential enabling mechanism to implement the other strategies.

Two additional strategies have been proposed to provide for more open and transparent communication of emissions related to transportation planning (TLU-13) and land development (TLU-14). This is based on a concern that enhance communication necessary to build the public and political support for investment particularly 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 descriptions of the proposed TLU-13 and TLU-14 strategies are included in the Summary Report Appendices. These strategies are to be further considered in the next steps of the MSWG process.

Combining GHG Reduction Strategies

Energy and Built Environment, Land Use and Transportation strategies interact with each other so that the combined effects of implementing all strategies is less than the sum of GHG reductions from each individual strategy. For instance, within the transportation and land use sectors, several strategies (e.g., land use, 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. 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. 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.

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. Table 63 summarizes the GHG effects for electricity, fuel use and waste emissions. Overall, emissions among these source categories are estimated to be about 41% below 2005 levels with the implementation of all strategies.

Table 63. 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
Sustainable Development – Building energy 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 64 summarizes the GHG effects for on-road mobile sources/transportation combustion. Overall, emissions among these source categories are estimated to be about 47% below 2005 levels with the implementation of all strategies.

Table 64. 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.

Table 65 summarizes the carbon sequestration benefits of Land Use strategies. These strategies provide for sequestration of greenhouse gases, so differ from the other strategies that reduce emissions.

Table 65. Carbon Sequestration Benefits

Land Use Related Emissions	GHGs (MMTCO2e)					
	2005	2012	2020	2030*	2040	2050
Tree canopy increase			0.09	0.21	0.32	0.44
Sustainable Development - Reduced vegetation loss			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 reported in Tables 63, 64, and 65 shows 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. They could reduce the region's total GHG emissions by 17.7 $MMTCO_2e$. 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 half of new buildings by 2040 and all 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 come from implementing the Clean Power Plan, and achieving larger renewable energy offsets in the District of Columbia, Maryland and Virginia.

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.

More compact development also yields a benefit of 0.98 $MMTCO_2e$ in carbon sequestration benefits by reducing the loss of trees and natural land cover and 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.

Implementing the Land Use Strategies will require significant investments in transit capacity and service 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 $MMTCO_2e$, 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 partially offset by the increased emission from electric utilities that would need to generate additional electricity to power electric vehicles, 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. Shifting trips to more efficient modes through increasing the cost of auto travel such as 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.

Transportation strategies that enhance 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, it 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 essential component of the region's effort to achieve its 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 and on the risks we face from inaction. 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 66 presents the estimated overall GHG emission reductions from implementing the Energy and Built Environment, Land Use and Transportation strategies in combination by 2050. It shows that beyond the reductions already "on the books", significant additional reductions might be achieved from the strategies analyzed in this effort.

Many of 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 "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 principally driven by federal actions.

Implementation of these viable and stretch strategies would take the region about two-thirds of 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 the on-the-books GHG reduction policies and actions will keep the growth total regional GHG emission in 2050 to just 8% above 2005 levels.

With continuation of current policies and full implementation of the viable and stretch Energy and Built Environment, Land Use and Transportation strategies considered in this analysis, total GHG emissions in 2050 could be reduced to 43% of 2005 levels.   This would be equivalent to a reduction of 87% from 2005 on a per capita basis.

Table 66. GHG Reductions from Current Policies and Potential Future Policies

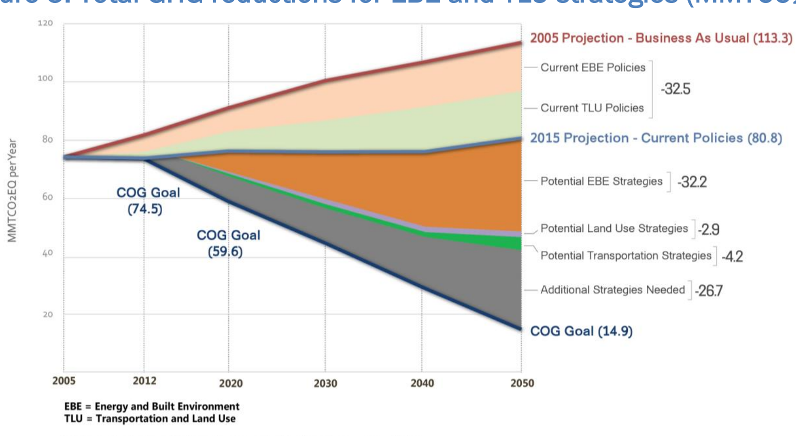
	GHG Emissions ($MMTCO_2e$)				
	2005	2012	2020	2040	2050
2005 BAU Projections	**74.5**	**82.3**	**91.3**	**103.3**	**106.3**
Revised 2005 BAU Projections	**74.5**	**82.2**	**91.0**	**106.9**	**113.3**
Reductions from Current Policies	--	8.4	14.9	30.5	32.5
2015 Current Policies Projection	**74.5**	**73.7**	**76.1**	**76.4**	**80.8**
Reductions from additional EBE Strategies	--	--	7.3	26.1	32.4
Reductions from additional TLU Strategies	--	--	1.1	3.7	5.9
Total Reductions from New Strategies	--	--	*8.4*	*29.8*	*38.3*
Carbon Sequestration			0.2	0.8	1.0
Net Projected Emissions	**74.5**	**73.7**	**67.5**	**45.8**	**41.5**
Projected Reductions from 2005 levels (%)	--	--	9%	39%	44%
Projected Reductions from 2005 BAU Projections (%)	--	10%	26%	57%	63%
Emission Reduction Goal*	**74.5**	**74.0**	**59.6**	**29.8**	**14.9**
Further Reductions Needed to Meet Goal	**–**	**-0.3**	**7.9**	**16.0**	**26.7**

*The emission reduction goals 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.
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 26.7 $MMTCO_2e$ 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 ($MMTCO_2e$)



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

- Local actions such as deeper financial and programmatic support for energy efficiency and renewable energy and increased investments in transit;
- Faster deployment of zero emission vehicles;
- Technology improvements;
- New fuel efficiency standards for medium and heavy-duty vehicles and engines;
- New Natural Gas Pipeline Rule;
- New energy efficiency standards for appliances and equipment;
- Increased fuel taxes / carbon tax;
- Reduction in commercial aviation GHG emissions;
- Faster deployment of zero emission vehicles;
- Expanded use of biofuels;
- Decarbonize power sector and carbon capture and storage; more nuclear power; improvements to solar; offshore wind power; and
- Lifecycle GHG reductions from products.

