TPB Climate Change Mitigation Study of 2021: Report Findings

Presentation to TPB Community Advisory Committee (CAC)

Michael Grant
ICF

December 9, 2021

Key Goals of Study

- Identify pathways to reduce greenhouse gases (GHGs) within on-road transportation commensurate with the region's 2030 and 2050 GHG reduction goals.
- Explore scenarios to understand what types of strategies (policies, programs, and investments) are needed to achieve the goals, and what level of GHG reductions might be achieved under different scenarios.

Key Analysis Steps

Review of past studies	Conduct review of climate change mitigation studies in the COG region (Phase I, performed by TPB staff)
Literature review	Conduct Phase II literature review of climate change mitigation studies and climate action plans
List of scenarios and actions	Develop a limited list of scenarios and associated GHG reduction actions to explore
Tool/model selection	Select tools/models for the analysis
Analysis	Calibrate and validate the selected tools and models; conduct analysis using the selected tools
Report	Document and present findings in a draft and final report

Pathways to On-Road GHG Reduction

Vehicle Technology and Fuels

- Improve fuel economy of vehicle fleet
- Advance alternative fuels
- Accelerate electric vehicle deployment

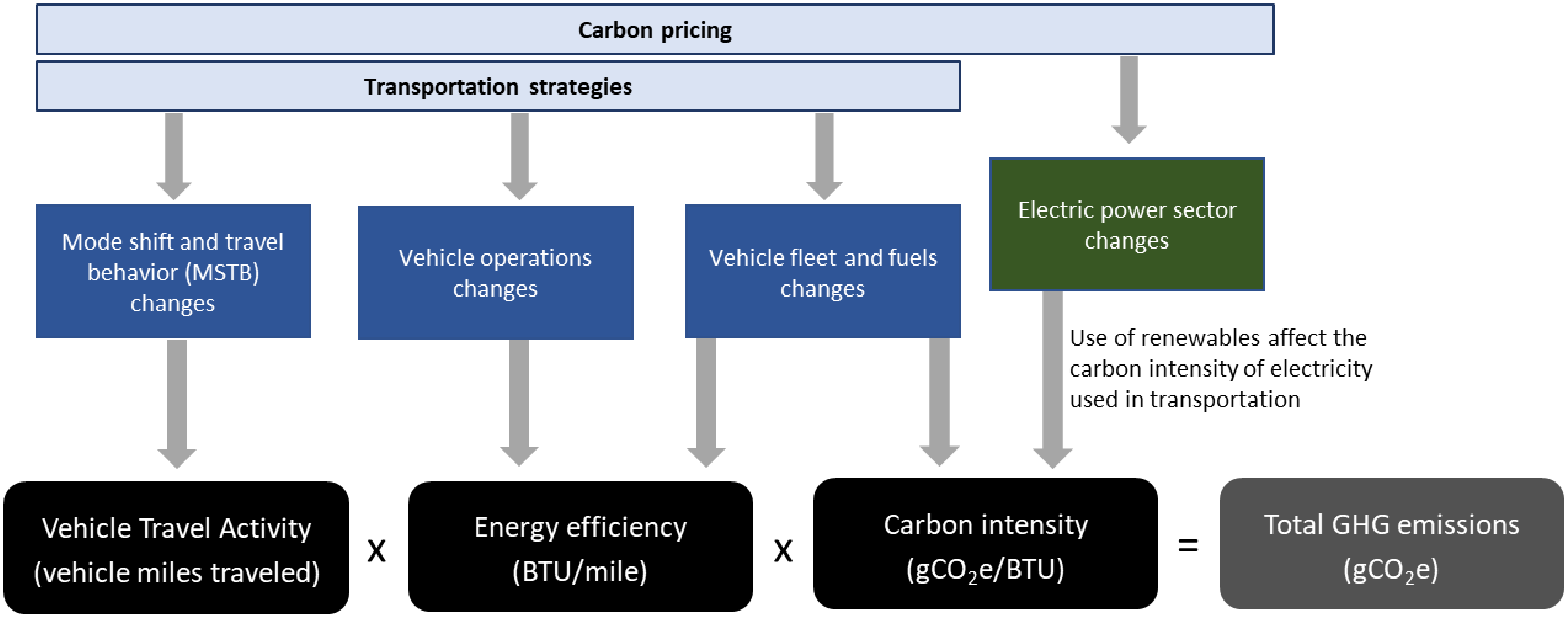
Mode Shift and Travel Behavior (MSTB)

- Mode shifts to transit, carpooling, nonmotorized
- Reduce trip lengths (e.g., brings jobs and housing closer together)
- Replace trips (e.g., telework, alternative work schedules)

Transportation Systems Management and Operations (TSMO)

- Enhance incident management, traffic signal coordination, and other operations strategies
- Reduce speeding and idling
- “Eco-driving”
- Deploy connected and automated vehicles (CAVs) regionwide

Strategies and Pathways for Reducing GHG Emissions from On-Road Vehicles



Analysis of Top-Down Scenarios

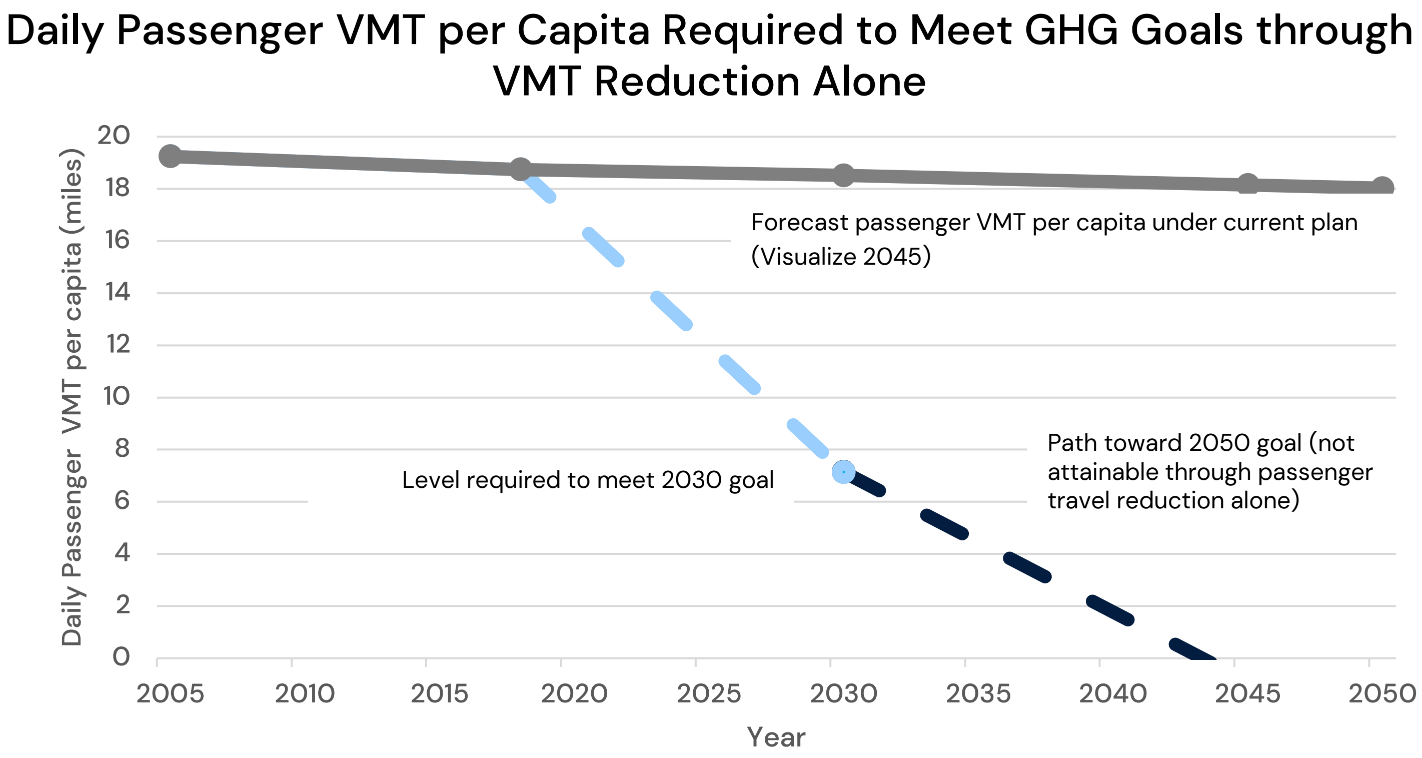
What level of VMT reduction would be needed to meet the regional 2030 and 2050 goals if VMT reduction were the sole focus of efforts?

