TITLE:
Meeting Transportation Greenhouse Gas Reduction Goals in the National Capital Region: A "What Would it Take" Scenario

ORIGINAL SUBMISSION DATE:
July 30, 2010

RESUBMISSION DATE:
November 15, 2010

WORD COUNT: 6,147

NUMBER OF FIGURES/TABLES: 4 figures, 1 table

CORRESPONDING AUTHOR:
Monica Bansal
Transportation Planner
Metropolitan Washington Council of Governments
777 North Capitol Street, NE
Suite 300
Washington, DC 20002
Phone: (202) 962-3290
Fax: (202) 962-3202
Email: mbansal@mwcog.org

CO-AUTHOR:
Erin Morrow
Transportation Engineer
Metropolitan Washington Council of Governments
777 North Capitol Street, NE
Suite 300
Washington, DC 20002
Phone: (202) 962-3793
Fax: (202) 962-3202
Email: emorrow@mwcog.org

ABSTRACT:

This paper provides a summary of the development, analysis and results of the "What Would it Take?" scenario, which examines what it would take in the National Capital Region to meet aggressive regional climate change mitigation goals in the transportation sector. This report includes a baseline inventory and forecast of carbon dioxide (CO_2) emissions in the region, identification and analysis of potential mitigation strategies, and an analysis of whether any combination of these strategies meets long-term mitigation goals. The report also includes cost-effectiveness analysis of these measures and specifically identifies short-term measures that can be feasibly implemented by local governments in the region. Major findings of the report are that it would be difficult to meet aggressive mitigation targets without a full suite of actions across the categories of fuel efficiency, alternative fuels, and travel efficiency. It was found that meeting early targets in transportation is possible if a wide range of short-term actions are taken by local governments immediately. The study also found that transportation strategies are unlikely to be implemented for CO_2 reduction alone and will have various other benefits from criteria pollutant reduction to increasing mobility and accessibility that should be factored into decision-making.

In the absence of national climate change legislation and regulatory action for the transportation sector, regional leaders in the National Capital Region began independently preparing for climate action in all sectors, including transportation. In 2007, the Metropolitan Washington Council of Governments (MWCOG) and the Transportation Planning Board (TPB), which is the Metropolitan Planning Organization (MPO) for the Washington metropolitan area, began large-scale regional efforts to address climate change in long-range planning across sectors. One of these efforts is the "What Would it Take" (WWIT) Scenario, which is a scenario analysis of how to achieve aggressive greenhouse gas (GHG) reductions in the transportation sector in the Washington region.

There has been significant national level research aimed at addressing climate change in the transportation sector, such as NCHRP Project 20-24 (59) (*1*); however, travel patterns, energy sources, mode splits, and land use patterns differ in every state, region and local jurisdiction and play a major role in the effectiveness of any particular strategy at reducing carbon dioxide (CO_2) emissions. The WWIT study provides this regional and sector specificity for a wide range of transportation strategies and may serve as a guideline for other regions. CO_2 emissions analysis was completed for individual transportation strategies to determine their emissions reduction potential, cost-effectiveness, and the timeframe for implementation. Since CO_2 is 99.5% of regional mobile GHG emissions, analysis was only completed for CO_2 emissions.

This study is intended to be a first step for local planners and officials to determine what types of strategies should be explored further as a response to climate change at the local level. It attempts to take national-level analysis a step further in specificity, but it is not a replacement for detailed case-by-case analysis needed for implementation-level planning.

THE WASHINGTON REGION'S CLIMATE CHANGE GOALS

The WWIT study is centered on meeting aggressive regional climate change goals. In November 2008, MWCOG approved voluntary short, medium and long-term regional emissions reduction targets that were based on international goals (*2*). These targets are to reduce annual regional CO_2 emissions to 2005 levels by 2012, 20% below 2005 levels by 2020, and 80% below 2005 levels by 2050 across all sectors. TPB's WWIT study applies these reduction targets to the transportation sector; however, since TPB's planning horizon at the time of this study was 2030, the final target for this study is a 40% reduction below 2005 levels by 2030. This study assumes an equal mitigation burden across sectors regardless of cost-effectiveness; however, it is unclear whether each sector will have equal reduction targets in future national climate legislation.

METHODOLOGY

The study followed five steps to determine what may be necessary to meet these aggressive regional climate change mitigation targets:

1. Created a baseline inventory of mobile source CO_2 emissions
2. Determined sources of reduction potential
3. Identified potential reduction strategies
4. Analyzed individual strategies for effectiveness, cost-effectiveness, and timeframe for implementation
5. Combined additive strategies to determine different pathways toward meeting goals

A detailed methodology can be accessed in the Technical Report completed for the "What Would it Take?" Scenario and is referred to throughout this paper (*3*).

Step 1: Baseline Inventory

"Business as Usual" CO_2 Inventory

In developing the CO_2 inventory, "business as usual" was first established, which assumes no major changes to the forecast of travel management programs or vehicle fleet. BAU was developed using the modeling output for the TPB's adopted 2009 Constrained Long-range Plan (CLRP), which contains detailed population and employment forecasts out to 2030 from the MWCOG Cooperative Forecast Round 7.2.

The CO_2 emissions calculation methodology was developed based on the TPB's experience with national air quality conformity regulations. The Washington DC region is currently designated nonattainment for the federal health standards for ozone and PM2.5 (*4*). Therefore, as used for air quality conformity assessments, Mobile6.2 was used to develop CO_2 rates. One of the key inputs to Mobile6.2 is information on the local vehicle fleet, which was last determined in 2008 by decoding Vehicle Identification Number (VIN) data provided by the state air agencies.

The final step was the application of a post-processor developed by E.H. Pechan to calculate the CO_2 inventories using the rates and output of the TPB travel demand model.