Next Steps

Following completion of this interim report, the MSWG will assess the feasibility of setting goals and targets by sector and enhancing communication of the change in GHG emissions from development. Additionally, the MSWG will further assess actions that could fill the gap to meet the region's 2050 goal.

The results of this assessment COG staff will present a final report to the COG Board, the National Capital Region Transportation Planning Board, the Metropolitan Washington Air Quality Committee and the Climate, Energy and Environment Policy Committee. COG staff will then work with its members and stakeholders to draft an Action Plan to implement the Board's and Committees' recommendations.

MEMORANDUM

To: Robert Griffiths, Multi-Sector Working Group Project Director

From: Benjamin Foster, Michael Grant, John Jameson, Cory Jemison, Jessica Klion, Lauren Marti, William Prindle, ICF International

Date: October 26, 2015

Re: Task 6: Explore GHG Goals and Targets in each Sector

The purpose of this memorandum is to present ICF's analysis of national level actions that could close the greenhouse gas (GHG) reduction gap to reach 80% by 2050. The national level strategies include actions that achieve GHG reductions through greater efficiencies in new and existing buildings, power sector improvements, and further reductions in the transportation sector through higher fuel economy standards and use of low carbon fuels. This memo also includes reductions achieved through increased commercial aviation efficiency and the reduction of hydroflourocarbons.

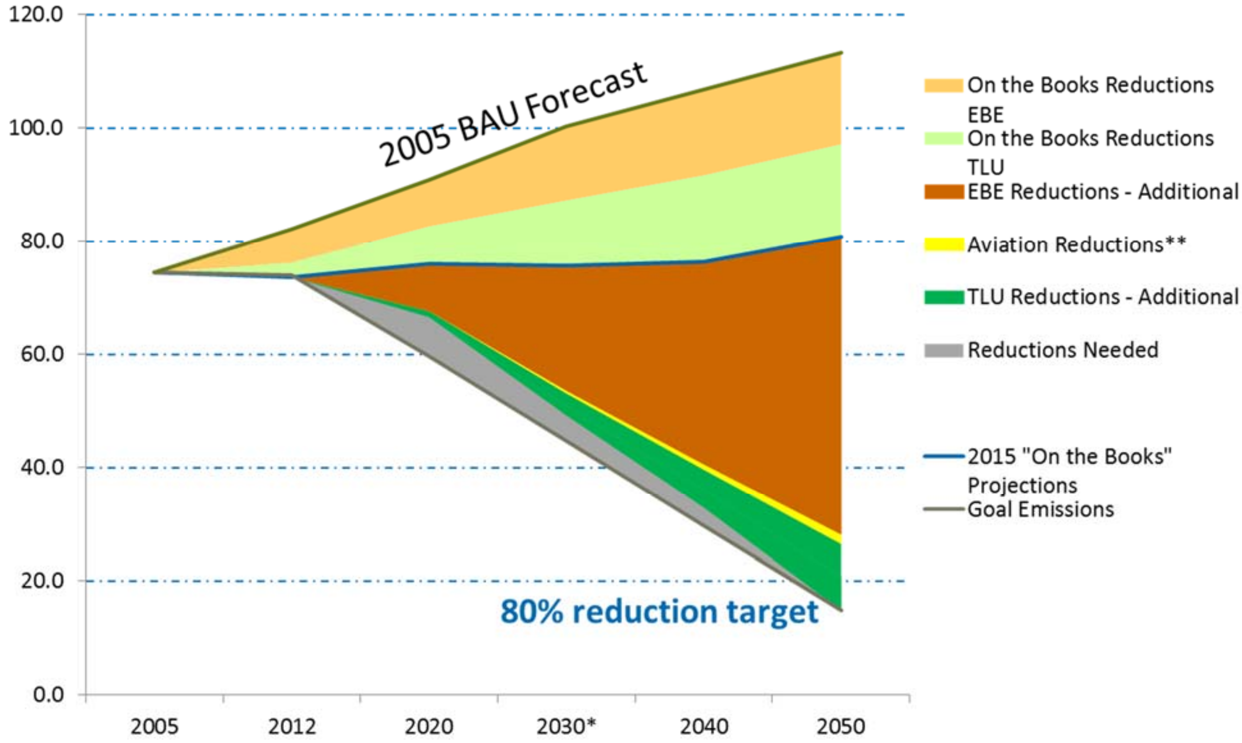
This memo serves as one of ICF's deliverable under Task 6 of this project.

The National Capital Region's goal is to reduce GHGs by 20 percent below 2005 levels by 2020 and by 80 percent below 2005 levels by 2050. Interim findings show that in order to achieve COG's GHG reduction goal for 2050, additional strategies beyond those identified by the Multi-Sector Working Group (MSWG) will be needed to further reduce the region's GHG emissions by another 27 to 39%. These additional strategies will likely require significant breakthrough improvements in existing technology and more substantial actions at federal, state, regional and local levels.

Studies addressing the technical feasibility of the U.S. to achieve significant reductions in CO_2 emissions from fossil fuel combustion have determined that it would be feasible. For instance, a study by the Sustainable Development Solutions Network, "Pathways to Deep Decarbonization" (2014) found that it would be technically feasible for the U.S. to reduce CO_2 emissions from fossil fuel combustion to 85% below 1990 levels, based on preliminary modeling results from several different scenarios (a main case, plus three alternative scenarios that more heavily emphasize renewable, carbon capture and storage, or nuclear power generation).

Taking an analogous approach with similar high-level national strategies applied to the COG region could provide a potential pathway to achieving the region's 80% GHG reduction goal. Accordingly, this analysis has generated estimates for potential additional reductions that could be realized in the energy, and transportation sectors. These estimates are summarized graphically in Figure 1.