What level of electric vehicle (EV) adoption would be needed to meet the regional 2030 and 2050 goals if vehicle technology were the sole focus of efforts?

NEW: What level of VMT reduction would be needed to meet the regional 2030 goal assuming vehicle technology assumptions in the Climate and Energy Action Plan (CEAP)?

VMT Reduction Alone

- To achieve the 50% emissions reduction goal by 2030 (compared to 2005 levels), using VMT reduction alone, passenger VMT
  - Would need to drop by 57% from 2018 level (61% compared to the 2030 forecast level).
  - Would need to drop from 18.7 daily vehicle-miles per capita in 2018 to 7.1 in 2030.
- 80% emissions reductions goal by 2050
  - Is not attainable through passenger VMT reduction alone.
  - Medium and heavy-duty vehicle emissions exceed the 2050 goal of 4.15 million metric tons by 2.24 million metric tons.



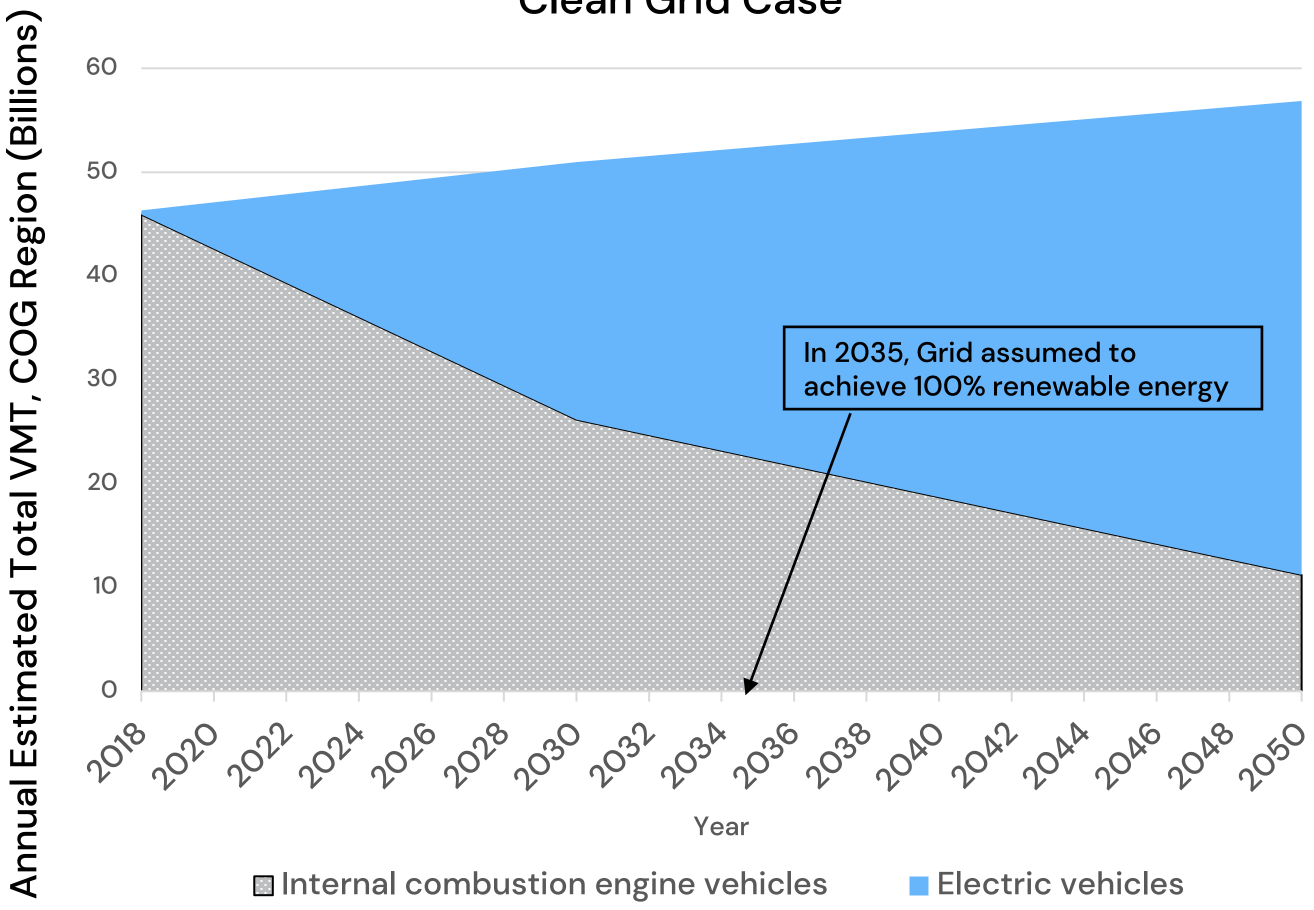
These are unprecedented levels of sustained VMT reduction that would likely require very high levels of pricing (road, parking, fuel), nearly complete telework, and/or restrictions on driving. Despite forecasted population growth, traffic volumes in the region would need to shrink to the level seen at the height of the COVID-19 stay-at-home orders during April 2020 and not rebound.

Vehicle Technology Improvements Alone

- To achieve the 50% emissions reduction goal by 2030, using vehicle technology alone:
  - 75% of vehicles on the road would need to be EVs by 2030 using the ICF Reference Case ("on the books policies") for carbon intensity of the electrical grid.
  - 48% would need to be EVs by 2030 in the Clean Grid Case.
- 80% emissions reduction goal by 2050:
  - Cannot be achieved under the ICF Reference Case assumptions for electricity carbon intensity.
  - 79% of vehicles on the road would need to be EVs by 2050 in the Clean Grid Case.

Note: This "top down" analysis used simplified assumptions with proportionate EV adoption across all vehicle classes; more robust analysis using different assumptions about EV adoption by different vehicle classes was conducted as part of the "bottom up" scenario analysis.