CO_2 Emissions Baseline Inventory

During study analysis there were federal and regional developments that could not be adequately reflected using Mobile6.2, which necessitated a refinement to the BAU forecast. Most notably, Mobile6.2 cannot account for the new federal Corporate Average Fuel Economy (CAFE) requirement (35.5 mpg for light-duty vehicles by 2016). In order to account for improved fleet fuel efficiency, a spreadsheet tool developed by consultant Dan Mezler was used to estimate the percentage CO_2 emissions reduction due to the new CAFE standard over BAU for both the light duty portion of the CO_2 inventory and the light duty CO_2 emission rates. Mr. Mezler was provided with local data, such as local VMT mix and vehicle fleet, by TPB staff as inputs to his calculations.

Also included in the CO_2 emissions baseline inventory are the reductions from Transportation Emissions Reduction Measures (TERMs), which are strategies with committed funding that TPB staff analyzes for criteria pollutant reduction. Many of these programs reduce fuel consumption through VMT reduction, which would also reduce CO_2. The TERMs were analyzed using regional survey data, MWCOG studies, consultant studies or national research. Some measures were analyzed using various components of MWCOG's four-step modeling process (trip generation, trip distribution, mode choice, and trip assignment) or the COMSIS TDM model. The assumptions and analysis approach for all of the strategies are detailed in the TERM document (*5*).

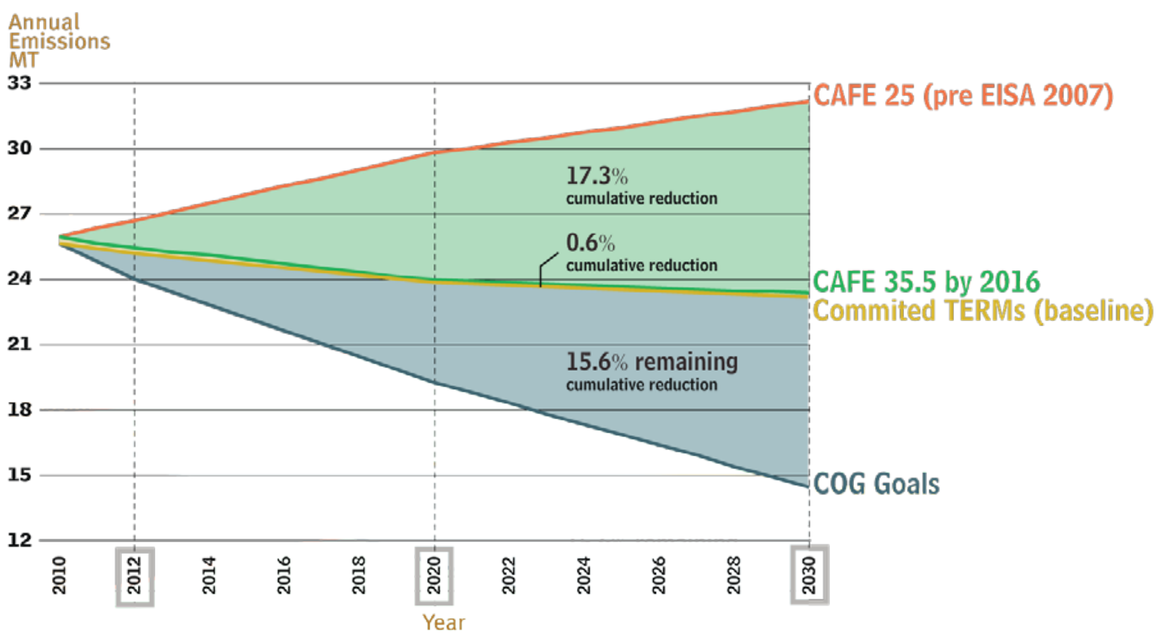
The Final Baseline Fills Part of the Gap between BAU and Regional Goals

Figure 1 shows the steps for calculating the "Final Baseline" as well as the MWCOG goals for 2020 and 2030 and the required reductions to meet those annual goals. After accounting for the federal and local reduction commitments already made the region is left with a significantly lower reduction goal than it began with under BAU.

Figure 1 displays the goals and reductions in "wedges." Analysis under this study was done on a cumulative basis. Experts have stated that the most prevalent GHGs, such as CO_2 and methane, remain in the atmosphere for decades, centuries or longer. As such, they behave differently than criteria pollutants, such as PM and NO_x, and thus require a different analytical framework (*6*). GHG emissions cannot be looked at on a daily or annual basis as is the case with criteria pollutants, but rather should be considered cumulatively over much longer periods of time than is traditional in current planning processes. Cumulative analysis also highlights issues with the overall effectiveness of strategies that may not be apparent with simple point-in-time analysis. When emissions are examined over time in a cumulative manner, early emissions reductions have a compounding effect upon future emissions levels, making early emissions reduction targets extremely important in building momentum. The study thus emphasizes strategies across the study timeframe—both short and longer-term.

The final baseline shows that a further 15.6% total emissions reduction below BAU levels, from 2010-2030, would be required to meet MWCOG goals, as illustrated by the bottom wedge.

FIGURE 1 Calculating the Final Baseline CO_2 Emissions Forecasts.



The bottom wedge represented the reduction still required to meet regional CO_2 reduction goals.

Other Federal Policies Included in the Analysis

An alternative fuel forecast to 2030 using national-level model output from the U.S. Department of Energy (US DOE) 2008 Annual Energy Outlook (AEO) was adapted to the Washington region and also included in the study. The analysis includes forecast alternative fuel use based on energy legislation, market forces, and fuel production potential for a wide range of fuels and vehicle types, including gasoline, diesel, compressed natural gas (CNG), corn and cellulosic ethanol, biodiesel, hydrogen, gasoline-electric hybrids, and plug-in hybrids (*7*).