Figure 1. Total GHG reductions for EBE and TLU strategies (MMTCO$_2$e)



*2030 emissions are interpolated from 2020 to 2040.

Further detail on the estimated impacts of these additional EBE and TLU national-level actions is shown in Table 1 through

Table 3. As shown in these tables below, the 80% reduction goal by 2050 – reaching 14.9 MMTCO_2e is achievable by implementing the national level actions described in this memo, in combination with regional level actions. Technologies to enhance energy efficiency, decarbonizing the power supply, shifting to low carbon fuels, and carbon capture and storage not only make up the gap, but also would overlap with or reduce the impacts of some potential regional strategies. For instance, decarbonizing the power supply means that energy efficiency strategies are less effective in reducing emissions per kwhr; similarly, more efficient motor vehicles means that reducing vehicle travel yields less emissions reduction per mile. Beyond on-road transportation, electric power, fuel use, and waste, additional potential reductions could also be achieved in commercial aviation and through the reduction of hydroflourocarbons, which are described following the energy and transportation reductions.

Table 1: Summary of Total GHGs with National and Regional Actions

EBE Improvements	GHG Emissions (MMTCO$_2$e)		
	2020	2040	2050
2005 BAU Projections	**91.0**	**106.9**	**113.3**
Impacts from Current Policies	-14.9	-30.5	-32.5
2015 "On the Books" Projections	**76.1**	**76.4**	**80.8**
EBE Impacts – Total National and Regional Policies	-8.3	-36.6	-54.3
TLU Impacts – Total National and Regional Strategies	-1.1	-6.8	-11.7
Aviation Reductions	-0.0	-0.9	-1.7
Total Reductions	***9.4***	***42.6***	***65.9***
Net Projected Emissions	**66.7**	**33.8**	**14.9**
Projected Reductions from 2005 levels (%)	10%	56%	80%
Projected Reductions from 2005 BAU Projections (%)	27%	69%	87%

*Note: Figures may not sum due to rounding; TLU reductions in this table account for the net benefit of transportation strategies, after accounting for off-setting electricity consumption.

Table 2: Summary of Total Additional Impact Estimates in Energy, Built Environment, and Other

EBE Improvements	GHG Emissions (MMTCO$_2$e)		
	2020	2040	2050
Energy BAU	62.9	73.7	78.3
Energy with Existing Policies (On the Books)	54.6	58.6	62.2
EBE Impacts from Regional Strategies (Original analysis)	-7.3	-26.1	-32.4
EBE Impacts from Additional National Policies*	-1.0*	-9.6*	-20.3*
Net Additional Impacts from Existing Buildings (EBE-1)	0.0	-2.1*	-1.5*
Net Additional Impacts from New Buildings (EBE-4)	-1.0*	-3.5*	-5.1*
Net Additional Impacts from the Power Sector (EBE-6)	0.0	-4.0*	-13.6*
Total EBE Impacts from Regional and National Actions	***-8.4***	***-35.8***	***-52.7***
EBE Emissions (After All Reductions)	**46.2**	**22.8**	**9.5**
% Reduction from 2005	-11%	-56%	-82%
% Reduction from 2005 BAU Projections (%)	-27%	-69%	-88%

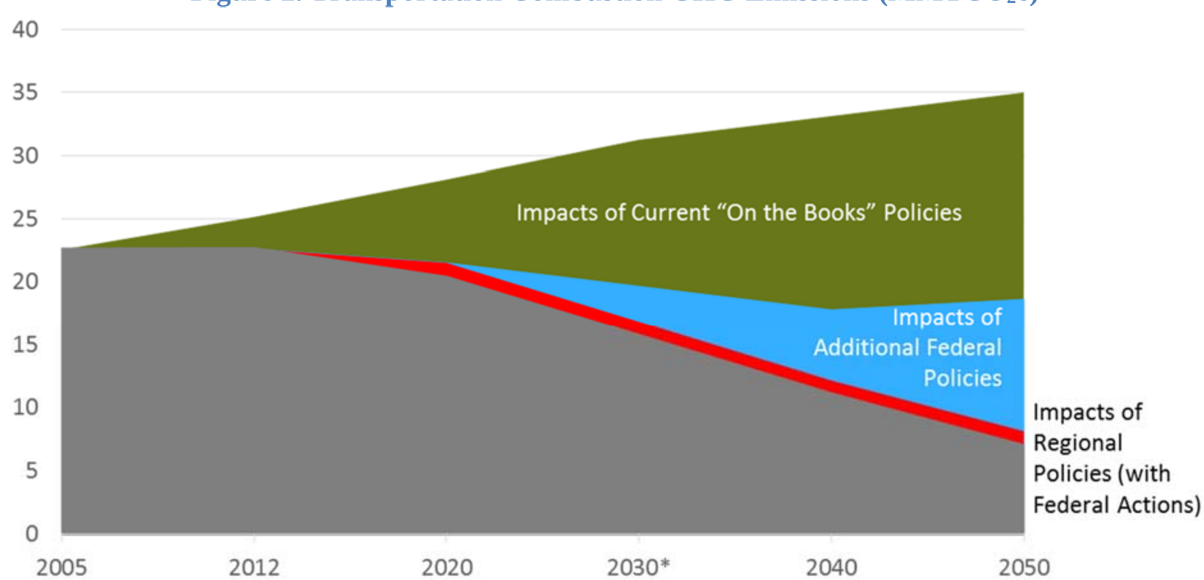
*Note: These figures are the incremental effects of national policies; in most cases, more stringent national standards and federal policies will overlap with and encompass many of the regional strategies.