Forecast VMT by Technology Type Required to Meet GHG Goals through Shifts to EVs Alone
Clean Grid Case

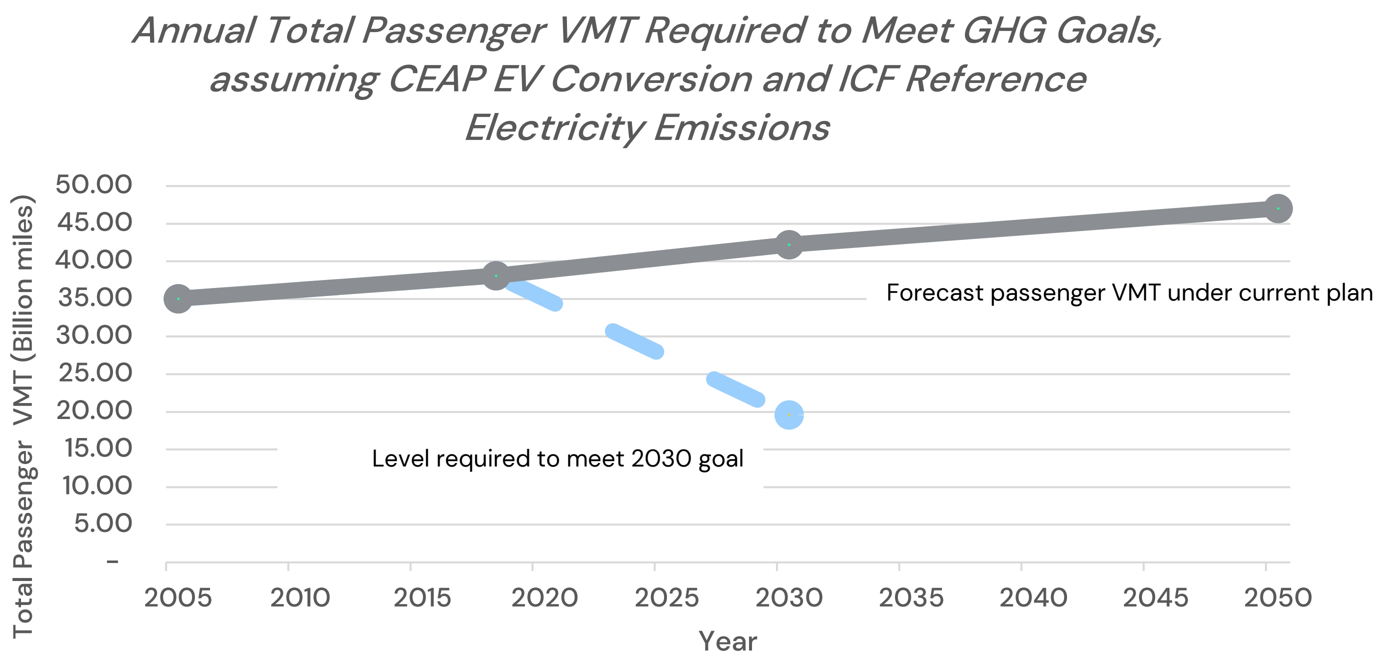


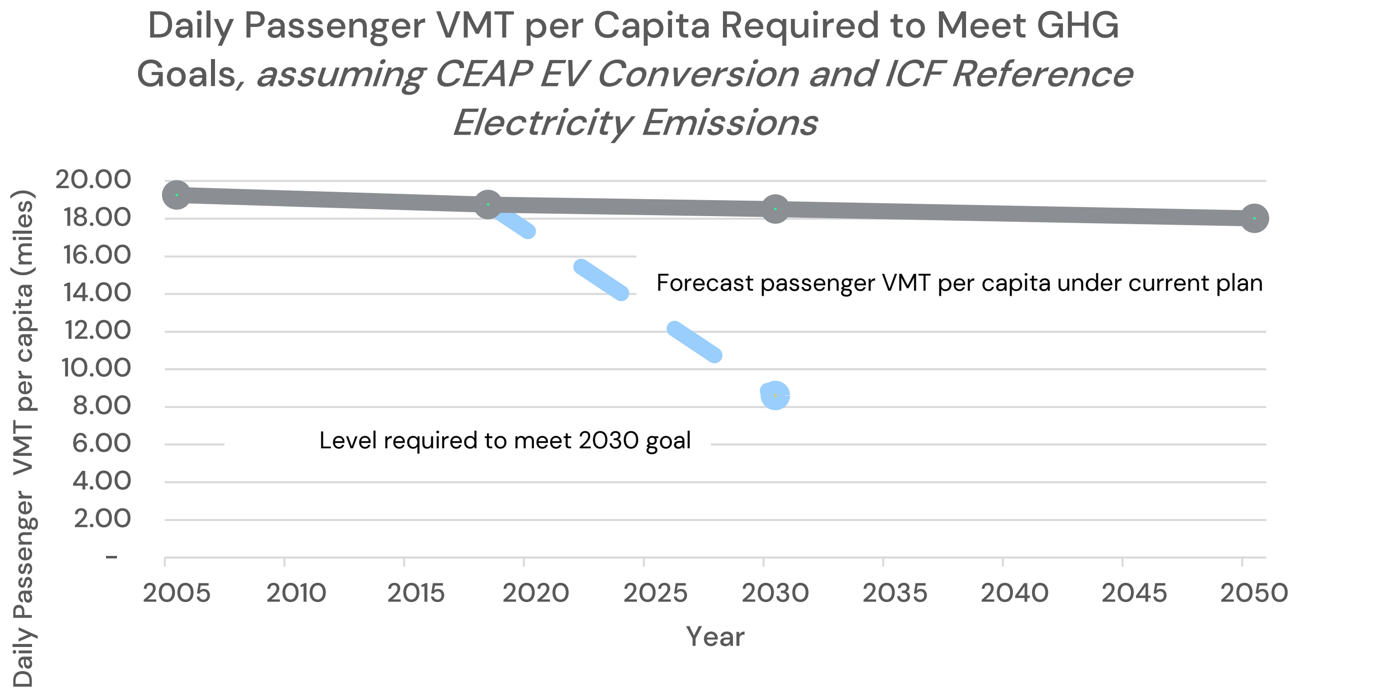
The required level of fleet change by 2030 is extremely ambitious and would likely require immediate shifts to all new vehicles sold as EVs, aggressive incentives to accelerate vehicle turnover, and/or carbon or fuel pricing increases.

VMT Reduction under the CEAP Technology Assumptions

- To achieve the 50% emissions reduction goal by 2030 with the CEAP technology assumptions, passenger VMT
  - Would need to drop by 49% from the 2018 level, while the region's population grows (drop 54% compared to the 2030 forecast level).
  - Would need to decline from 18.7 daily vehicle-miles per capita in 2018 to 9.6 in 2030.

These analyses highlight the challenge facing on-road transportation sources in meeting the regional goals.