The forecast for the region was calculated using lifecycle emissions rates for each fuel type based on a 2005 study commissioned by General Motors and Argonne National Laboratory (*8*), and EPA and DOE research, as detailed in the Technical Report (*3*). Baseline emissions rates and all other emissions analyses were done using tailpipe emissions rates; therefore, the alternative fuel forecast was not included in the baseline emissions inventory and rates because of compatibility issues. Instead, the forecast was treated as a separate strategy, with the forecast CO_2 reductions additively applied to the baseline. Double-counting between CAFE standards and the alternative fuel forecast was avoided by eliminating reductions attributable to fuels and vehicle types that would likely be used by auto manufacturers to achieve CAFE, such as any type of hybrid vehicle. Although the tailpipe/life cycle accounting issue still creates an apples-to-oranges comparison, it was decided to be a better solution than ignoring the impact of this legislation or using tailpipe emissions rates for the alternative fuel forecast, which would grossly overestimate emissions reductions in most cases, such as electric vehicles, and underestimate reductions in other cases, such as cellulosic ethanol. This strategy will be referred to as the "Alternative Fuel Forecast".

The addition of the alternative fuel forecast to the baseline results in an additional 2.1% emissions reduction from 2010-2030. The contribution of the alternative fuel forecast leaves the region with 13.5% reduction left to meet the regional goal, which is down from the initial 15.6% reduction. This reduction shortfall is revisited in the "Results" section.

Step 2: Identifying Sources of Potential Emissions Reductions

Once the CO_2 reduction necessary to meet regional climate goals was identified, an assessment of emissions sources was completed before developing a comprehensive list of potential reduction strategies for analysis. Mobile CO_2 emissions are generally affected by fleet composition, fuel choice, and travel behavior. Examples of analysis of current conditions are discussed below.

Fleet Composition

While sweeping CAFE standards are outside of the legislative capacity of regional and local governments, the impacts on emissions from substantial changes to regional fleet fuel economy must be understood to properly account for emissions and potential reductions of local and regional strategies. Changes in fuel economy of the fleet directly impact CO_2 emissions rates, meaning that as the fleet becomes "cleaner" and more fuel efficient via stricter CAFE standards, the CO_2 reductions achieved by other mechanisms, such as vehicle-miles traveled (VMT) reduction, are reduced. Therefore, rather than only examining aspects of transportation that regional and local governments have direct policy and implementation control over, the WWIT study contains a broad analysis of transportation factors including those that indirectly impact the emissions characteristics of regional policies and programs, such as CAFE standards.

The regional fleet is comprised of light duty vehicles, such as passenger cars and SUVs, and heavy duty vehicles, such as buses and trucks. Through CAFE standards and vehicle technology, the light duty vehicle fleet has become more fuel efficient over time, thus reducing the fleet's CO_2 emissions rate. Although CAFE standards set in 2008 drastically improved light duty fuel economy, fuel economy standards in other countries, such as the E.U., Japan, and China, point to the technological feasibility of even higher fuel economy standards (*9*).

Heavy duty vehicles have not been subjected to similar fuel efficiency requirements and in the Washington region are projected to comprise a growing share of emissions. Based on output of the MWCOG travel demand model and Mobile6.2, trucks and buses account for 10% of VMT and 20% of CO_2 emissions. In 2030, absent heavy duty fuel economy standards, they are projected to remain at 10% of total VMT, but grow to 30% of CO_2 emissions. Energy legislation in 2007 required the National Academy of Sciences (NAS) to study and recommend heavy duty CAFE standards for adoption by Congress, signaling progress in this area in the future (*10*).

Fuel Choice

According to national data from the U.S. Department of Energy (DOE), in 2009 gasoline was the source of 99% of energy consumed in the light duty transportation sector (*7*). Even with significant alternative fuel mandates from the Energy Independence and Security Act (EISA) of 2007, fuel use in 2030 is still projected to be dominated by gasoline at 81% of energy consumed in the light duty transportation sector.

Travel Behavior

Travel behavior includes trip purposes, lengths, mode, vehicle occupancy, congestion, and driving behavior. For example, an examination of trip lengths by mode shows that 45% of non-work trips and 18% of work trips are projected to be less than three miles in 2030. Given that the average bike trip length in the region is approximately two miles according to the 2007/2008 TPB Household Travel Survey, auto trips under three miles could be shifted to bicycling, walking, and low- or non-polluting vehicles if barriers to using these modes are overcome, such as urban design and land use issues.

Longer trips can also be shifted to less polluting modes or not traveling at all. In 2030, the region is forecast to be dominated by single occupant vehicle (SOV) use, at 87% of auto work trips and 72% of all motorized work trips. While transit shares are forecast to grow, they still only represent a small share of trips at 6% in 2008. Moreover, residential and commercial growth is forecast to be the fastest in the region's outer suburbs where transit access is sparser than in inner jurisdictions, resulting in more and longer auto trips in the future (*11*). Improvements to transit access, commuter services, cycling and pedestrian infrastructure, and financial signals or incentives to switch from SOV use to either high occupant vehicle (HOV) or transit are all potential sources of CO_2 emissions reduction.

The number of auto trips taken in this region under less than optimal operating conditions, such as sitting in congestion, driving aggressively, or starting and stopping frequently at untimed signalized intersections also impacts CO_2 emissions. Research from the University of California, Riverside shows that CO_2 emissions follow a U-curve, where for a typical vehicle fleet very slow vehicle speeds and very high speeds have much higher CO_2 rates than speeds in the middle range (35 mph-60 mph). Emissions reductions can be achieved through congestion mitigation, speed management, and traffic smoothing (*12*).

Step 3: Identifying Specific Reduction Strategies

A list of strategies to be analyzed were identified based on TERMs that had already been considered for the purposes of reducing criteria pollutants, transportation strategies listed in the National Capital Region Climate Change Report, and strategies from local, regional, and federal initiatives that responded to challenges identified in the aforementioned analysis of current conditions in the region. The regional, state and local strategies chosen were reviewed by TPB's

Travel Management Subcommittee and were thus largely limited to what the region may be willing to consider for implementation.

In total, thirty-seven strategies were analyzed within three categories: (1) Vehicle Fuel Efficiency, (2) Alternative Fuels, and (3) Travel Efficiency. A list of all strategies and descriptions are available in the study's full final and technical reports.

"Vehicle Fuel Efficiency" is comprised mostly of federal measures regarding light and heavy duty CAFE standards. These strategies were analyzed because of their technical feasibility and therefore potential implementation in the future. Examples include CAFE 55 mpg by 2030, heavy duty vehicle CAFE by 2020, and local tax incentives for fuel efficient vehicle purchase.