Table 3: Summary of Impacts of Potential Federal and Regional Strategies on On-Road Transportation Combustion

	GHG Emissions ($MMTCO_2e$)					
	2005	2012	2020	2030*	2040	2050
Transportation Combustion Emissions						
2005 BAU Projections	**22.58**	**25.17**	**28.14**	**31.25**	**33.13**	**35.00**
Impacts of Current Policies		-2.54	-6.60	-11.58	-15.33	-16.36
2015 "On the Books" Projections	**22.58**	**22.63**	**21.54**	**19.67**	**17.80**	**18.64**
Impacts of Advanced Technology / National Actions				-2.82	-5.64	-10.51
Total With Additional National Actions	**22.58**	**22.63**	**21.54**	**16.85**	**12.16**	**8.13**
Impacts of Sustainable Development			-0.34	-0.58	-0.83	-0.60
Impacts of Other Regional Strategies			-0.85	-0.56	-0.27	-0.57
Net Projected Emissions	**22.58**	**22.63**	**20.35**	**15.70**	**11.06**	**6.95**
Projected Reductions from 2005 levels (%)			10%	30%	51%	69%
Projected Reductions from 2005 BAU Projections (%)			28%	50%	67%	80%

As can be seen in Figure 2 below, the combination of current "on the books" federal fuel economy and GHG emissions standards, combined with additional federal policies to significantly increase fuel efficiency and use of low carbon fuels would make a significant contribution toward reducing GHG emissions from on-road transportation. These federal policies would go beyond the impacts of regional strategies to increase ZEVs in the fleet and low carbon fuels (impacts of the regional strategies are encompassed within the more aggressive federal policy actions related to vehicles and fuels). With much more fuel efficient passenger vehicles, the impacts of land use, TDM, transit, pricing strategies, and vehicle operations improvement strategies on GHG emissions is also reduced.

Figure 2. Transportation Combustion GHG Emissions ($MMTCO_2e$)



Additional GHG Reduction Measures from the Energy Sector

In the Energy and Built Environment sectors, additional reductions were developed using a combination of more-stringent federal appliance standards, more-stringent state and local building energy codes, and reduced power sector emissions. These actions were added to the impacts calculated for strategies EBE-1, EBE-4, and EBE-6 respectively, and are described below

Existing Buildings

Doubling appliance standards impacts (within EBE-1). This supplemental analysis incorporated a 14% annual reduction in electric consumption from existing buildings from 2030-2050 based in increased impacts from appliance efficiency standards, and relates directly to EBE-1 of the strategy analysis.

In the initial scenario analysis, impacts of federal standards for products and equipment covered by the National Appliance Energy Conservation Act (NAECA) were assumed to be included in business as usual electricity forecasts, as the Energy Information Administration works to include such effects based on standards that are in effect at the time of a given forecast. However, a number of NAECA standards have been promulgated but have not yet become effective, or are still in the rulemaking process, and their effects have not been captured in business as usual forecasts.

Based on an analysis of such standards (Lowenberger et al. 2012)[1], it is estimated that new standards currently in the rulemaking pipeline could reduce national electricity usage by 7% in 2035, compared to the current business as usual forecast. The authors of this report are planning a new study anticipated to be issued in 2016, which is expected to double the projected impacts of the Lowenberger study.[2]

Based on these estimates, the analysis added an additional "stretch" action in EBE-1, representing a very aggressive and continuing push to drive appliance and equipment efficiencies. The analysis accelerated the 2035 projected impacts of the Lowenberger study to 2030, and then doubled them, holding those reductions constant through 2050.

New Buildings

Doubling energy code stringency (within EBE-4). For this supplemental action, the analysis took a similar approach for building energy codes as that applied to appliance efficiency standards. Building energy codes in the U.S. are a hybrid national/state/local policy matter: model codes are developed by the International Code Council and the engineering society ASHRAE, in whose code development processes federal agencies such as the Department of Energy participate. The applicable energy codes are the International Energy Conservation Code (IECC) for residential buildings, and ASHRAE Standard 90.1 for commercial buildings. Some jurisdictions use the commercial provisions of the IECC in lieu of

[1] Lowenberger et al. 2012. *The Efficiency Boom: Cashing In on the Savings from Appliance Standards.* American Council for an Energy-Efficient Economy, report no. A123
[2] Personal Communicatopm, Andrew DeLaski, Executive Director of the Appliance Standards Awareness Project (ASAP), 10/20/15.

ASHRAE standards. States then adopt model codes, often with implementing amendments. Local jurisdictions then implement and enforce codes under governing state law and regulations.

To develop additional impacts from energy codes, this analysis doubled energy savings impacts from the original estimates, based on a more aggressive assumption that national mode code stringency, supported by state adoption and local enforcement, would make new buildings twice as efficient.

In the original analysis, code stringency was increased in modest increments from 2015 to 2027, with a cumulative improvement in stringency of just over 20% by 2027, compared to the 2015 IECC and ASHRAE Standard 90.1. For this more aggressive action, it was assumed that building energy code stringency improve more rapidly, and will also continue beyond 2027, such that stringency would double by 2030, and would be held constant from 2030-2050. ICF's analytics work on the IECC indicates that from 1992 to 2012, the basic stringency levels of the national model energy code roughly doubled. This was used as a basis for projecting that stringency could be doubled again by 2030. This more aggressive analysis also used ICF's Clean Power Plan Energy Code Savings Calculator as the basis for impact estimates.

The impacts of added code stringency were added to EBE-4, without adjusting for the "net zero" actions in EBE-4 (50% of new construction to be net zero at 2040, 100% at 2050). In the net zero concept, renewable technologies such as photovoltaics would normally be added to new buildings, or renewable energy credits would be purchased, such that renewable product or credits fully offset building site energy usage. That would suggest that if code stringency were increased, electricity use would fall, and renewable impacts would be reduced accordingly. However, for this "what would it take" analysis, the renewables impacts were held constant. This produces a "net producer" effect, such that the buildings sector in this more aggressive action would provide a net positive contribution to the region's electric grid via distributed generation under the strategy's net zero policies. While such a future is very aggressive, it is also worth noting that new photovoltaics collectors have recently come into the market that promise 40% improvements in conversion efficiencies. Such technology advances, coupled with new buildings efficiency improvements, could well make the buildings sector a net contributor to the region's energy system.

