Analysis of Refined Greenhouse Gas Reduction Strategies from the Multi-Sector Working Group Study

Strategies analyzed:

EBE[1]-1. Reduce energy and water consumption in existing buildings

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

EBE-3. Encourage Development in Activity Centers

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

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

EBE-6. Targeted reductions in power sector emissions

EBE-7. Reduce natural gas pipeline leaks

EBE-8. Targeted reductions in municipal solid waste

EBE-9. Reduce emissions from non-road engines

TLU-1[2]. Reduce Loss of Vegetation due to Sustainable Development Patterns and Programs to Increase Tree Canopy

TLU-2. Sustainable Development Patterns and Urban Design

TLU-3. Improve Fuel Economy of Light-Duty Vehicle Fleet

TLU-4. Increase Alternative Fuels in Public Sector Fleets

TLU-5. Truck Stop Electrification

TLU-6. Low-Carbon Fuel Standard

TLU-7. Enhancing System Operations

TLU-8. Reduce Speeding on Freeways

TLU-9. Travel Demand Managemen

TLU-10. Transit Enhancements

TLU-11. Transit Incentives / Fare Reductions

TLU-12. Road Pricing

[1] EBE: Energy & Built Environment Sectors
[2] TLU: Transportation & Land Use Sectors

Disaggregated Results

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

[1] 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)

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

This strategy is designed to reduce annual energy and water consumption in existing buildings through policies and programs that support high building performance.

Modeled Outcomes

2016-2050 (viable/stretch)

- Achieve a 2% annual (30% cumulative) reduction in building energy and water use by 2030

Implementation Actions

- Leverage energy utility ratepayer-funded programs and water utility partnerships
- Expand financing options for energy and water efficiency improvements.
- Extend enforcement of building energy code provisions
- Expand low-income housing retrofits and water saving programs
- Utilize mandatory benchmarking and voluntary challenge initiatives

Summary of GHG Reduction for EBE-1[3]

Year	Net GHG Reductions (MMTCO2e[4])
2020	2.73
2040	10.55
2050	10.55

Costs

Public sector implementation costs are expected to be low (under $50 million) to medium (up to $500 million with local incentives) in the short term and yield cost savings in the long term. Efficiency encompasses cost-effective measures that typically yield positive net present value over the study period. Numerous analyses typically show a range of efficiency measures costing less than available energy supply options.

Co-Benefits

- Reduction in criteria air pollutants
- Local job growth
- Improved occupant comfort and health

[3] ICFI utilized a customized sketch planning tool with MWCOG-provided regional electricity, natural gas and water consumption data, and Round 8.3 Cooperative Forecast data to estimate benefits from strategy.
[4] MMTCO2e=Million Metric Tons of Carbon Dioxide Equivalent. Non CO2 gases are converted based on potency.

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

This strategy is designed to 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.

Modeled Outcomes

2016-2026 (viable)

- Continue growth in solar and renewables by 20% per year for 5 years, 5% per year thereafter

2016-2050 (stretch)

- Provide local incentives to further grow building-level renewable technologies by 2 to 5%
- Government cooperative solar purchase offsets 10% of government energy use
- Reduce commercial and industrial electricity usage by 5% through implementing additional solar and renewables

Implementation Actions

- Baseline Solar/Wind deployment across all sectors
- Support cooperative/aggregated renewable energy purchasing
- Provide incentives for building-level renewable technologies
- Broaden adoption of solar access ordinances and similar regulations to provide a more stable investment environment

Summary of GHG Reduction for EBE-2[5]

Year	GHG Reductions (MMTCO2e)
2020	1.15
2040	1.86
2050	2.78

Cost

Actions have low program and implementation costs (under $50 million) to medium (up to $500 million) depending on the planned incentive levels. Renewable energy generally reduces energy costs over the lifetime of the equipment.

Co-benefits

- Reduction in criteria air pollutants
- Electric reliability
- Local job growth

[5] ICFI utilized a customized Excel sketch planning tool with PVWatts and data provided by MWCOG on energy usage, renewable energy deployment and Round 8.3 Cooperative Forecast to estimate benefits from strategy.