One strategy was studied under "Alternative Fuels", which examined the impact of high fossil fuel prices using the U.S. DOE AEO High Price Case. The AEO assumes the equivalent of $7/gallon gasoline, which could be the result of any number of federal policies or an external market force, such as an oil shock (*7*). DOE analysis provides model outputs for VMT and transportation energy consumption by fuel source, which was adapted for the Washington region using the same methodology as the "Alternative Fuel Forecast".

"Travel Efficiency" is the primary category for analysis of regional, state and local measures, including potential TERMs and other possible measures. The thirty-three measures analyzed here range from small scale, such as real-time bus schedule information and bike stations at rail transit stations, to large scale, such as concentration of forecast land use in regional activity centers and region-wide value pricing of existing and new highway lanes. The measures analyzed here are specific to the Washington metropolitan region, such as a major Metrorail expansion using the Dulles rail project as an example; however, the types of strategies explored are likely to be feasible in other regions and have likely already been examined in some form for non-climate reasons, such as criteria pollutant reduction or congestion mitigation.

A list of all strategies and descriptions are available in the study's full final and technical reports (*3*).

Step 4: Individual Analysis of Strategies

Each individual strategy listed in the previous section was analyzed for emissions reduction potential using the sketch planning methodology used for the TERM analysis, as described under Step 1 of this section. The assumptions and analysis approach for all of the strategies are detailed in the TERM document and the Potential TERM document. The Technical Report includes detailed methodology for each of the thirty-seven strategies in its appendices (*3)*. The CO_2 emissions rates used to calculate emissions benefits were those developed using Mobile6.2 and reduced to reflect the reductions from federal CAFE standards using the same percentage reduction from the Dan Mezler spreadsheet tool as was used to develop the CO_2 inventory baseline. Category 3 measures were only analyzed using these baseline rates. The federal measures in Categories 1 and 2 were assumed to be a separate scenario and were not assumed to be in place when analyzing feasible regional/state/local measures. As such, both the base case and the effect of stricter federal policies were examined separately.

Measures were also assessed for their cost-effectiveness in terms of dollars of program or project cost per ton of CO_2 abated as a method of prioritizing the variety of possible interventions. The cost-effectiveness calculation was based on the procedure used to determine the cost-effectiveness for TERMs in reducing criteria pollutants. The cost-effectiveness is a simplified calculation dividing the annualized cost of the project by the annualized emissions. In most cases, the only costs considered were those incurred by the project/program owner/administrator, such as capital or operating costs. The user costs (or cost savings) were not factored in. The cost-effectiveness for each of the strategies was calculated for year 2020 in current year dollars, except for the examples from the TERM Tracking Sheet which have cost-effectiveness for 2010. The methodology for calculating cost-effectiveness is in the “Potential TERMs” document (*13*).

Lastly, measures were analyzed over a twenty-year time period (2010-2030) to determine the timeframe for implementation and also their cumulative reduction impacts. Analysis beyond this point was not possible within this study because the regional travel demand model, which provides the basis for assumptions used in the sketch planning analysis, used 2030 as the horizon year at the time of this study; however it is understood that a long planning horizon is important in climate action planning

Step 5: Grouping Strategies for Final Analysis

Individual strategies were grouped according to the level of government able to implement the strategy. There are two groups as follows:

1. High federal role: Current legislation is augmented with hypothetical longer term policies, such as an extension and enhancement of CAFE standards to 55 mpg by 2030, creation of an average fuel economy standard for heavy duty vehicles that doubles current heavy duty fuel economy by 2020, and national gas price increases to $7/gallon. Although the region cannot count on a higher federal role in the future, there are indications that these strategies are being considered in some form, particularly fuel economy strategies. As such, it is important to understand their potential effect on regional emissions levels.
2. Short- and long-term regional strategies: This analysis assumes current federal legislation, which includes baseline assumptions and the Alternative Fuel Forecast. Short-term strategies are assumed to be implementable by state and local governments before 2020 and includes twenty-seven different strategies across five categories of:
    a. Increase transit use: Strategies to improve existing services, such as Metrorail feeder service, new cleaner-fueled transit buses, free bus service, priority bus treatments
    b. Increase bicycle/pedestrian use: Improved pedestrian access to transit, bike stations, bike-sharing, etc.
    c. Pricing: Parking cash-out subsidies, parking impact fees, and pay-as-you-drive insurance
    d. Improve operational efficiency: Strategies intended to improve traffic flow to ensure more steady operating speeds, such as a region-wide eco-driving education and training campaign, idling reduction, regional incident management, and traffic signal optimization
    e. Reducing travel: Carpool and vanpool incentives, telecommuting, and car-sharing.

    Long-term strategies are assumed to be implementable by state and local governments between 2020. Three categories of long-term strategies were examined:
    a. Increasing non-auto mode share: Major transit and bicycle/pedestrian infrastructure projects, such as a Metrorail expansion project and the accelerated completion of the TPB Bicycle and Pedestrian Plan
    b. Pricing: TPB Value Pricing Study, which studied variable pricing of new and existing freeway and select arterial lanes throughout the region

c. Reducing travel: Concentrated, transit-oriented land use development in the region's activity centers examined in a TPB land use and transportation scenario.

The full list of strategies and their descriptions can be found in the Technical Report (*3*).

The groupings combine additive strategies to the fullest extent possible at this time. It is possible that further combinations can be made to move closer to achieving regional goals, but careful analysis will be needed to avoid double-counting or overstating benefits. It should also be noted that each grouping represents only the additive impacts of strategies, rather than a true "bundling" of strategies, which would account for interactions, both positive and negative, between multiple strategies. Further explanation of both issues is included in the following section.