Power Sector

Reducing power sector emissions factor (within EBE-6). Additional reductions in the energy sector could be realized in EBE-6 in order to achieve the MWCOG regional goal of reducing emissions by 80% in 2050. Once the additional emissions reductions from standards and codes impacts were estimated, the power sector emissions rate was reduced to the level needed to reach the total 80% reduction. The remaining power sector reductions could come from any number of federal and state policies, and private sector actions, including:

- Successor policies to the current federal Clean Power Plan, which could force further reductions in emissions rates in the post-2030 period;
- Additional increases in state Renewable Portfolio Standards (RPS), which could increase District of Columbia, Maryland, and Virginia utilities' acquisition of renewable generation;

- Increasingly rapid transition away from coal power facilities to natural gas, nuclear and/or other less carbon intensive fuel sources due to market or other regulatory forces;
- Additional green power purchasing from MWCOG member governments, or from individual building owners, which could indirectly drive further renewable energy development in the regional power sector.

Additional GHG Reduction Measures from the Transportation Sector

In the transportation sector, achieving significant reductions in GHG emissions could be achieved through significant advancements in vehicle technologies and shifts to low carbon fuels across both light-duty (passenger) vehicles and medium and heavy duty vehicles. Technologies to achieve significant GHG reductions, along with federal policies to support these advancements, are described below.

Light-duty Vehicles

Advancing beyond Current Standards. Established by the Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA), the National Program for GHG and fuel economy standards are already forecast to result in significant reductions in GHG emissions from light-duty vehicles, and are accounted for in the COG analysis as "on the books" reductions from existing policies. This program sets fuel economy standards for light-duty cars and trucks through model year 2025 (first phase, 2012-2016, and second phase, 2017-2025), which significantly reduce the GHG emissions profile of passenger vehicles.[3] Together the final standards are projected to result in an average industry fleetwide level of 163 grams of CO_2 per mile in model year 2025, which is equivalent to 54.5 miles per gallon (mpg) if achieved exclusively through fuel economy improvements.[4] Moreover, the Renewable Fuel Standard (RFS), established in 2005, and the standard's 2007 amendment (RFS2) mandate the volumes of renewable fuels to be consumed by US transportation between 2008 and 2022. The standards mandate: 15 billion gallons/year of ethanol derived from corn grain or other biofuels; 1 billion gallons/year of biomass based diesel; and advanced biofuels from cellulose or certain other feedstocks that can achieve a life-cycle GHG reduction of at last 50 percent.

Potential Technologies and Further GHG Reductions. While these current policies yield substantial reductions in GHG emissions through 2030 and beyond, additional technologies, spurred through federal policies, could continue to yield additional reductions in GHG emissions from light-duty vehicles through 2050. A National Research Council report assessed the potential for reducing petroleum consumption and GHG emissions by the U.S. light-duty vehicle fleet by 80% by 2050, and found that four general pathways could contribute to attaining both goals: 1) highly efficient internal combustion engine vehicles; 2) vehicles operating on biofuels, 3) vehicles operating on electricity, and 4) vehicles operating on hydrogen.[5] These may include plug-in hybrid electric vehicles (PHEVs), battery-electric vehicles (BEVs), or fuel cell electric vehicles (FCEVs), which are similar to BEVs except that the electric power comes

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[3] CAFE Standards for 2022-2025 are not final, pending a midterm review.
[4] U.S. Environmental Protection Agency (EPA), Regulations and Standards website, available at: http://www3.epa.gov/otaq/climate/regs-light-duty.htm
[5] National Research Council, Division on Engineering and Physical Sciences, Committee on Transitions to Alternative Vehicles and Fuels. *Transitions to Alternative Vehicles and Fuels.* National Academies Press, Washington, DC: 2013.

from a fuel cell system with on-board hydrogen storage. It found that reductions of about 60 to 70% in light-duty GHG emissions relative to 2005 are potentially achievable by 2050, but that an 80% reduction will be very difficult (although technically achievable); in part, due to estimated increases in vehicle miles traveled. The National Research Council (NRC) study indicates that CAFE test values of 74 mpg might be achieved for the average of all conventional LDVs sold in 2050, with hybrid LDVs reaching 94 mpg by 2050 (on-road fuel economy is likely to be about 17 percent lower). The discussion below largely builds on the NRC study findings.

In addition to making all LDVs highly efficient so their fuel use per mile in greatly reduced, almost all petroleum-based fuels (gasoline and diesel) will need to be replaced with fuels with low net GHG emissions, such as biofuels, electricity, or hydrogen. For instance, in the scenarios with an emphasis on electric vehicles, these vehicles increase to about 80% of new light-duty vehicle sales, consistent with rates in previous study *Transitions to Alternative Transportation Technologies: Plug-In Hybrid Electric Vehicles* (NRC, 2010); in the scenario emphasizing internal combustion engine vehicle efficiency and biofuels, the share of petroleum-based gasoline as a liquid fuel falls to about 25%. This is an expensive transition that would likely need to be part of an economy-wide transition, given the expense and required infrastructure changes. In addition, the benefits of biofuels depends on how the biofuel is produced as well as on changes in land use that could impact GHG emissions. While studies provide evidence that enough biomass will be available in the future to produce adequate amounts of biofuels, longer term assurance of resources and costs are unclear. The costs of producing hydrogen and electricity long term are similarly unclear. Continued improvements in vehicle efficiency, especially load reduction through the use of lightweight materials, are also essential to achieving high GHG reductions were assumed in the NRC study in all scenarios as a key step in improving the feasibility of all the other pathways. Other opportunities include lowering rolling resistance (via tire materials and design, tire pressure maintenance, low-drag brakes), aerodynamics, and accessory efficiency (e.g., air conditioning, lighting, power steering).

Federal Policies to Advance Technology Adoption. Reaching these levels of GHG reduction by 2050 will require a significant policy role by the Federal government to support manufacturers in widely applying the new technologies, according to the NRC study. These would likely include significantly higher vehicle fuel economy standards, combined with policies to ensure they are achieved. Policies such as “feebates” (rebates to purchase high fuel-economy vehicles), taxes on low fuel-economy vehicles, or significantly higher fuel taxes, would assist manufacturers in selling the more-efficient vehicles produced to meet fuel economy standards. Moreover, federal research and development (R&D) investments related to fuel cells, batteries, biofuels, low-GHG production of hydrogen, carbon capture and storage, and vehicle efficiency can help to advance technology development and reduce the costs of alternative fuels and vehicles.