EBE-3. Encourage Development in Activity Centers

This strategy depends on the implementation of strategy TLU-2 (Sustainable Development Patterns and Urban Design). These strategies jointly would reduce the growth in emissions from passenger vehicles and reduce building and infrastructure related emissions through directing more of the region's anticipated growth and redevelopment in compact, walkable, mixed use activity centers served by premium transit (Metrorail, Commuter rail, LRT and BRT).

Modeled Outcome

2020-2040 (viable)

- Future growth within each jurisdiction is shifted to, in order of priority: 1) Activity Centers with premium transit; 2) other locations with premium transit; or 3) other Activity Centers without premium transit

2020-2050 (stretch)

- Regional job-housing imbalances are addressed by shifting future growth across jurisdictional boundaries, and then concentrated as described as above

Implementation Actions

- Update comprehensive plans, zoning, and permitting guidelines to include energy and transportation efficiencies as a factor in public siting decisions
- Significant additional investments in transit capacity and service would be required.

Implementation Considerations

This is an aggressive strategy as about 60% of the region's projected future residential development and 75% of its projected commercial development is already forecast to occur in activity centers. Directing 100% of the region's future residential and commercial development to less auto-reliant locations currently planned to be served by premium transit services may be difficult given existing lifestyle preferences and market forces.

Summary of Greenhouse Gas Reductions for EBE-3

Summary Metric	2020	2040	2050
GHG Reductions - layered with EBE-4 (MMTCO2e)	0.01	0.16	0.19
GHG Reductions (MMTCO2e)	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

Cost

The direct costs are low and are generally within existing planning functions. For the public sector, tradeoffs between costs and savings are complex, but compact development should be cheaper to provide and sustain infrastructure. For the private sector, these strategies could mean potentially higher costs for building in infill and higher density areas, but counterbalanced by higher sales prices. Additionally, these

strategies should reduce transportation costs for households and improve access for employers and commercial establishments.

Co-Benefits

- Safety
- Congestion Reduction
- Reliability
- Air Quality
- Energy Savings
- Economic Vitality
- Accessibility
- Resiliency
- Reduced Stormwater Run-off
- Community Amenity

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

This strategy is designed to reduce energy and water consumption in new buildings through implementing stringent building code and energy performance standards, providing for new buildings to use Water Sense fixtures, and having all new buildings designed to be net-energy zero.

Modeled Outcomes

2016-2020 (viable)

- Phase-in stringent building code/energy performance standards by 2020

2016-2040 (viable)

- 100% of new buildings use WaterSense fixtures by 2030
- 50% of new buildings designed for net zero energy use by 2040

2016-2050 (stretch)

- 100% of new buildings designed for net zero energy use by 2050

Implementation Actions

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

Summary of Electricity, Natural Gas, Water and GHG Reduction for EBE-4[6]

Year	Electricity Reductions (MWh)	Natural Gas Reductions (MMBtu)	Water Reductions (Gallons)	GHG Reductions (MMTCO2e)
2020	754,305	8,258,484	0	1.03
2040	3,290,694	44,607,606	196,932,718	4.18
2050	5,069,696	71,577,122	323,257,485	6.59

Cost

Public sector costs are estimated to be low (under $50 million) for this measure. Private sector costs may be higher to meet the code requirements, yet efficiency would realize substantial cost savings over building life cycles.

Co-benefits

- Reduction in criteria air pollutants
- Local job growth
- Improved occupant comfort

[6] ICFI utilized a customized sketch planning tool with MWCOG-provided regional electricity, natural gas and water consumption data, and Round 8.3 Cooperative Forecast data to estimate benefits from strategy.

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

This strategy is designed to reduce fossil fuel energy use through efficiency improvements and expanded renewable options in the COG region infrastructure institutions, including water and wastewater systems, the Washington Metropolitan Area Transit Authority (WMATA), and airports.