RESULTS

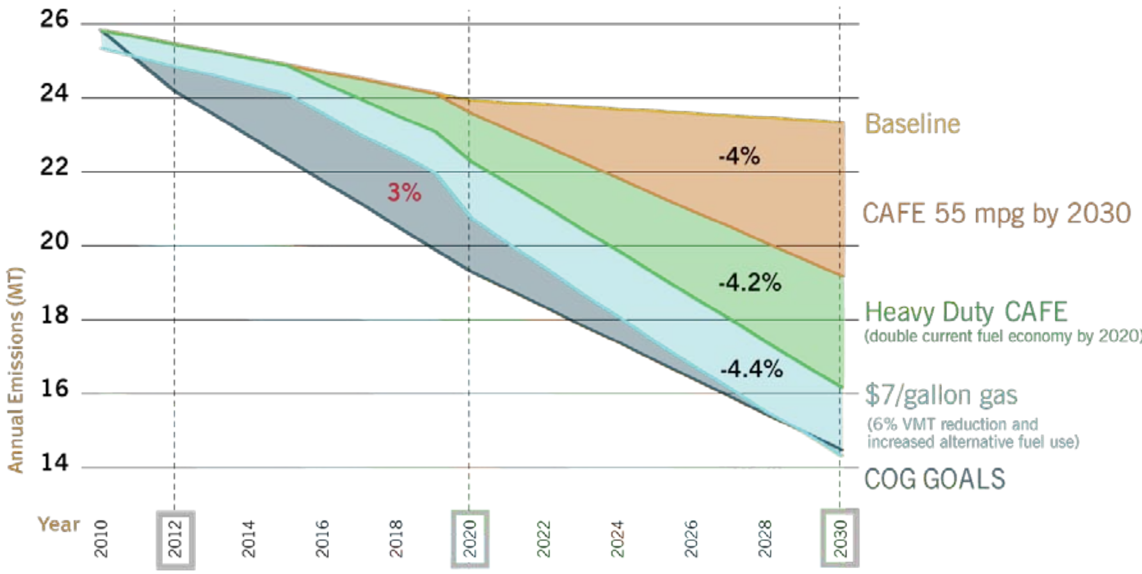
The four groupings outlined in the previous section were all analyzed to determine whether their cumulative reduction over the twenty-year study period would achieve the 15.6% remaining emissions reduction necessary to meet the COG goals.

Group 1: High Federal Role

The "high federal role" grouping examines the impact of hypothetical, large-scale action taken by the federal government, including enhanced light duty CAFE standards, heavy duty CAFE standards, and high gas prices. According to U.S. DOE's national-level models the national increase in gas prices produced second order effects that greatly impact CO_2 emissions: a 6% reduction in VMT and a significant increase in use of alternative fuel/hybrid vehicle technology. The 6% VMT reduction assumes less travel as a result of high gas prices and does not assume specific regional travel demand strategies to offset this VMT reduction with increased demand on other modes, such as increased transit, compact land use, or bike and pedestrian infrastructure.

Figure 2 shows that these three actions combined reduce CO_2 emissions to almost meet the overall GHG reduction goal. Together the actions achieve reductions in excess of the 2030 target; however, they do not ramp up fast enough to meet the 2012 or 2020 targets. Cumulatively, by 2030 the actions in Group 1 reduce CO_2 emissions by 12.6%, still 3% short of the regional reduction goal.

FIGURE 2 "High Federal Role" Grouping CO_2 Emissions from 2010-2030.



The three aggressive federal actions almost meet regional goals, but do not meet early targets.

Group 2: Short- and Long-Term Regional Actions

Group 2 focuses on actions that can be taken by local, state, or regional governments and thus includes smaller scale strategies than Group 1.

Table 1 shows that the short-term strategies combined produce a significant reduction in emissions, by 3.9% below BAU levels. The two most effective categories of strategies are the pricing and improve operational efficiency. Both categories include wide-reaching measures, such as pay-as-you drive insurance and eco-driving. The eco-driving strategy was found to be the most effective because of its potential impact on a large percentage of light duty drivers.

Table 1 also shows that the long-term strategies combined produce a cumulative reduction of 0.8% below BAU levels by 2030. Significantly fewer longer-term strategies were studied than the almost thirty shorter-term strategies and several strategies were assumed to be completed in 2030, which is the upper limit of the study analysis time period. For instance, the smart growth land use strategy is expected to be completed in 2030; therefore, while it is a wide-reaching measure, the benefits are diluted over the 20-year period since it has a long implementation timeframe. Further benefits that would be accomplished beyond 2030 were not incorporated in this study.

While the strategies alone do not achieve the overall goal, they almost meet the earliest 2012 target putting the region on the right track toward meeting the later targets.