Despite its technical feasibility, several uncertainties remain. No one technology, such as improved efficiency in combustion engines and vehicles that run on biofuels, electricity, or hydrogen, can individually achieve the 80% GHG reduction by 2050, and the cost, implementation, and reception by the public of these technologies is unknown. While no entirely clear path forward exists, some steps are certain. For example, improvements in vehicle efficiency, like load reduction, will be necessary. Moreover, currently, alternative fuel and efficient vehicles are more expensive than conventional vehicles. Prices of these vehicles are not anticipated to fall rapidly enough to achieve the 2050 GHG goal.

As such, Federal action is necessary to fully incorporate alternative fueled and highly efficient vehicles into the market. Even with Federal action, shifting away from conventional vehicles will be a challenge. Costs of the new technologies will come before benefits are fully realized. If polices do not overcome the early, high cost of technologies, the transition to the new technologies will not occur. Moreover, the NRC study notes that there are high uncertainties due to economic feedback effects, which may include increased vehicle use associated with reduced motor vehicle energy costs and increased new vehicle demand with improved technology, as well as competition for market share among different advanced technologies.

Analysis Assumptions and Results. For purposes of this analysis, ICF assumed a 80% reduction in CO_2 eq. emissions per vehicle compared to 2012 levels; this is equivalent to about a 99 mpg overall average if achieved exclusively through fuel economy improvements.

Table 4: Estimated On-Road Transportation GHG Emissions Impacts of Further Increases in Light-Duty Vehicle Technology

	GHG Emissions ($MMTCO_2e$)		
	2020	**2040**	**2050**
Overall Impact of Further Technology Advancements to LDVs emissions	-	-4.20	-7.60

It is important to recognize that the high level of vehicle technology advancement assumed in this scenario means that many of the state/regional/local policy actions initially analyzed will have considerably diminished effectiveness. Specifically:

- Land use policies and VMT reduction policies will have significantly less benefit on GHG emissions reductions. Every vehicle mile reduced through these policies will eliminate just over one-third as much when compared to no further federal or regional actions (about 89 g CO_2 eq reduced compared to 247 g CO_2 eq) for 2050.
- Operational improvement strategies will also have significantly less benefit in a situation where a high portion of vehicles on the road are electric.
- The federal policies associated with achieving this level of improvement will encompass the advancements in ZEV share that were analyzed under TLU-3.

Other Implications. Just as in TLU-3 but to a higher degree, this policy will have important implications for transportation agency funding via the federal and state fuels taxes. With limited use of gasoline or diesel in light-duty vehicles, the primary source of the Highway Trust Fund and state funding for transportation investments will be eliminated, and there will be a need for new transportation funding mechanisms at the federal level.

Medium- and Heavy-Duty Vehicles

Proposed Standards Likely to be Implemented. The EPA's proposed Phase 2 regulations[6] for medium- and heavy-duty vehicles in June 2015 include performance standards designed to promote a diverse range of technologies that will reduce fuel consumption and decrease CO_2 emissions. The EPA's Preferred Alternative (also known as Alternative 3) will deliver fuel reductions ranging from 13–24% in combination tractors by model year 2027, reduce fuel consumption from trailers by 4–8%, and reduce fuel consumption from vocational vehicles (in Classes 2b-8) by 7–16%. ICF estimates that the Phase 2 regulations could reduce GHGs per mile by about 30% from 2012 levels by 2040–2050.

Potential Technologies and Further GHG Reductions. It is conceivable that further federal regulations could improve fuel economy of medium- and heavy-duty vehicles further. For instance, analyses by the Union of Concerned Scientists (UCS),[7] International Council on Clean Transportation (ICCT),[8] the National Research Council,[9] and TIAX LLC[10] find that the technologies required to achieve fuel consumption reductions in the medium- and heavy-duty vehicle sectors can be adopted cost-effectively with payback periods ranging from 1–5 years. The following is a summary of the maximum achievable improvements and corresponding fuel economies for relevant medium- and heavy-duty vehicles.

- Heavy-duty pick-ups and vans: ICF estimates an improvement in heavy-duty pick-ups and vans is 10–15% with a fuel economy upwards of 15–16 mpg.
- Vocational vehicles: ICF estimates an improvement of vocational vehicles around 75%, depending on vehicle type, with fuel economies in the range of 11.7–15.5 mpg.
- Tractor-trailers: Tractor-trailers can improve fuel economy by 45–56% with a fuel economy range of 9.6–11.4 mpg.

These changes could be implemented through expansion or acceleration of the federal program as early as MY2024 by varying amounts, with an estimated maximum annual increase in fuel economy of 4%.

In addition to the fuel economy improvements for medium- and heavy-duty vehicles outlined above, the implementation of a low carbon fuel standard program could help reduce emissions further. Low carbon fuel standards are based on a performance target, not a volumetric target. In that regard, the absolute emission reductions attributable to the program are dependent on the forecasted volumes of diesel. The decreasing demand for diesel as a result of improved fuel economy would yield a lower absolute emission reduction potential of a low carbon fuel standard. However, with the low carbon fuel standard incentivizing the use of liquid biofuels such as biodiesel and renewable diesel, as well as the consumption

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[6] Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2, Federal Register, Vol. 80, No. 133, July 13, 2015. Available online at http://www.gpo.gov/fdsys/pkg/FR-2015-07-13/pdf/2015-15500.pdf

[7] Union of Concerned Scientists, Big Fuel Savings in Available in New Trucks, May 2014.

[8] Delgado, O. and Lutsey, N. Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe, April 20145. Available online at http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf.

[9] National Research Council (NRC). 2010. Technologies and approaches to reducing the fuel consumption of medium- and heavy-duty vehicles. Washington, DC. Online at http://www.nap.edu/catalog.php?record_id=12845.

[10] Kromer, M.A., Bockholt, W.W., and Jackson, M.D. Assessment of fuel economy technologies for medium- and heavy-duty vehicles. TIAX, LLC Report. Cupertino, CA. July 2009.

of natural gas in medium- and heavy-duty vehicles, the reduction potential still remains in the range of 15-25% based on ICF estimates.