Modeled Outcomes

2016-2050 (viable/stretch)

- 1% annual reduction in fossil energy use (35% cumulative)

Implementation Actions

- Improve energy efficiency by reducing leaks in water and wastewater systems
- Fostering system efficiency process improvements
- Implementing outdoor lighting and end-use efficiency technologies
- Installing on-site renewable power systems at facility locations

Summary of Electricity, Natural Gas, and GHG Reduction for EBE-5[7]

Year	Electricity Reductions (MWh)	Natural Gas Reductions (MMBtu)	GHG Reductions (MMTCO2e)
2020	68,435	13,574	0.05
2040	398,109	155,840	0.23
2050	562,946	226,972	0.32

Costs

Public sector costs for building and infrastructure upgrades are expected to be low (under $50 million) and would yield positive net present value over time.

Co-benefits

- Reduction in criteria air pollutants
- Economic vitality, jobs, equity
- Resiliency

[7] ICFI utilized a customized sketch planning tool with MWCOG- and utility-provided data to estimate strategy benefits.

EBE-6. Targeted reductions in power sector emissions

This strategy would reduce total power sector emissions 30 percent on a mass basis through implementation of the Clean Power Plan by Virginia and Maryland. The stretch strategies would achieve an additional 20% renewable energy offsets in Maryland by 2040, and an additional 10% renewable energy offsets in the District of Columbia and Virginia as part of a preferred portfolio of stretch strategies.

Modeled Outcomes

2016-2030 (viable)

- Implement the Clean Power Plan in Maryland and Virginia

2030-2050 (stretch)

- Implement preferred portfolio of power sector actions

Implementation Actions

- Support state implementation of the Clean Power Plan

Summary of GHG Reductions for EBE-6[8]

Year	Total GHG Reductions (MMTCO2e)
2020	1.97
2040	8.05
2050	10.74

Cost

Costs could range from to medium ($50 to $500 million) to high (over $500 million) for the power sector but low for COG members depending on how measures are implemented. Clean energy measures may yield long term cost savings.

Co-Benefits

- Local job growth
- Reduction in criteria air pollutants

[8] ICFI utilized a customized sketch planning tool with PJM grid factors and EIA data to estimate benefits from strategy.

EBE-7. Reduce natural gas pipeline leaks

This strategy would reduce emissions from natural gas leaks in the COG region through natural gas utility company investments to reduce pipeline emissions. Regional action should support utility investments before regional utility commissions.

Modeled Outcomes

2016-2040 (viable/stretch)

- 20% reduction in total methane emissions by 2030

Implementation Actions

- Support pipe and infrastructure upgrades by the region's three natural gas utilities

Summary of GHG Reductions and Methane Emissions Reductions for EBE-7[9]

Year	Methane Reductions (MT)	GHG Reductions (MMTCO2e)
2020	601	0.02
2040	4,205	0.11
2050	4,205	0.11

Cost

Annual Cost is estimated as low (under $50 million). Reductions in gas distribution system emissions will reduce utility losses, which help offset upfront costs.

Co-Benefits

- Safety
- Local Job growth

[9] ICFI utilized a customized sketch planning tool with WGL and PHMSA data to estimate benefits from strategy.

EBE-8. Targeted reductions in municipal solid waste

This strategy is designed to reduce emissions from municipal solid waste by increasing reuse of wastes, recycling, green purchasing, landfill gas recovery, and waste to energy projects.

Modeled Outcomes

2016-2020 (viable)

- Increase reuse of construction and demolition waste to 15%
- Increase use of waste to energy projects

2016-2040 (stretch)

- Divert 100% of organic waste from landfills

2016-2050 (stretch)

- Increase total landfill diversion rate to 100%
- Increase reuse of construction and demolition waste to 100%
- Recover 50% of methane emissions at landfills from 2030-2050

Implementation Actions

- Implement green purchasing programs
- Implement pay as you throw programs and tipping fees

Summary of Life Cycle and Direct GHG Reduction for EBE-8[10],[11]

Year	Tons Landfilled	Direct GHG Reductions (MMTCO2e)
2020	839,723	0.08
2040	279,908	0.15
2050	0	0.27

Cost

Annual Cost is estimated as low (under $50 million) for the public sector, involving tipping fees and waste collection fees. Cost savings could result through energy production, materials reuse, and reduced waste management needs.