TABLE 1 CO_2 Emissions Reductions from Short- and Long-term Strategies

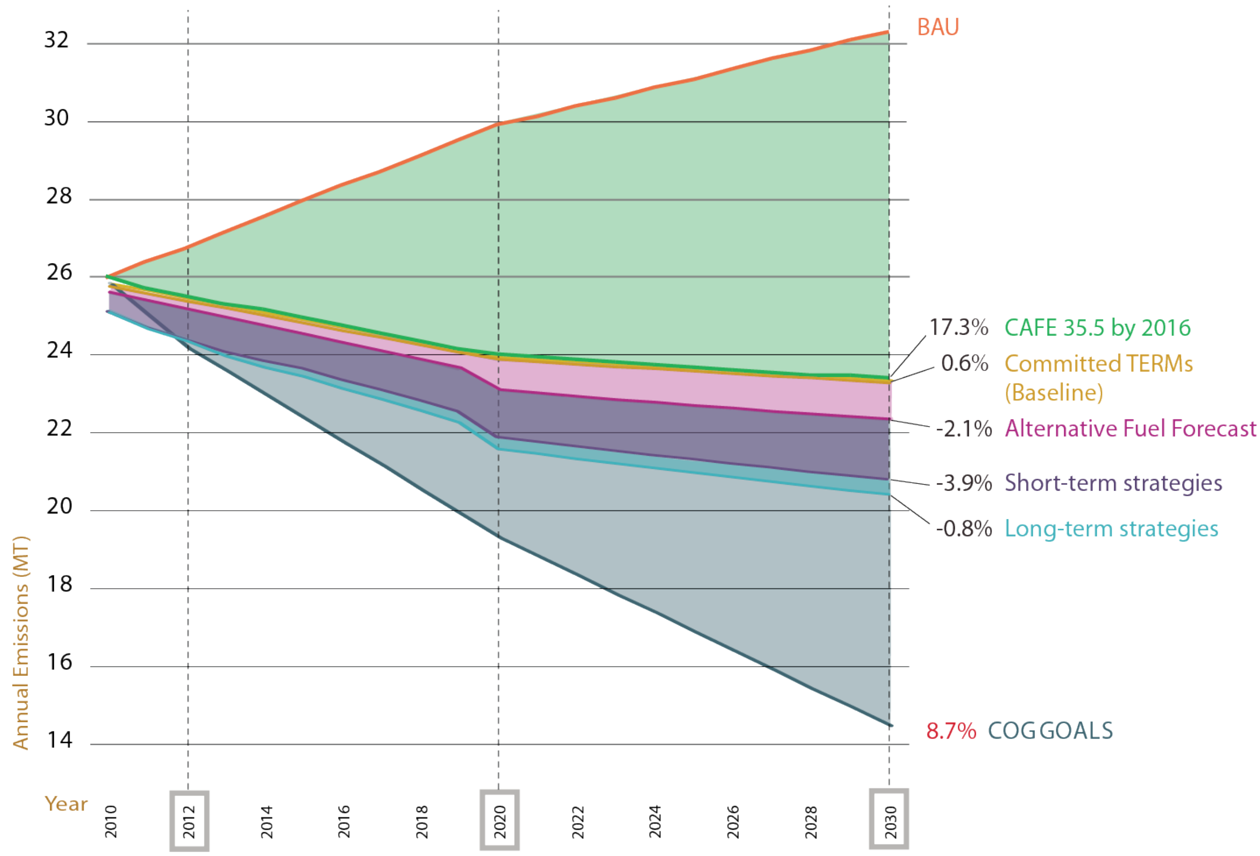
CO2 Emissions (millions of tons)					
	2010	**2020**	**2030**	**Cumulative Emissions (2010-2030)**	**% Reduction off of BAU levels**
Business as Usual (BAU)	**26.05**	**29.91**	**32.28**	**619.99**	**n/a**
COG CO2 Emissions Targets	***24.14***	***19.28***	***14.46***	***412.40***	***33.5%***

CO2 Emissions Reductions (millions of tons)					
	2010	**2020**	**2030**	**Cumulative Reductions (2010-2030)**	**% Reduction off of BAU levels**
Federal Policies					
CAFE 35.5 by 2016	0.00	5.86	8.84	107.24	17.3%
Regionally Committed TERMs	0.26	0.14	0.12	3.46	0.6%
BASELINE (CAFE 35.5 by 2016 + Committed TERMs)	**0.26**	**6.00**	**8.96**	**110.70**	**17.9%**
Alternative Fuel Forecast	**0.19**	**0.81**	**0.98**	**13.21**	**2.1%**
TOTAL (Baseline + Alt. Fuel Forecast)	**0.45**	**6.81**	**9.94**	**123.91**	**20.0%**
Short-term Strategies:					
(1) Increase Transit use (13 measures)	0.10	0.10	0.09	1.95	0.3%
(2) Increase Bike/ped mode share (3 measures)	0.003	0.005	0.008	0.12	0.02%
(3) Pricing (3 measures)	0.32	0.48	0.44	8.99	1.45%
(4) Improve Operational Efficiency (4 measures)	0.07	0.59	0.95	11.61	1.87%
(5) Reduce Travel	0.03	0.07	0.08	1.78	0.29%
TOTAL (all Short-term Strategies)	**0.52**	**1.24**	**1.57**	**24.45**	**3.9%**
Long-term Strategies:					
(1) Increase Transit use (2 measures)	0.00	0.05	0.05	0.81	0.13%
(2) Increase Bike/ped mode share (1 measure)	0.00	0.12	0.11	1.85	0.30%
(3) Pricing (1 measure)	0.00	0.08	0.11	1.48	0.24%
(4) Reduce Travel (1 measure)	0.00	0.04	0.10	0.91	0.15%
TOTAL (all Long-term Strategies)	**0.00**	**0.29**	**0.36**	**5.04**	**0.8%**
TOTAL Reductions (All Strategies)	0.97	8.34	11.87	153.41	24.8%
Reduction still required to meet goal		**2.30**	**5.95**	**54.18**	**8.7%**

Figure 3 shows the reduction of the Group 2 strategies from the combination of the baseline and the alternative fuel forecast. Group 2 is not shown in combination with Group 1 because of issues with double-counting and the relative effectiveness of the strategies would also decrease since the fleet emissions rates would be significantly lower.

The full list of strategies and their descriptions can be found in the technical report (*3*).

FIGURE 3 "Long-term Regional Actions" Grouping CO_2 Emissions from 2010-2030.