Analysis Assumptions and Results. For purposes of this analysis, ICF assumed a 55% reduction in CO_2 emissions per vehicle compared to 2012 levels; based on a 35% savings from efficiency improvements (increasing beyond the currently proposed medium-heavy duty vehicle standards) and about 20% from lower carbon fuels. This GHG reduction is equivalent to more than doubling fuel economy if achieved exclusively through fuel economy improvements.

Table 5: Estimated On-Road Transportation GHG Emissions Impacts of Further Increases in Medium/Heavy-Duty Vehicle Technology

	GHG Emissions ($MMTCO_2e$)		
	2020	**2040**	**2050**
Overall Impact of Further Technology Advancements to M/HDVs	-	-1.45	-2.91

It is important to recognize that the assumptions in this scenario would encompass the low carbon fuel standard assumptions that were analyzed under TLU-6.

Additional GHG Reduction Measures

Commercial Aviation

Proposed Aviation Efficiencies Likely to be Implemented. While MWCOG's multi-sector approach didn't explicitly include commercial aviation as part of the evaluated strategies, there are potential reductions that exist that could help the region achieve their reduction goal. Reductions for commercial aviation are dependent on a number of factors including the development of lighter weight aircraft materials, an increase in aircraft operation efficiency (such as the reduction of taxiing and idling time), and fuel composition (moving towards sustainable alternative aviation fuels). According to Federal Aviation Administration (FAA), the technological advancement in aircraft engine design has reduced aircraft fuel consumption and emissions on a per flight basis significantly over the past several decades. During this same era, the industry developed and deployed new, lightweight, high-strength materials, automated navigational, operational, and engine control systems, and employed vast new computational capabilities to improve aerodynamic efficiency and integrate highly complex operational structures such as hub and spoke airport networks (FAA, 2015)[11].

As a result of this historical improvement, the USG (United State Government) set forth a goal (accepted by the aviation industry) of carbon neutral growth from 2020 and then 50% reduction of carbon by 2050. As such, the 50% reduction goal for the US was applied to the commercial aviation estimates for the WASHCOG region, resulting in a decrease of 1.66 $MMTCO_2e$ by 2050.

[11] Federal Aviation Administration, *Aviation Emissions, Impacts & Mitigation: A Primer*. Office of Environment and Energy, January 2015. Available online at: Commercial Aviation http://www.faa.gov/regulations_policies/policy_guidance/envir_policy/media/Primer_Jan2015.pdf.

Table 6: Estimated GHG Emissions Reductions from Commercial Aviation

	GHG Emissions ($MMTCO_2e$)		
	2020	2040	2050
Incremental Impacts of Commercial Aviation Improvements	0	-0.94	-1.66

Hydroflourocarbons (HFCs)

Proposed HFC Reductions in the Montreal Protocol. While MWCOG's multi-sector approach didn't explicitly include hydroflourocarbons (HFCs) as part of the evaluated strategies, there are potential reductions that exist that could help the region achieve their reduction goal. Through amendments adopted through the Montreal Protocol, the United States could achieve up to 86% reduction of HFC emissions[12] by 2050.

[12] Belenky, Maria. *Achieving the U.S. 2050 Emissions Mitigation Target*. Climate Advisers, April, 2015.

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

Strategies for Closing the Gap to Reach 80% by 2050

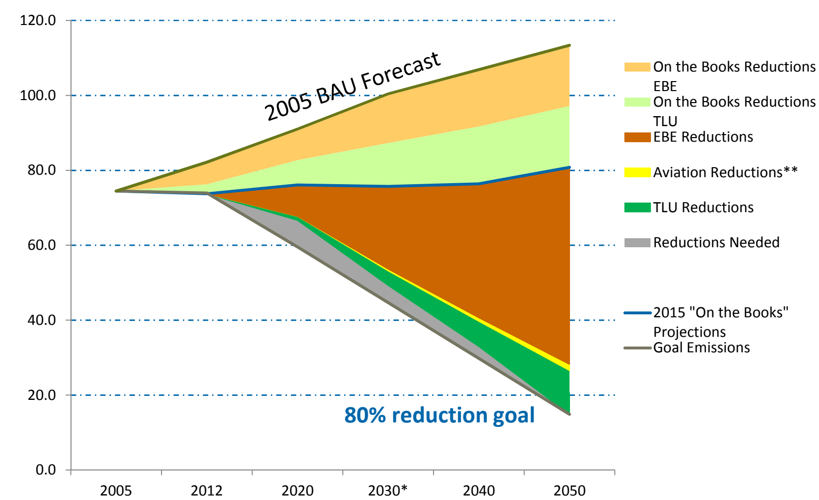
Prepared for:
Metropolitan Washington Council of Governments

Tuesday, October 27, 2015

Closing the Gap

- **27.7 MMTCO$_2$e gap in GHG emissions between the potential GHG reductions identified from state, regional, or local strategies and the region's adopted voluntary 80% reduction goal for 2050**
- **Additional strategies for closing the gap may include:**
  - More stringent federal appliance standards
  - More stringent building energy codes
  - Power sector policies including Clean Power Plan successors
  - Reduction in HFCs resulting from amendments submitted to the Montreal Protocol
  - Lower emissions light-duty vehicles
  - Lower emissions medium-heavy duty vehicles
  - Reduction in aviation emissions

Estimated Potential Reductions to Meet 80% Reduction Goal



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Key Levers for Significant Reductions in GHGs

- **Energy and Built Environment**
  - Existing building efficiencies through appliance standards, retrofit strategies, voluntary labeling
  - New Buildings efficiencies through aggressive energy codes
  - Power sector emission reductions through federal decarbonization policies
- **On-Road Transportation**
  - Light-duty vehicle fuel efficiency and low carbon fuels: 99 mpg on-road fuel economy equivalent
  - Medium- and heavy-duty vehicle efficiency and low carbon fuels – more than doubling of fuel economy equivalent
- **Other**
  - 50% reduction in commercial aviation emissions
  - Up to 86% reduction in HFC emissions

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Reduce Emissions from New Buildings