Co-Benefits

- Local job growth
- Reduction in criteria air pollutants
- Reductions in landfilling of waste

[10] Tools: MS Excel, EPA's LandGEM and WARM models, SMART BET calculator
[11] ICFI also modeled product life cycle GHG reductions for net zero waste in 2012: 4.8 MMTCO2e

EBE-9. Reduce emissions from non-road engines

This strategy is designed by increasing the market penetration of energy efficient or lower emission back-up generators, construction, agriculture, lawn and garden, commercial and industrial equipment, recreational equipment and other non-road engine equipment. Additional idling reductions and electric alternatives would further reduce non-road engine emissions.

Modeled Outcomes

2016 to 2030 (viable/stretch)

- 2% annual (30% cumulative) reduction in non-road emissions by 2030

Implementation Actions

- Public programs to encourage the switch to lower-emitting equipment

Summary of GHG Reductions for EBE-9[12]

Year	Direct GHG Reductions (MMTCO2e)
2020	0.28
2040	0.85
2050	0.85

Cost

Annual Cost is estimated as low (under $50 million) to medium ($50 million to $500 million. More efficient equipment will reduce operating costs.

Co-Benefits

- Reduction in criteria air pollutants

[12] ICFI used a customized sketch planning tool to estimate benefits from strategy with MWCOG-provided non-road engine emissions inventory data.

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

Between 2012 and 2040, projected development expansion in the region is expected to consume 48,465 of the region's current 949,891 acres of forest, and 86,935 of 599,179 acres of undeveloped grassland. The carbon sequestration provided by the current forest and natural ground cover is estimated at 9.06 annual $MMTCO_2e$; current development projections would reduce total sequestration in 2040 by 0.65 $MMTCO_2e$.

Modeled Outcome

2016-2050 (viable)
Under the TLU-2 alternative land use scenarios, nearly 20,000 fewer acres of land would be consumed.

2016-2050 (stretch)

- Implement proactive strategy to expand region's capacity to sequester CO_2 emissions by expanding the region's tree canopy by 5% by the year 2040.
- This policy would result in 1.2 million acres of canopy and 9.4 $MMTCO_2e$ of annual sequestration.

Implementation Actions

- Public sector planting program
- Voluntary or required planting by development entities in exchange for project approvals
- Creation of silvicultural districts or similar local policies

Summary of Greenhouse Gas Sequestration for TLU-1

Summary Metric	2020	2040	2050
GHG Sequestration – Avoided Less due to more compact development (MMTCO2e)	0.10	0.50	0.54
GHG Sequestration – Increase due to expanding tree canopy (MMTCO2e)	0.09	0.32	0.44
Total GHG Sequestration benefits (MMTCO2e)	0.19	0.82	0.98

Co-Benefits

- Air Quality
- Economic Vitality
- Resiliency
- Reduced storm water run-off
- Community Amenity
- Heat Island Effect Mitigation

Costs

Low to medium. Tree reforestation over 56,350 acres is estimated to cost approximately $245 million. This investment would be made gradually over time. Public sector costs include direct expenditures for tree planting and maintenance, and program costs for easements, incentives, education, or forest mitigation banking. Private developers would likely be required to plant trees or pay toward reforestation. Costs could be partially offset by timber harvesting in undeveloped parts of the region. In urban/suburban areas, cost savings would result from lower energy costs for nearby buildings, improved public health, and increased commerce in treed areas.

TLU-2. Sustainable Development Patterns and Urban Design

This strategy supports realization of the reductions in strategy EBE-3 (Encourage development in activity centers). These strategies jointly would reduce the growth in emissions from passenger vehicles by directing more of the region's anticipated growth and redevelopment to 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.

Modeled Outcome

2020-2040 (viable)

- Future growth within each jurisdiction is shifted to, in order of priority: 1) Activity Centers with premium transit; 2) other locations with premium transit; or 3) other Activity Centers without premium transit

2020-2050 (stretch)

- Regional job-housing imbalances are addressed by shifting future growth across jurisdictional boundaries, and then concentrated as described as above

Implementation Considerations

This is an aggressive strategy as about 60% of the region's projected future residential development and 75% of its projected commercial development is already forecast to occur in activity centers. Directing 100% of the region's future residential and commercial development to less auto-reliant locations currently planned to be served by premium transit services may be difficult given existing lifestyle preferences and market forces.