Development of Bottom-Up Scenarios

Overview of 10 Scenarios

Pathway	Scenario	Title
Vehicle Technology and Fuels Improvements	VT.1	Vehicle Technology and Fuels Improvement Scenario
	VT.2	Amplified Vehicle Technology and Fuels Improvement Scenario
Mode Shift and Travel Behavior	MS.1	Mode Shift Scenario
	MS.2	Mode Shift Scenario + Road Pricing
	MS.3	Amplified Mode Shift Scenario + Road Pricing
Transportation Systems Management and Operations (TSMO)	TSMO	Transportation Systems Management and Operations Improvement Scenario
Combined Pathways	COMBO.1	Combined Scenario (VT.1 + MS.1 + TSMO)
	COMBO.2	Combined Scenario with More Aggressive Technology Emphasis (VT.2 + MS.1 + TSMO)
	COMBO.3	Combined Scenario with More Aggressive Mode Shift Emphasis (VT.1 + MS.3 + TSMO)
	COMBO.4	Combined Scenario with Aggressive Actions Across All Pathways and Shared Connected and Automated Vehicle (CAV) Future (VT.2 + MS.3 + TSMO + shared CAV assumptions)

Electricity Grid Sensitivity Analysis

- Emissions from EVs depend on the emissions profiles of electricity generation
- Performed a sensitivity analysis using three emissions cases:

Reference Case

- Based on current **on-the-books** policies in VA, DC, and MD

Modified Reference Case

- Slightly more aggressive than Reference Case, assuming **policy for zero-carbon** grid by 2040 in MD

Clean Grid Case

- Most aggressive, assumes 100% clean grid by 2035

Tools and Models for Use in Analysis

Sketch planning tools and models to analyze individual strategies and combinations.

- For vehicle technology and fuels strategies, used the Argonne National Laboratory's VISION model to estimate fleet penetration, along with spreadsheet analysis on emissions rates.
- For MSTB strategies, used the Trip Reduction Impacts of Mobility Management Strategies (TRIMMS) analysis tool (developed by the Center for Urban Transportation Research), the regional travel demand model, and spreadsheet analysis using literature review findings.
- For TSMO strategies, applied adjustments to emissions rates based on literature review.

Spreadsheet-based model developed for study to analyze effects of scenarios.

Sensitivity analysis conducted by varying the carbon intensity assumptions for the electric power grid.

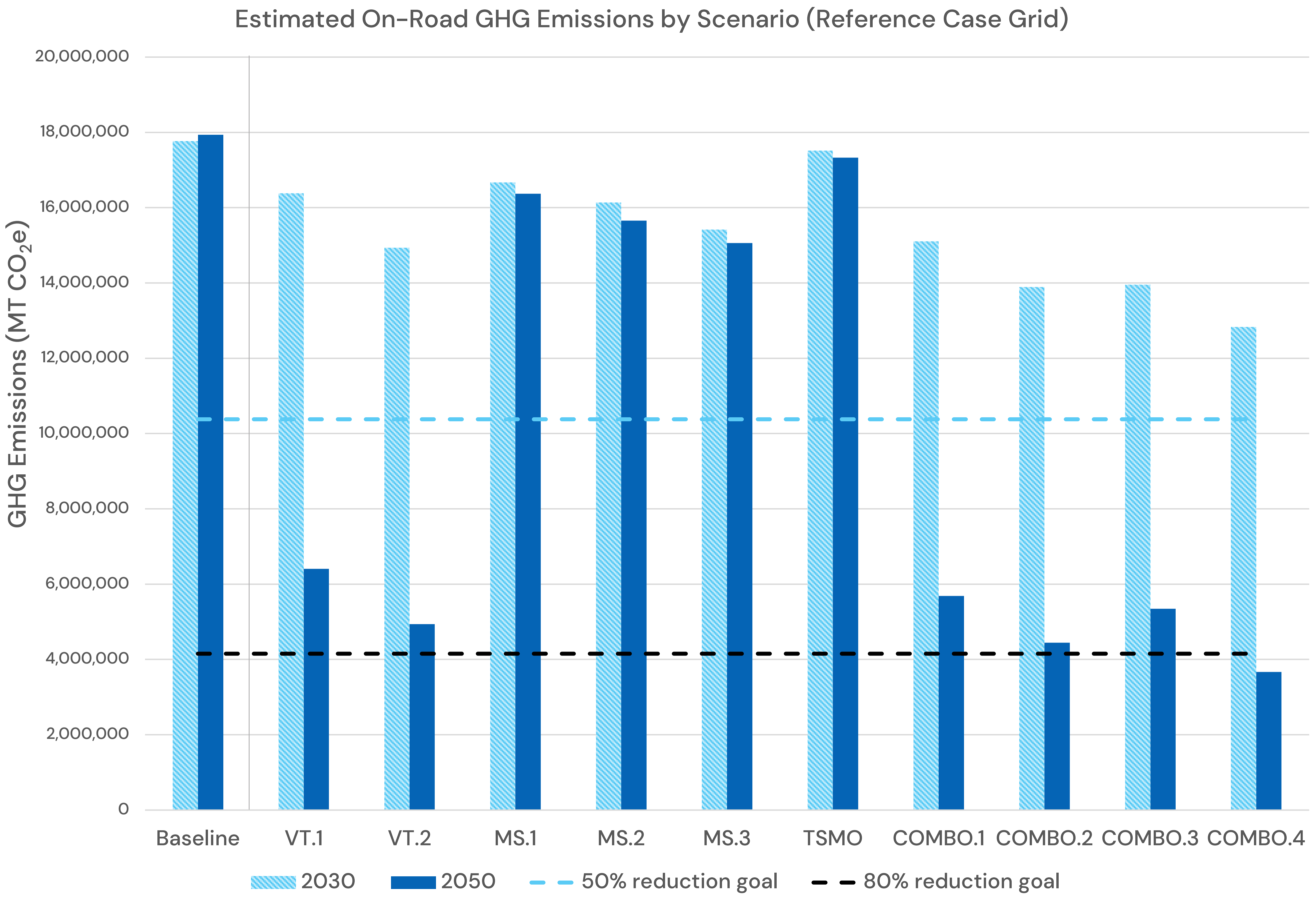
- Building on ICF's Integrated Planning Model (IPM), focusing on power markets.

Note: While sketch planning tools have been widely utilized by peer agencies, they have limitations (e.g., generally do not account for indirect or secondary effects). Literature also suggests fairly high levels of uncertainty of effects for some strategies (e.g., telework, fare free transit, road pricing). Thus, while results are informative, they generally should be viewed as addressing order-of-magnitude effects.

Findings from Analysis of Bottom-Up Scenarios

Estimated On-Road GHG Emissions by Scenario (under Reference Case Electric Grid)

- Vehicle technology and MSTB scenarios yield estimated reductions of 20-28% by 2030 (compared to 2005 levels), with combinations performing best (27-38% reduction).
- By 2050, vehicle technology improvements generate the largest estimated reductions (at least 69% reduction, under Reference Case grid).



Note: 2005 level of on-road GHG emissions was about 20.75 MMT CO_2e

Summary of GHG Reductions Estimated for Scenarios: % Reductions from 2005 On-Road Emissions Level

- None of the scenarios achieve 50% reduction in on-road GHG emissions by 2030.
- Several scenarios provide on-road GHG emissions reductions at levels assumed in COG's multisector 2030 Climate and Energy Action Plan (CEAP).
- 80% reduction by 2050 is met only with the most aggressive scenario under the reference case electric grid but can be achieved under other scenarios with vehicle technology/fuels strategies and a cleaner electric grid.