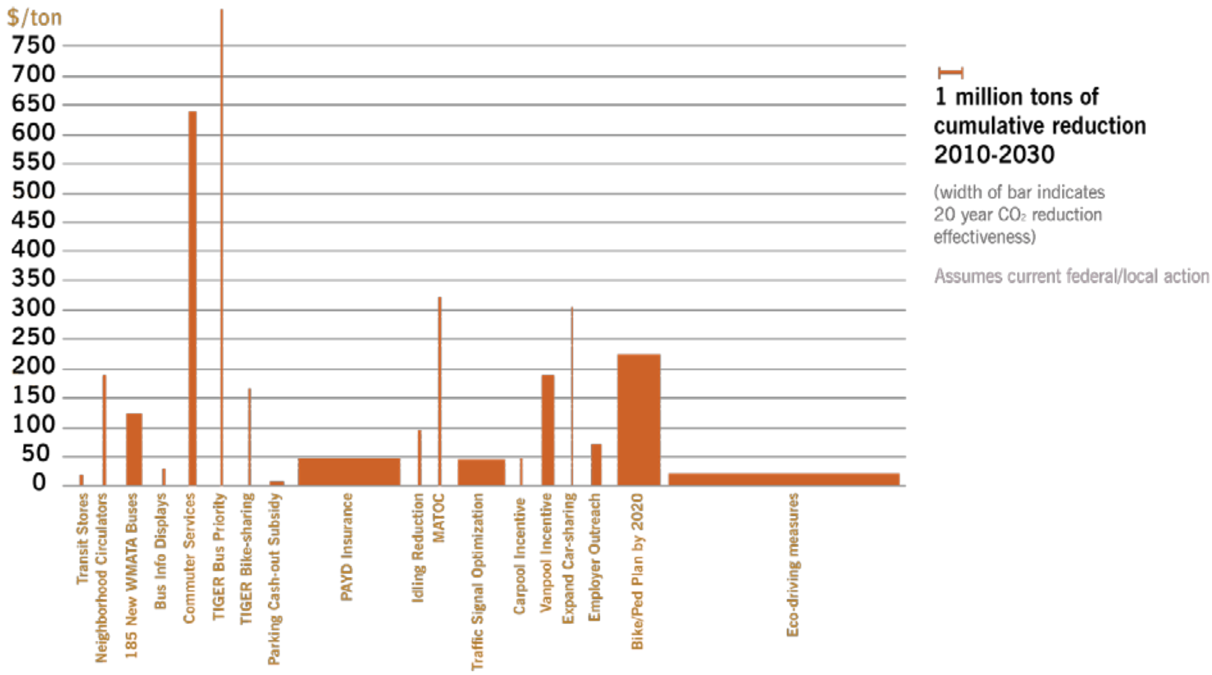
The short and long term regional actions almost meet early targets, but ultimately do not meet the regional goals.

Cost-Effectiveness Analysis

Strategies were also analyzed for their cost-effectiveness as a prioritization metric, following procedures used to evaluate TERMs for reducing criteria pollutants. In Figure 4, a subset of the strategies analyzed is shown in terms of cost-effectiveness (the length of the bars) and effectiveness at reducing CO_2 (the width of the bar). The shortest and widest bars represent strategies that could be considered low-hanging fruit for implementation.

Currently federal guidelines provide general direction on how to value CO_2 by setting values for the "social cost of carbon" at $33 per ton for the year 2030 in 2010 dollars, which is an estimate of the monetized damages associated with an incremental increase in CO_2 emissions in a given year (*14*). Based on this valuation alone, some cost-effective measures include the pay-as-you-drive insurance, parking cash-out subsidies, and purchase of new CNG transit buses. The accelerated completion of the TPB Bicycle and Pedestrian Plan also stands out as an effective strategy in the middle of the cost-effectiveness range. Most measures demonstrated modest CO_2 reduction potential and thus show high cost-per-ton values. Since CO_2 emissions reductions are unlikely to be the sole justification for investing in transportation projects, other methods of weighing costs and benefits are necessary. Through the course of this study and growing experience with comprehensive benefit cost analysis, as required by the US Department of Transportation TIGER Grant Program, it was concluded that the cost-effectiveness methodology used for criteria pollutants is not the most appropriate tool for evaluating strategies for CO_2 reduction effectiveness.

FIGURE 4 Cost-Effectiveness Analysis for Subset of Individual Strategies (Cost per Ton of CO_2 Abated)



The strategies with short and wide bars could be the region's low-hanging fruit.

DISCUSSION

The strategies analyzed in this study do not combine to meet the Washington region's CO_2 reduction goals. *So what will it take?* Since the study largely adhered to strategies that were deemed politically and financially feasible, it was found that meeting aggressive regional targets would require more than what the federal government and many state and local governments are prepared to consider at this time. In the Washington region this was an important lesson, particularly for planners and elected officials. As such, this analysis provided a starting point for planners and policymakers by making relative comparisons between strategies based on CO_2 reduction potential and cost-effectiveness.

This study also confirmed that meeting the region's goals will require a diverse portfolio of strategies across all levels of government and across the three categories of fuel efficiency, alternative fuels and travel efficiency. The "high federal role" grouping illustrated that while aggressive measures can be ramped up over time to achieve the later targets, the overall reduction goal cannot be met without meeting the earlier targets as well—which will require local, state, and regional actions. At the same time, the study shows that the most aggressive CO_2 reduction strategies can only be accomplished by the federal government; however, local governments have the ability to achieve important early targets by implementing a wide range of early actions.

There were certain types of strategies within state and local government control that emerged as drivers of success in reducing CO_2 emissions. First, given the growing share of emissions by heavy duty vehicles, among the most successful strategies were those that affected the whole fleet, both light and heavy duty. The most effective example from this study was traffic signal optimization, which can improve traffic flow for any vehicle passing through a signalized intersection, whether heavy or light duty.

Second, strategies that can affect the whole light duty fleet were shown to be more effective than those that target small portions of the whole fleet. Since light duty vehicles represent around 90% of VMT in the region, targeting light duty drivers were shown to have a significant impact on CO_2 emissions. For example, the analysis of the eco-driving measure assumes that light duty vehicle drivers could increase their vehicle fuel efficiency by 10% through a variety of eco-driving practices and subsequently resulted in a major fuel efficiency gain for a large percentage of drivers. Similarly, since auto insurance is a requirement for all drivers, the pay-as-you-drive insurance measure was assumed to affect a significant portion of drivers.

Third, given the growing proportion of emissions from heavy duty vehicles, even a small-scale application of a measure that targets the highest polluting vehicles, such as buses, was highly effective. The purchase of new CNG buses for crowded bus routes was found to be among the highest performing measures. The low fuel efficiencies and slow speeds of buses leave significant room for improvement on the operations and technology side, such as through heavy duty fuel efficiency, transit signal priority, and alternative fueled vehicles.

Fourth, if done on a large enough scale, providing wide-spread non-polluting transportation options was also effective. For instance, the accelerated completion of the 2030 TPB Bicycle and Pedestrian Plan by 2020 was among the best performing strategies over the twenty-year period because of the extensiveness of the network and connections to other non-motorized and transit infrastructure.