Significant additional investments in transit capacity and service would be required to support this sustainable development pattern.

Summary of Greenhouse Gas Reductions for TLU-2

Summary Metric (MMTCO2e)	2020	2040	2050
GHG Reductions – TLU-2 strategy alone (MMTCO2e)	0.34	1.32	1.67

Cost

The direct costs are low and are generally within existing planning functions. For the public sector, tradeoffs between costs and savings are complex, but compact development should be cheaper to provide and sustain infrastructure. For the private sector, these strategies could mean potentially higher costs for building in infill and higher density areas, but counterbalanced by higher sales prices. Additionally, these strategies should reduce transportation costs for households and improve access for employers and commercial establishments

Co-Benefits

- Safety
- Congestion Reduction
- Reliability
- Air Quality
- Energy Savings
- Economic Vitality
- Accessibility
- Resiliency
- Reduced Stormwater Run-off
- Community Amenity

TLU-3. Improve Fuel Economy of Light-Duty Vehicle Fleet

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

Modeled Outcome

2016-2020 (viable)

- Increase light-duty zero emission vehicles to 2% of total vehicle population in region (beyond those anticipated with existing policies)

2020-2040 (viable)

- Increase light-duty zero emission vehicles to 15% of total vehicle population in region (beyond those anticipated with existing policies)

2040-2050 (stretch)

- Increase light-duty zero emission vehicles to 25% of total vehicle population in region (beyond those anticipated with existing policies)

Implementation Actions to Support/Promote Zero Emissions Vehicles

- Invest in a system of public-access vehicle recharging stations,
- Offer tax credits to businesses that install recharging stations,
- Offer benefits (HOV access, priority parking) to owners of electric vehicles, and offer tax credits for electric vehicle purchases, among others.

Implementation Actions to Incentivize More Fuel Efficient Passenger Vehicles

- Implement a "Cash for Clunkers" program to encourage replacement of older, less fuel efficient vehicles
- Offer incentives for consumer/private sector purchase of electric vehicles and charging equipment
- Offer incentives for purchases of fuel-efficient vehicles (fee-bates)
- Provide disincentives for purchases of fuel inefficient vehicles (gas guzzler tax/registration fees)
- Adoption of CA Low-Emission Vehicle (LEV) Phase II program

Summary of GHG Reduction for TLU-3[13]

Year	Net GHG Reductions ($MMTCO_2e$)[14]
2020	0.09
2040	0.50
2050	0.88

[13] ICFI customized sketch planning tool used to estimate benefits from strategy.

[14] Net GHG reduction accounts for increase in power sector emissions for electric vehicles; the net is highly dependent upon other power sector strategies which are not accounted for here as strategies were analyzed individually

Cost

Public sector costs are expected to be medium ($50 million to $500 million). Costs include infrastructure improvements for widespread plug-in electric vehicle use and costs for incentives and program implementation costs. Private sector cost savings from driving a plug-in electric vehicle can be up to $950/year due to reduced fuel costs.

Co-Benefits

Reduction in criteria air pollutants

TLU-4. Increase Alternative Fuels in Public Sector Fleets

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

Modeled Outcome

2016 – 2020 (viable)

- Add 200 zero emission buses to public transit fleet in the study region (replacements).

2020 – 2040 (viable)

- Increase zero emission vehicles in municipal light-duty fleets to 15% of total fleet population; require B5 in all municipal fleets and school buses; require 15% of public transit fleet to be ZEVs.

2040 – 2050 (stretch)

- Increase zero emission vehicles in municipal light-duty fleets to 25% of total fleet population; require B20 in all municipal fleets and school buses; require 25% of public transit fleets to be zero emission vehicles.

Summary of GHG Reduction for TLU-4[15]

Year	GHG Reductions (MMTCO2e)
2020	0.007
2040	0.050
2050	0.093

Cost

Costs are estimated to be low (under $50 million) considering incremental costs of vehicle replacements. Costs include incremental costs of purchasing alternative fuel vehicles and costs associated with fueling stations.

Co-Benefits

- Reduction in criteria air pollutants

[15] ICFI customized sketch planning tool used to estimate benefits from strategy.