Scenario	Key Components	2030			2050		
		Ref. Grid	Mod. Grid	Clean Grid	Ref. Grid	Mod. Grid	Clean Grid
Baseline	Base assumptions in Visualize 2045	-14%	--	--	-14%	--	--
VT.1	50% of new LD vehicle sales are EVs in 2030, with 100% by 2040; 30% of new M/HD truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biofuels/renewable diesel make up 10% of diesel fuel use in 2030 and 20% in 2050	-21%	-21%	-24%	-69%	-75%	-84%
VT.2	100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biofuels/renewable diesel make up 20% of diesel fuel use in 2030 and 30% in 2050	-28%	-29%	-34%	-76%	-83%	-93%
MS.1	Land use changes, including new housing in the region; transit fares reduced 50% by 2030 and 75% in 2050; all workplace parking in activity centers priced by 2030; 10% reduction in transit travel time by 2030 and 20% by 2050; 25% telework; increased bike/ped/micromobility	-20%	-20%	-20%	-21%	-21%	-22%
MS.2	MS.1 + DC core cordon pricing + VMT-fees of $0.05 per mile in 2030 and $0.10 per mile in 2050 (analyzed for passenger vehicles)	-22%	-22%	-23%	-25%	-25%	-25%
MS.3	MS.2 with amplified strategies, including free transit; all workplace parking priced by 2050 (not just in activity centers), 15% reduction in transit travel time by 2030 and 30% by 2050; 40% telework	-26%	-26%	-26%	-27%	-28%	-28%
TSMO	Optimized ITS/TSMO, with benefits from connected/automated vehicles (CAVs) by 2050	-16%	-16%	-17%	-16%	-17%	-18%
COMBO.1	Combined scenario: VT.1+ MS.1 + TSMO	-27%	-28%	-30%	-73%	-78%	-86%
COMBO.2	Combined scenario with more aggressive technology emphasis: VT.2 + MS.1 + TSMO	-33%	-34%	-38%	-79%	-85%	-94%
COMBO.3	Combined scenario with more aggressive mode shift emphasis: VT.1 + MS.3 + TSMO	-33%	-33%	-36%	-74%	-79%	-87%
COMBO.4	Combined scenario with aggressive actions across all pathways and shared CAV future: VT.2+MS.3+TSMO+additional sharing in 2050	-38%	-39%	-43%	-82%	-87%	-95%

KEY:

Meets level of on-road GHG reductions in 2030 CEAP

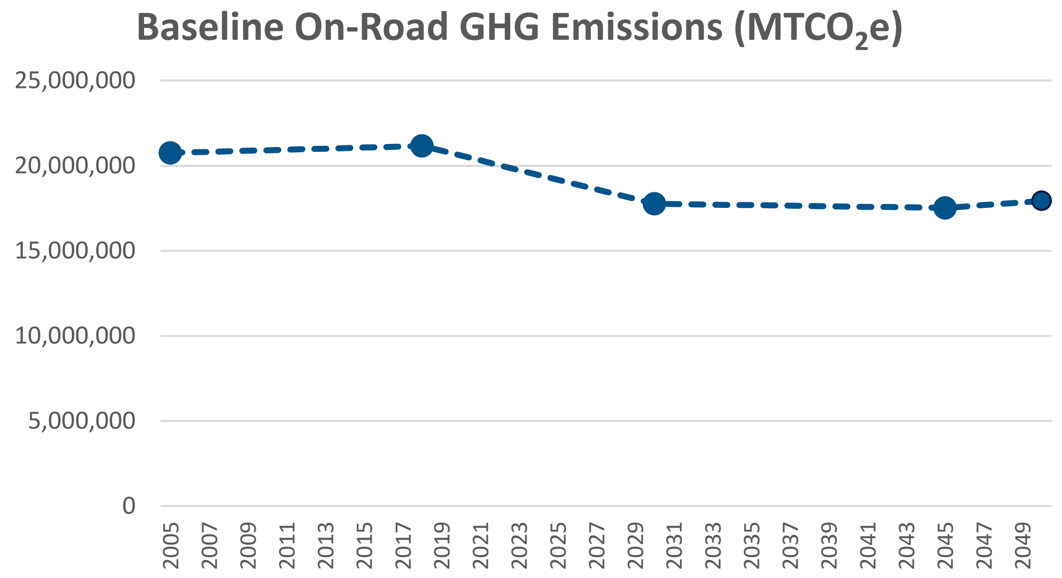
Meets level of GHG reductions commensurate with regional goal

ICF

Baseline Forecast

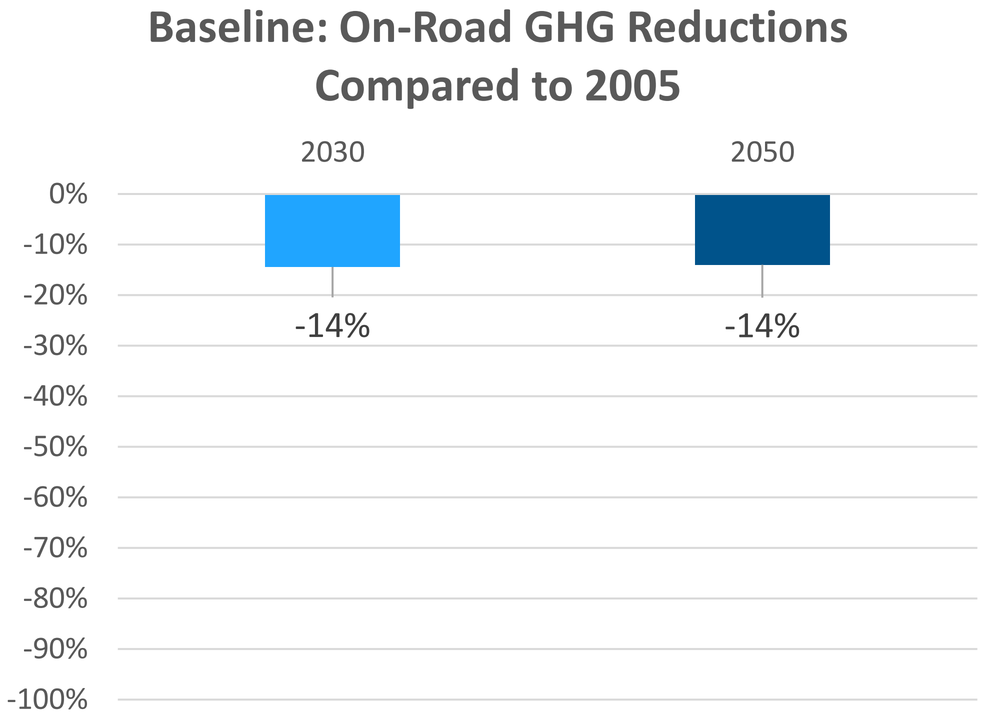
<u>Scenario Assumptions:</u>

- Land use and transportation assumptions in *Visualize 2045* (2018 version).
- Anticipated vehicle fleet makeup, based on National Renewable Energy Lab (NREL) reference forecasts.
- Assumes Reference Case Electric Grid (includes improvements from current grid).