- **Technologies**
  - Improved efficiencies in appliances, lighting, and equipment
  - Improved efficiencies in building thermal envelopes
- **Potential Impacts – Additional 5.1 MMT CO_2 Eq in 2050**
- **Federal Policies to Advance Technology Adoption**
  - Zero energy buildings research, development, and deployment
  - Department of Energy engagement in advancing building codes

Reduce Emissions from Existing Buildings

- **Technologies**
  - Improved efficiencies in appliances, lighting, and equipment
  - Advanced building retrofit technologies
- **Potential Impacts – Additional 1.5 MMT CO_2 Eq in 2050**
- **Federal Policies to Advance Technology Adoption**
  - More aggressive National Appliance Energy Conservation Act (NAECA) appliance and equipment standards rulemakings
  - Advanced voluntary labeling via ENERGY STAR

Reduce Emissions from the Power Sector

- **Technologies**
  - Increased generation share from renewable, nuclear, and high-efficiency natural gas resources
- **Potential Impacts – Additional 13.6 MMT CO_2 Eq in 2050**
- **Federal Policies to Advance Technology Adoption**
  - Clean Power Plan successor rulemakings
  - Congressional climate change legislation
  - Federal Renewable Portfolio or Clean Power Standard
  - Continued/expanded tax incentives for renewable power production

Reduce Emissions from Light-Duty Vehicles

- **Technologies**
  - Highly efficient vehicles (efficient internal combustion engines); load reduction through use of lightweight materials, lower rolling resistance, aerodynamics, and accessory efficiency
  - Most petroleum-based fuels replaced with fuels with low net GHGs, including biofuels, electricity (plug-in hybrid electric, battery-electric), or hydrogen (fuel cell electric vehicles) – multiple potential technology pathways
- **Potential Impacts – 7.6 MMT CO_2 Eq in 2050**
  - 80% reduction in CO_2 emissions per vehicle mile compared to 2012 levels
  - Equivalent to about a 99 mpg overall average fuel economy on-road
- **Federal Policies to Advance Technology Adoption**
  - Significantly higher vehicle fuel economy standards
  - Supportive policies, such as “feebates”, taxes on low fuel-economy vehicles, higher fuel taxes
  - R&D investments related to fuel cells, batteries, biofuels, low-GHG production of hydrogen
- **Implications**
  - Impacts of land use, VMT-reduction (TDM, transit, road pricing), and operations improvements (eco-driving, system operations, bottleneck relief) are significantly diminished

Reduce Emissions from Medium-Heavy Duty Vehicles

- **Technologies**
  - More efficient internal combustion engines
  - Shifts to biodiesel and renewable diesel, as well as natural gas
- **Potential Impacts – 2.9 MMT CO_2 Eq in 2050**
  - 55% reduction in CO_2 emissions per vehicle mile compared to 2012 levels
  - More than doubling of on-road fuel economy
- **Federal Policies to Advance Technology Adoption**
  - Expansion of proposed Phase 2 regulations for medium-heavy-duty vehicles, which may reduce GHGs per mile by about 30% from 2012 levels by 2040-2050.
  - Implementation of low carbon fuel standard

Critical Role of Vehicle Technologies and Low Carbon Fuels to Meet Long Term Goals for Transportation

	GHGs (MMTCO2e)					
	2005	2012	2020	2030*	2040	2050
Transportation Combustion Emissions						
2005 BAU Projections	**22.58**	**25.17**	**28.14**	**31.25**	**33.13**	**35.00**
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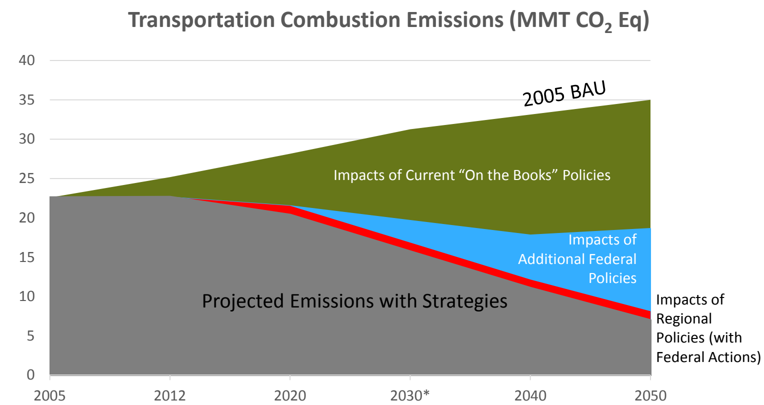
Total With Additional National Actions	**22.58**	**22.63**	**21.54**	**16.85**	**12.16**	**8.13**
Impacts of Sustainable Development			-0.34	-0.58	-0.83	-0.60
Impacts of Other Regional Strategies			-0.85	-0.56	-0.27	-0.57
Net Projected Emissions	**22.58**	**22.63**	**20.35**	**15.70**	**11.06**	**6.95**
Projected Reductions from 2005 levels (%)			10%	30%	51%	69%
Projected Reductions from 2005 BAU Projections (%)			28%	50%	67%	80%

Critical Role of Vehicle Technologies and Low Carbon Fuels to Meet Long Term Goals for Transportation



Note: Regional policies/strategies in the initial analysis included vehicle technology (ZEVs) and low carbon fuel standards; some of these impacts are assumed to be encompassed within more aggressive Federal policy actions starting after 2020.

Reduce Emissions from Commercial Aviation

- **Potential Impacts – 1.7 MMT CO_2 Eq in 2050**
  - 50% reduction in CO_2 emissions to 2012 levels
- **Increases in Commercial Aviation Efficiency**
  - Development of lighter weight aircraft materials
  - Increase in aircraft operation efficiency
    - Reduction of taxiing and idling time
  - Fuel composition
    - Move towards sustainable alternative aviation fuels

Reduce Emissions from HFCs

- **Potential Impacts – 3.7 MMT CO_2 Eq in 2050**
  - Up to 86% reduction in HFC emissions
- **Amendments to the Montreal Protocol**
  - Schedule to phase down the production and consumption of HFCs
- **Private sector commitments**
  - Span the entire supply chain from HFC manufacturers to consumers