TLU-5. Truck Stop Electrification

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

Modeled Outcome

2016-2020

- One TSE location with 20 bays/site in the region.

2020-2040

- Six (6) TSE locations with 20 bays/site in the region.

2040-2050 (stretch)

- Fourteen (14) TSE locations with 20 bays/site in the region. There are currently 14 truck stops located within the metropolitan Washington region so the long-term stretch scenario essentially assumes that all are fitted with TSE bays.

Implementation Actions

- Adoption of truck stop electrification bays.

Summary of GHG Reduction for TLU-5[16]

Year	GHG Reductions (MMTCO2e)
2020	< 0.001
2040	0.002
2050	0.006

Cost

Public sector costs are estimated to be low (<$50 million). Installation of TSEs would require public sector expenditures for the infrastructure, as well as on-going operating and maintenance (O&M) costs. Capital costs were estimated as $10,000 per space, and O&M costs per space were $100 for maintenance, $25 for insurance, and $1,314 for overhead labor, based on data for two truck stops in New York, as cited in the Moving Cooler study. These technologies results in cost savings to freight carriers due to reduced vehicle fuel consumption during extended idling. These costs savings can be calculated by multiplying an estimate of annual diesel fuel savings by average diesel fuel costs per gallon.

Co-Benefits

- Reduction in criteria air pollutants

[16] ICFI customized sketch planning tool and MOVES2014 data used to estimate benefits from strategy.

TLU-6. Low-Carbon Fuel Standard

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

Modeled Outcome

2016-2020 (viable)

- No reductions (assume measure will not be implemented by this date).

2020-2040 (viable)

- Reduction in total on -road fuel emissions in region by 10%.

2040-2050 (stretch)

- Reduction in total on -road fuel emissions in region by 15%.

Implementation Actions

- Implement market-based program to reduce carbon intensity of on-road fuels through use of lower-carbon alternatives (e.g., natural gas, electricity, biofuels, and hydrogen)

Summary of GHG Reduction for TLU-6[17]

Year	GHG Reductions (MMTCO2e)
2020	0
2040	1.02
2050	1.29

Cost

As a regulatory measure, public sector costs for implementing a low carbon fuel standard are very low (< $50 million). Costs borne on the private sector and consumers are somewhat difficult to estimate given the variety of ways in which a low carbon fuel standard could affect.

Co-Benefits

- Reduction in criteria air pollutants

Economic vitality, jobs, equity

[17] ICFI customized sketch planning tool used to estimate benefits from strategy.

TLU-7. Enhancing System Operations

This strategy includes a wide array of strategies to improve the operational performance of freeways and arterial/collectors. It should be noted that many operational strategies are already in place or anticipated in BAU conditions, so this measure is associated with additional strategy deployments. This analysis did not explicitly examine highway bottleneck improvements, but these improvements might be part of the overall improvement in vehicle operating conditions considered in these scenarios.

Modeled Outcome

2016- 2020 (viable)

- 20% of drivers adopt eco -driving practices (based on public campaigns); region-wide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).

2020-2040 (viable)

- 80% of drivers adopt eco -driving practices (based in part via connected vehicle/automated vehicle technologies); region-wide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).

2040 -2050 (stretch)

- 100% of drivers utilize eco -driving practices (via connected vehicle/automated vehicle technologies); region-wide operational improvements reduce vehicle operating emissions by additional 1.65% (based on best available regional simulation study).

Implementation Actions

- Integrated corridor management on freeway and major arterial corridors
- Ramp metering
- Signal retiming
- Use of roundabouts
- Intersection efficiency improvements
- Roadway bottleneck improvement
- Increased adoption of eco -driving practices by drivers
- Use of connected and autonomous vehicles

Summary of GHG Reduction for TLU-7[18]

Year	GHG Reductions (MMTCO2e)
2020	0.34
2040	0.56
2050	0.85

[18] ICFI customized sketch planning tool and MOVES2014 data used to estimate benefits from strategy.

Cost

Operational strategies are generally low cost, although they can take a wide array of forms. 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 eco-driving; and costs associated with installing, operating, and maintaining V21 infrastructure. Bottleneck relief projects can vary significantly based on the size and scope of the bottleneck improvement project and can range from low (under $50 million) to medium ($50 million to $500 million).