<u>Observations:</u>

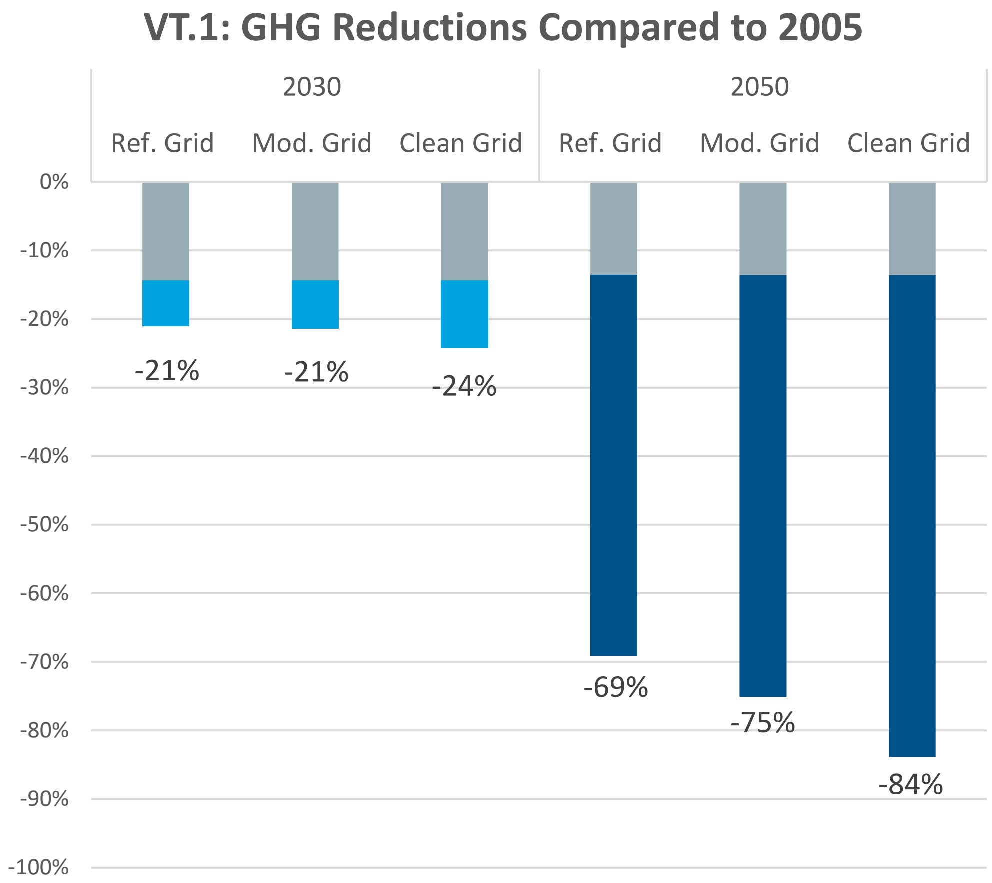
- On-road emissions (including emissions from electricity) are forecast to decrease about 14% (from 2005 level) by 2030 and stay generally stable.
  - Population is forecast to increase about 12% between 2018 and 2030 and about 28% by 2050 (assumes continued trends beyond 2045).
  - Improvements in vehicle technology counteract growth in VMT.



VT.1: Vehicle Technology and Fuels Improvement Scenario

Scenario Assumptions:

- *Light-duty passenger vehicles*: 50% of new sales are EVs in 2030, increasing to 100% in 2040
- *Medium- and heavy-duty trucks*: 30% of new sales are EVs in 2030, increasing to 100% in 2050
- *Transit and school buses*: 50% of buses on the road are EVs in 2030, 100% in 2050
- *Biodiesel/renewable diesel*: 10% of diesel in 2030 and 20% in 2050



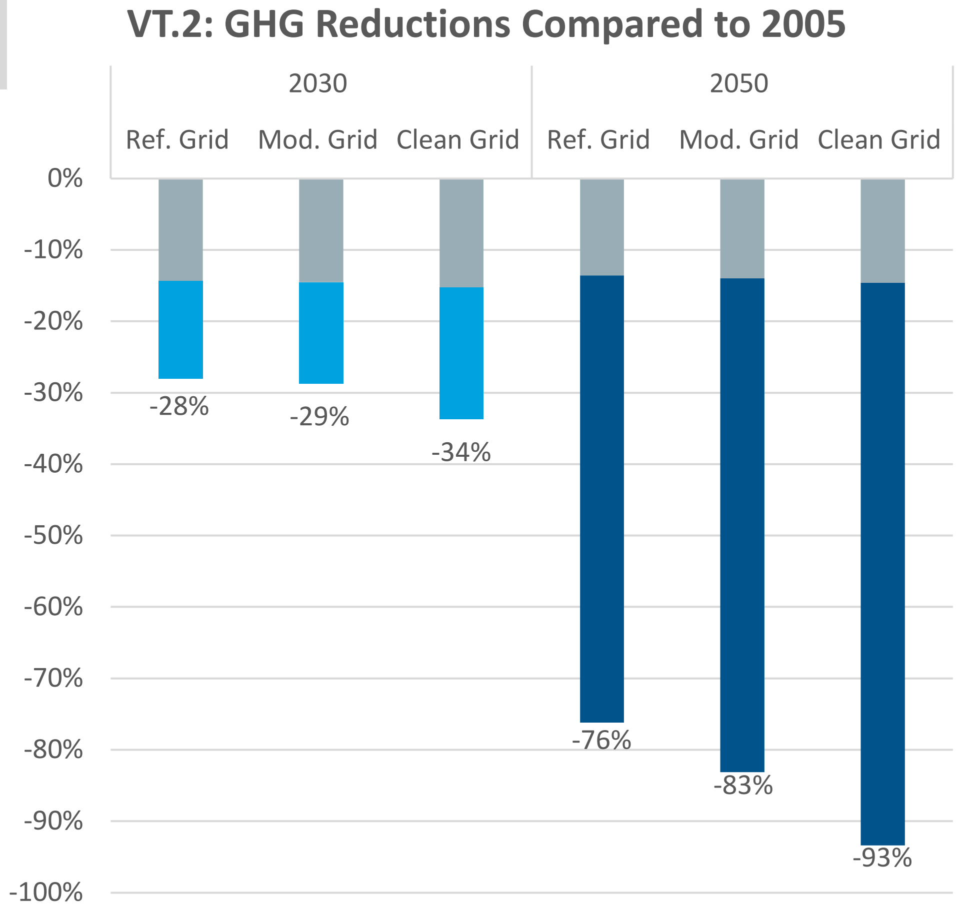
Observations:

- Short time-frame for vehicle fleet to turnover by 2030.
  - Estimated 26% of cars and 9% of light-duty trucks on the road are EVs (including battery electric and plug-in hybrids) in 2030; 10% of medium-duty trucks and 3% of heavy-duty trucks are EVs in 2030.
- By 2050, substantial change in on-road fleet.
  - Over 92% of light-duty vehicles (cars and light-duty trucks) are EVs, nearly all of which are battery electric.
- Clean grid plays an important role in meeting 2050 goal.

VT.2: Amplified Vehicle Technology and Fuels Improvement Scenario

Scenario Assumptions:

- *Light-duty passenger vehicles*: 100% of new sales are EVs by 2030
- *Medium- and heavy-duty trucks*: 50% of new sales are EVs in 2030, increasing to 100% in 2040.
- *Transit and school buses*: 100% of buses on the road are EVs by 2030
- *Biodiesel/renewable diesel*: 20% of diesel in 2030 and 30% in 2050



Observations:

- Similar issues of time-frame for vehicle fleet to turnover by 2030.
  - Estimated 35% of cars and 27% of light-duty trucks on the road are EVs (including battery electric and plug-in hybrids) in 2030; 14% of medium-duty trucks and 5% of heavy-duty trucks are EVs in 2030.
- By 2050, nearly all light-duty vehicles are EVs.