Lastly, since roughly 20% of all trips are work trips there is significant CO_2 emissions reduction potential in targeting commute trips. Many commuter services are already offered throughout the region, but there is still potential in offering additional services aimed at lowering the SOV rate and reducing VMT from commuting. For instance, enhancing commuter transit services, incentivizing carpooling/vanpooling, and encouraging public and private employers to offer increased telecommuting support have potential for reducing CO_2 emissions.

When looking at strategies for potential CO_2 reductions, it should be noted that TPB has a long history of supporting projects and programs designed to reduce congestion and vehicle emissions and improve accessibility and mobility. It is unlikely that strategies adopted throughout this region in the transportation sector will have the sole intended benefit of CO_2 reduction, as may be the case in other sectors such as electricity generation and delivery. Many measures, such as improving transit, increasing telecommuting options, expanding regional incident management, and implementing road and/or parking pricing options have benefits beyond climate change mitigation, such as congestion reduction, greater access to employment and services, time savings, and safety benefits. Therefore, an evaluation tool such as comprehensive cost benefit analysis would be more appropriate than the cost-effectiveness calculation used in this analysis.

NEXT STEPS

Climate change will continue to be a pressing issue on the international, national and local stages for many years to come regardless of federal legislation. The outcomes of this study have not only uncovered the potential of many strategies to move the region closer to meeting GHG emissions targets, but have also highlighted several possible directions for regional climate change work to progress:

1. Prepare CO_2 emissions inventories and analyze reductions from strategies using updated air quality modeling tools such as MOVES (Motor Vehicle Emissions Simulator) which will allow for CO_2 emissions sensitivity by speed and the impact of federal CAFE standards to be incorporated in the modeling process.
2. Work with local governments to further analyze effective strategies for potential implementation, such as telecommuting and compressed work week options, incentivized carpooling and vanpooling, bicycle and pedestrian infrastructure improvements, bus priority treatments, real-time transit arrival information, concentrated transit-oriented/mixed use development, eco-driving, incident management and regional coordination, and traffic flow improvements on identified corridors.
3. Analyze additional strategies, such as bus rapid transit and light rail, broader exploration of pricing, such as pricing of existing lanes and cordon pricing, and major freight improvements.
4. Begin analyzing strategies in bundles. Bundling should be studied further to determine potential effects, both positive and negative, of combining multiple strategies. For example, several bicycle strategies were analyzed independent of each other, but if grouped could have an even larger VMT reduction potential. On the other hand, if carpool and vanpool incentive programs target the same commuters, their combined emissions reduction potential could be lower than anticipated.
5. Consider unintended impacts and second order demand effects for all strategies. For instance, operational improvements, such as traffic signal optimization, that improve travel times and reduce congestion must be studied on a case-by-case basis to determine potential loss of benefit from induced travel demand.
6. Further analyze the study's strategies within a comprehensive cost-benefit framework in order to account for multiple benefits.
7. Estimation of lifecycle emissions for the CO_2 emissions inventory and strategy analysis.

ACKNOWLEDGEMENTS
The report authors would like to acknowledge Daivamani Sivasailam, Anant Choudhary, Yu Gao, Eulalie Gower- Lucas, Jinchul (JC) Park, Daniel Son, Michael Clifford, and Ronald Kirby for their assistance on this study.

REFERENCES

1. Burbank, Cynthia. Strategies for Reducing the Impacts of Surface Transportation on Global Climate Change. NCHRP Project 20-24 (59), Transportation Research Board of the National Academies, Washington, D.C., 2009.
2. *National Capital Region Climate Change Report*. Publication 20087334. Metropolitan Washington Council of Governments, 2008.
3. Preliminary Analysis of Potential Transportation-related Greenhouse Gas Reduction Strategies for the Washington, D.C. Region. Presented to Scenario Study Task Force of the National Capital Region Transportation Planning Board, Washington, D.C., May 19, 2010. https://www.mwcog.org/uploads/committee-documents/aF5YX1lX20100621122605.pdf
4. *Air Quality Conformity Determination for the 2009 CLRP and FY 2010-2015 TIP*, Publication 20096360. National Capital Region Transportation Planning Board, 2009.

5. *TERM Section-Appendix A and B of Call for Projects 2009 CLRP & FY 2010-2015 TIP, Appendix B TERM Reporting – TERM Tracking Sheet*. National Capital Region Transportation Planning Board, 2009. http://www.mwcog.org/transportation/activities/quality/terms.asp

6. U.S. Global Change Research Program. *Global Climate Change Impacts in the United States*. Cambridge University Press, New York, 2009.

7. *Annual Energy Outlook 2009*. Report DOE/EIA-0383(2009). EIA, U.S. Department of Energy, 2009.

8. Brinkman, Norman et al. Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems — A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions. General Motors Corporation and Argonne National Laboratory, 2005.

9. An, Feng and Sauer, Amanda. Comparison of Passenger Vehicle Fuel Economy and Greenhouse Gas Emission Standards around the World. Pew Center on Global Climate Change, Washington, D.C., 2004.

10. Energy Independence and Security Act, Pub. L. 110-140 § 108, 121 Stat. 1492, 1505 (2007)

11. *2009 Constrained Long Range Plan*. Publication 20096369. National Capital Region Transportation Planning Board, 2009.

12. Barth, Matthew et al. Traffic Congestion and Greenhouse Gases. *Access*, No. 35, University of California Transportation Center, Berkeley, CA, Fall 2009, pp 2-9.

13. Analysis of Potential Transportation Emissions Reductions Measures (TERMs) Under Consideration for the 2009 CLRP & FY2010-15 TIP. Presented to Travel Management Subcommittee of the National Capital Region Transportation Planning Board, Washington, D.C., 2009.
http://www.mwcog.org/uploads/committee-documents/Y15bW1ZW20090728103436.pdf

14. Interagency Working Group on Social Cost of Carbon. Appendix 15A: Social Cost of Carbon for Regulatory Impact Analyses Under Executive Order 12866. United States Government, 2010.