Co-Benefits

- Safety
- Reliability
- Congestion reduction
- Reduction in criteria air pollutants
- Economic vitality, jobs, equity
- Mobility
- Accessibility
- Weather resilient
- Enhanced road weather management and incident management
- Chesapeake Bay/ storm water

TLU-8. Reduce Speeding on Freeways

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

Modeled Outcome

2016- 2050 (viable/stretch)

- One-third of freeway speeding eliminated by 2020
- All freeway speeding eliminated by 2040

Implementation Actions

Increased speed enforcement, which may include more speed patrols and/or electronic monitoring of freeway speeds.

Summary of GHG Reduction for TLU-8[19]

Year	GHG Reductions (MMTCO2e)
2020	0.005
2040	0.006
2050	0.006

Costs

Reducing speeding will require additional highway speed enforcement, whether through deployment of additional law enforcement staff or electronic monitoring. Costs could range from low (under $50 million) to medium ($50 to $500 million).

Co-Benefits

- Safety
- Reduction in some criteria air pollutants

[19] ICFI customized sketch planning tool and MOVES2014 data used to estimate benefits from strategy.

TLU-9. Travel Demand Management

This strategy encompasses a wide range of strategies designed to reduce vehicle travel by shifting motorists to higher occupancy modes (carpools, vanpools), public transit, walking, and bicycling, as well as telecommuting.

Modeled Outcome

2016 to 2020 (viable)

- 50% of parking in activity centers is priced at an average of $8 per day
- Expand employer-based incentives to cover 40% of employees in the region receiving a subsidy of $50/month for transit, carpool, vanpool, etc.

2020 to 2040 (viable)

- 90% of parking in activity centers is priced at an average of $8 per day
- Expand employer-based incentives to cover 80% of employees in the region receiving a subsidy of $50/month for transit, carpool, vanpool, etc.

2040 to 2050 (stretch)

- 100% of parking in activity centers is priced at an average of $8 per day
- Expand employer-based incentives to cover 100% of employees in the region receiving a subsidy of $80/month for transit, carpool, vanpool, etc.

Implementation Actions

- Encourage employers to offer incentives to employees to switch to carpooling/vanpooling, non-motorized modes, and telecommuting.
- Incentives to employers to offer or ordinances to require employers to offer parking cash out / transit benefits
- Expansion of Park-and-ride facilities to meet anticipated increase in rideshare and transit demand
- Incentives or ordinances such as parking tax, parking impact fees, parking caps to reduce free parking in activity centers to realize the above assumptions.

Summary of Travel Impacts and GHG Reduction for TLU-9[20]

Year	Daily VMT Reduced	Percent Reduction in VMT from Regional Base	Percentage Increase In Transit Trips	GHG Reductions (MMTCO2e)
2020	1,709,504	0.9%	2.2%	0.13
2040	5,857,877	2.4%	7.0%	0.24
2050	12,631,603	5.3%	38.5%	0.54

Cost

[20] TRIMMS sketch planning model and MOVES2014 data used to estimate benefits from strategy.

Annual Cost is estimated as low. Only the cost of incentives to the public sector is taken into account. Increase transit service cost could be off-set by the parking tax. Loss of revenue from lower gas tax collection from VMT reduction is possible.

Co-Benefits

- Congestion reduction
- Reduction in criteria air pollutants
- Economic vitality, jobs, equity
- Mobility
- Accessibility
- Weather resilient
- Chesapeake Bay/storm water

Note The current employer outreach program in the region which promotes TDM program similar to the above on a voluntary basis through the "Employer Outreach" TERM estimates a daily VMT reduction of 1,327,000 or an annual reduction of 331,750,000 due to the program. This program has been in operation for over 12 years and the program aims to maintain the criteria pollutant goal set as part of transportation conformity.

TLU-10. Transit Enhancements

This strategy is designed to increase the share of transit trips through increased or improved services. For this analysis, the focus on transit enhancements that reduce transit travel times and reliability, as well as schedule improvements to reduce wait times, rather than expansions to services. TIGER is implementing signal priority projects along high transit corridors and could be operational in a year.