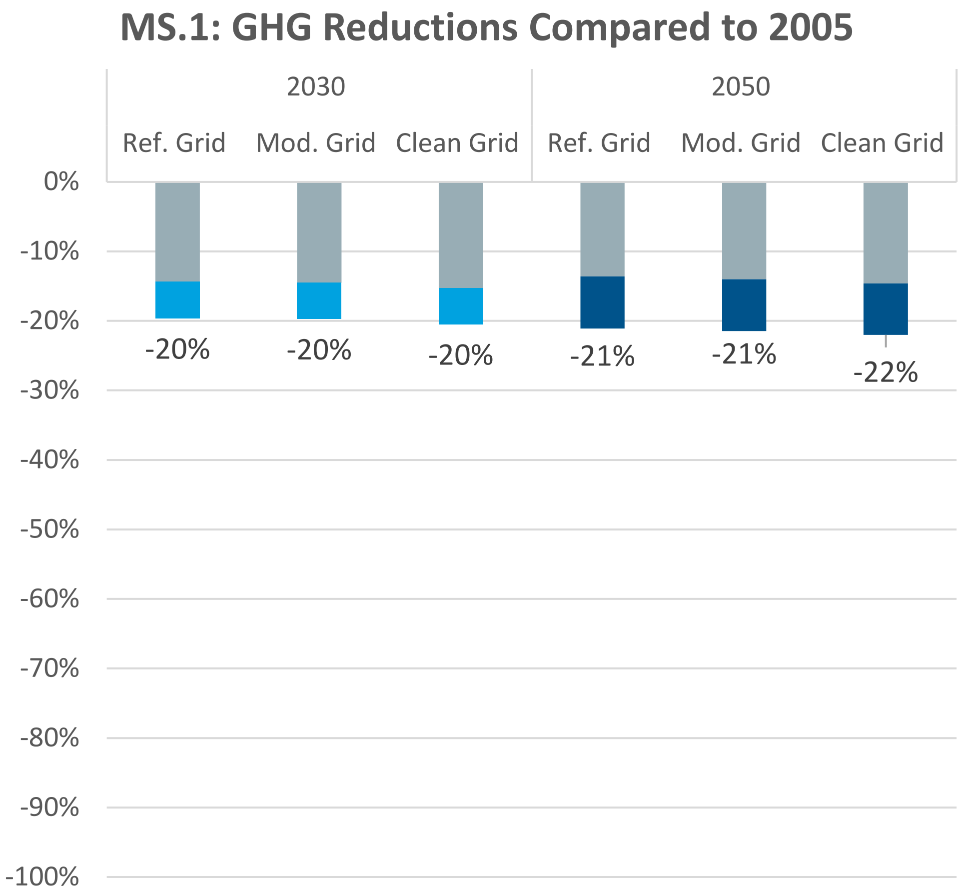
MS.1: Mode Shift Scenario

<u>Scenario Assumptions:</u>

- *Land use changes*: Shifts incremental growth after 2025 to Activity Centers/high-capacity transit station areas; adds households to the region to improve jobs-housing balance
- *Reduced transit fares*: 50% reduction in 2030, 75% in 2050
- *Transit enhancements:* Reduction of transit travel times by about 10% by 2030 and 20% by 2050 (assumes small increase in bus VMT)
- *Telework*: 25% on average day
- *Parking pricing*: All workplace parking in Activity Centers is priced
- *Bike/ped/micromobility*: Increased availability and use

<u>Observations:</u>

- Strategies primarily affect light-duty vehicles (which make up about 2/3 of total on-road GHG emissions).
- Yields estimated 10% reduction in passenger VMT in 2030 and 13% reduction in passenger VMT in 2050 compared to baseline forecast.
  - Passenger VMT in 2030 would be at about the 2018 level, despite over 12% increase in population.
  - Telework has substantial effects; land use and transit enhancement effects increase by 2050.



MS.2: Mode Shift Scenario + Road Pricing

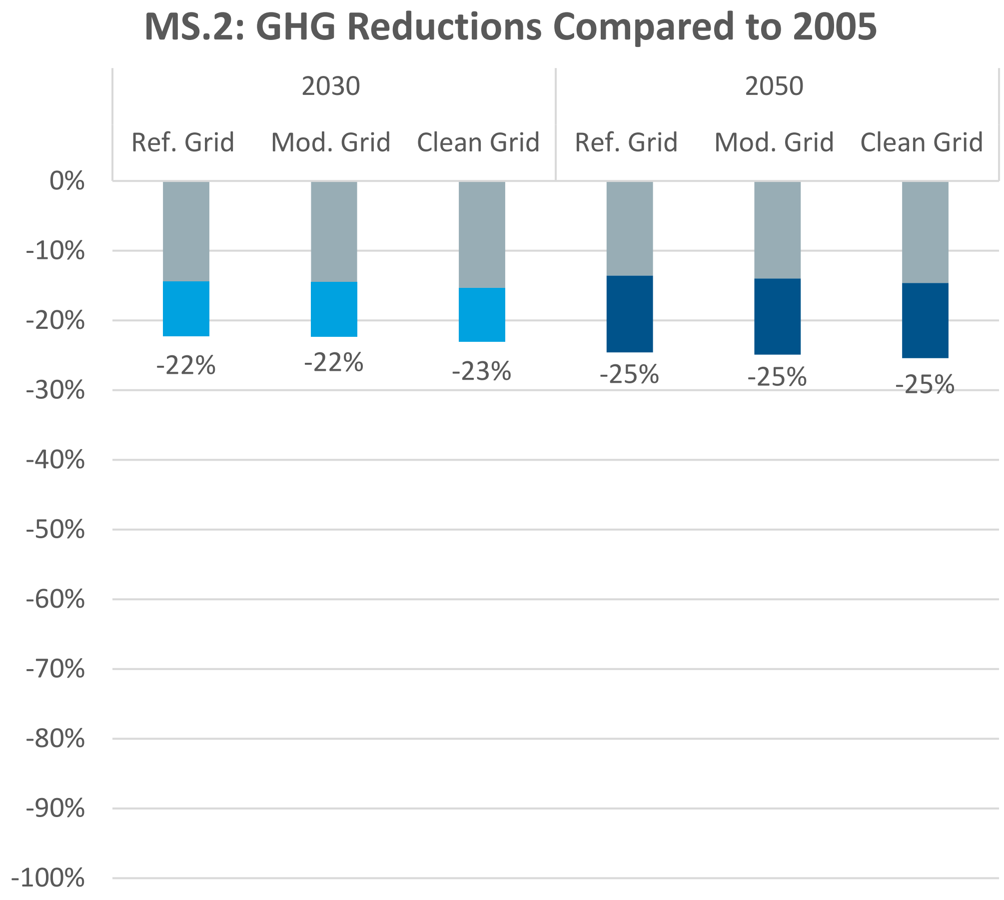
Scenario Assumptions:

Same as MS.1 plus:

- VMT fees of $0.05 per mile in 2030 and $0.10 per mile in 2050
- Cordon pricing of $10 per motor vehicle trip in DC by 2030

Observations:

- Incremental effects:
  - Although substantial reduction in VMT to the DC core, the cordon addresses a relatively small share of overall regional VMT.
  - VMT fee generated notable reductions in VMT, but there are high uncertainties about responses to price increases; some literature suggests pricing might yield even larger reductions. Higher fees would likely yield more substantial VMT reductions.
- Yields estimated 14% reduction in passenger VMT in 2030 and 20% reduction in passenger VMT in 2050 compared to baseline forecast.
  - Passenger VMT in 2030 is estimated below the 2018 level, despite over 12% increase in population.