Modeled Outcome

2016 to 2020 (viable)

- Reduce transit travel and wait times by 10%

2020 to 2040 (viable)

- Reduce transit travel and wait times by 15%

2040 to 2050 (stretch)

- Reduce transit travel and wait times by 20%

Implementation Actions

Strategies may include a) increased circulator buses; b) enhanced commuter bus services; c) real time bus schedule information; d) transit signal priority improvements; e) bus rapid transit improvements; f) expanded Metrorail/commuter rail; g) bus stop improvements; h) schedule coordination between transit agencies; i) permitting buses on highway shoulders; j) transit access improvements; k) establishing dedicated bus lanes; and l) bus infrastructure commitments.

Summary of Travel Impacts and GHG Reduction for TLU-10[21]

Year	Daily VMT Reduced	Percent Reduction in VMT from Regional Base	Percentage Increase In Transit Trips	GHG Reductions (MMTCO2e)
2020	751,961	0.4%	2.2%	0.06
2040	1,380,300	0.6%	3.4%	0.06
2050	1,898,793	0.8%	4.7%	0.08

Cost

Annual Cost is estimated as high. Even though some enhancements can be low cost, bus rapid transit, transit signal priority, and corridor treatments can be high.

Co-Benefits

- Reliability
- Congestion reduction
- Reduction in criteria air pollutants
- Economic vitality, jobs, equity
- Mobility & accessibility
- Community amenity

[21] TRIMMS sketch planning model and MOVES2014 data used to estimate benefits from strategy

TLU-11. Transit Incentives / Fare Reductions

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

Modeled Outcome

2016 to 2020 (viable)

- Reduce transit fares regionally by 20%.

2020 to 2040 (viable)

- Reduce transit fares regionally by 25%

2040 to 2050 (stretch)

- Reduce transit fares regionally by 40% partially funded through pricing strategies

Implementation Actions

- Reduced price monthly transit passes
- Free bus-rail transfers
- Free or reduced price off-peak bus service

Summary of Travel Impacts and GHG Reduction[22]

Year	Daily VMT Reduced	Percent Reduction in VMT from Regional Base	Percentage Increase In Transit Trips	GHG Reductions (MMTCO2e)
2020	1,646,775	0.8%	4.6%	0.12
2040	2,502,666	1.0%	5.9%	0.10
2050	4,418,938	1.8%	10.8%	0.19

Cost Annual Cost is estimated as low. Only the cost of incentives to the public sector is taken into account. Increase transit service cost could be off-set by the parking tax. Loss of revenue from lower gas tax collection from VMT reduction is possible.

Co-Benefits

- Congestion reduction
- Reduction in criteria air pollutants
- Mobility
- Accessibility
- Chesapeake Bay/storm water

[22] TRIMMS sketch planning model and MOVES2014 data used to estimate benefits from strategy.

TLU-12. Road Pricing

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

Modeled Outcome

2016 to 2020 (viable)

- Nothing new will be implemented as part of this strategy by 2020

2020 to 2040 (viable)

- Cordon pricing into downtown DC at $5/trip

2040 to 2050 (stretch)

- In addition to the cordon pricing, VMT charge of $0.10/mile on all roads.

Summary of Travel Impacts and GHG Reduction[23]

Year	Daily VMT Reduced	Percent Reduction in VMT from Regional Base	Percentage Increase In Transit Trips	GHG Reductions (MMTCO2e)
2020	None	None	none	None
2040	611,723	0.3%	8.6%	0.03
2050	18,559,839	7.8%	25.2%	0.79

Implementation Actions

- Conversion to full electronic tolling in the region
- Implementation of the District of Columbia's $ 5/vehicle cordon pricing for all vehicles
- Implementation of VMT charge of $ 0.10/mile on all roads

Public sector cost would be low after paying for transportation improvements using revenue generated from tolls and VMT fees. Private sector costs could be high.

Co-Benefits

- Safety
- Reliability
- Congestion Reduction
- Reduction in criteria air pollutants
- Chesapeake Bay/storm water

[23] TRIMMS sketch planning model and MOVES2014 data used to estimate benefits from strategy.