MS.3: Amplified Mode Shift Scenario + Road Pricing

Scenario Assumptions:

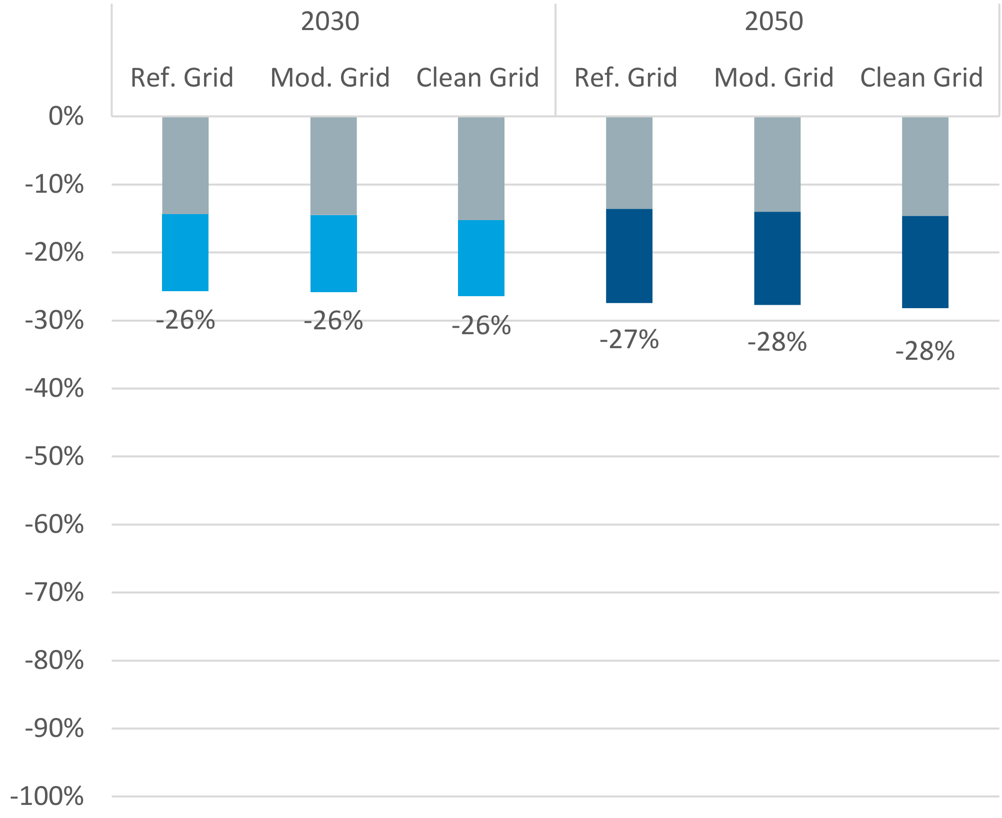
Same as MS.2 but:

- Change transit fares from reduced fares to free regionwide
- Enhance transit further to reduce transit travel times 15% by 2030 and 30% by 2050 (compared to 10% and 20% respectively in other scenarios)
- Increase telework from 25% to 40% on an average day (essentially 80% of office workers telecommute on a typical day)

Observations:

- Incremental effects:
  - Free transit and transit enhancements generate additional mode shifts.
  - Increase in telework has largest estimated impact, but there are high uncertainties.
- Yields estimated 20% reduction in passenger VMT in 2030 and 25% reduction in passenger VMT in 2050 compared to baseline forecast.
  - Passenger VMT in 2030 is estimated to be below the 2005 level.
  - Effects are highly uncertain, given uncertainties about additional non-work trip-making for teleworkers and potential that significant improvements in roadway traffic induce some shifts back to driving.

MS.3: GHG Reductions Compared to 2005



TSMO: Transportation Systems Management & Operations Scenario

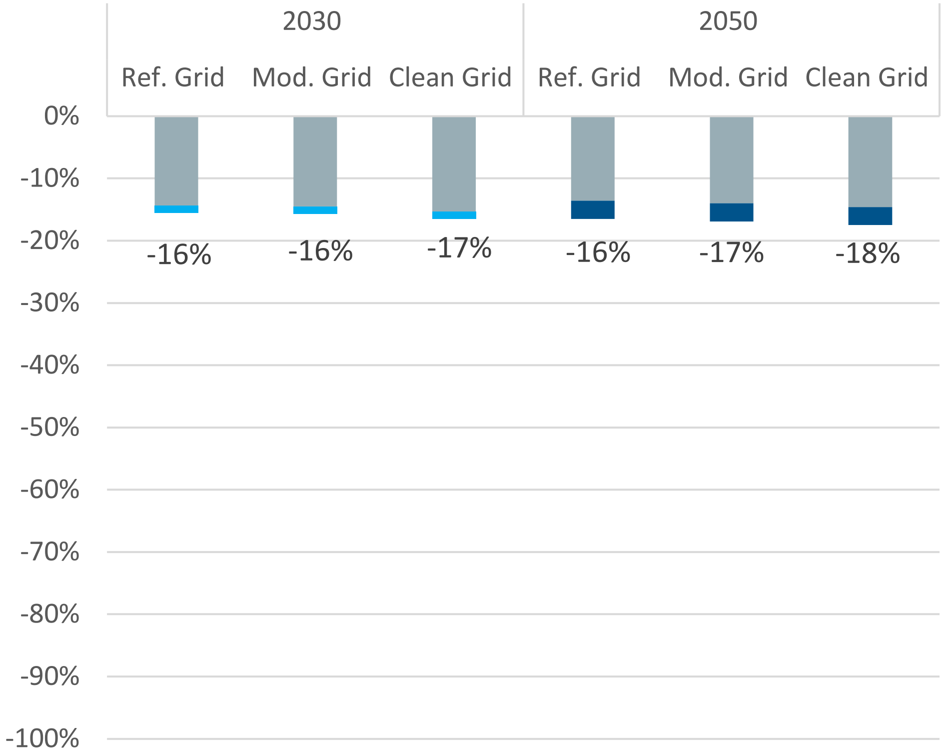
Scenario Assumptions:

- Extensive operational strategy deployment regionwide to optimize traffic flow for 2030
- Eco-driving deployment associated with CAVs in 2050

Observations:

- Small impacts compared to baseline forecast (<2% in 2030, higher in 2050 due to CAVs assumptions).
- Effects are generally small improvements in fuel economy for conventional vehicles.
  - High level of uncertainty of effects, based on existing deployments and potential future technologies, as well as potential for increase in VMT.

TSMO: GHG Reductions Compared to 2005



Combined Scenarios

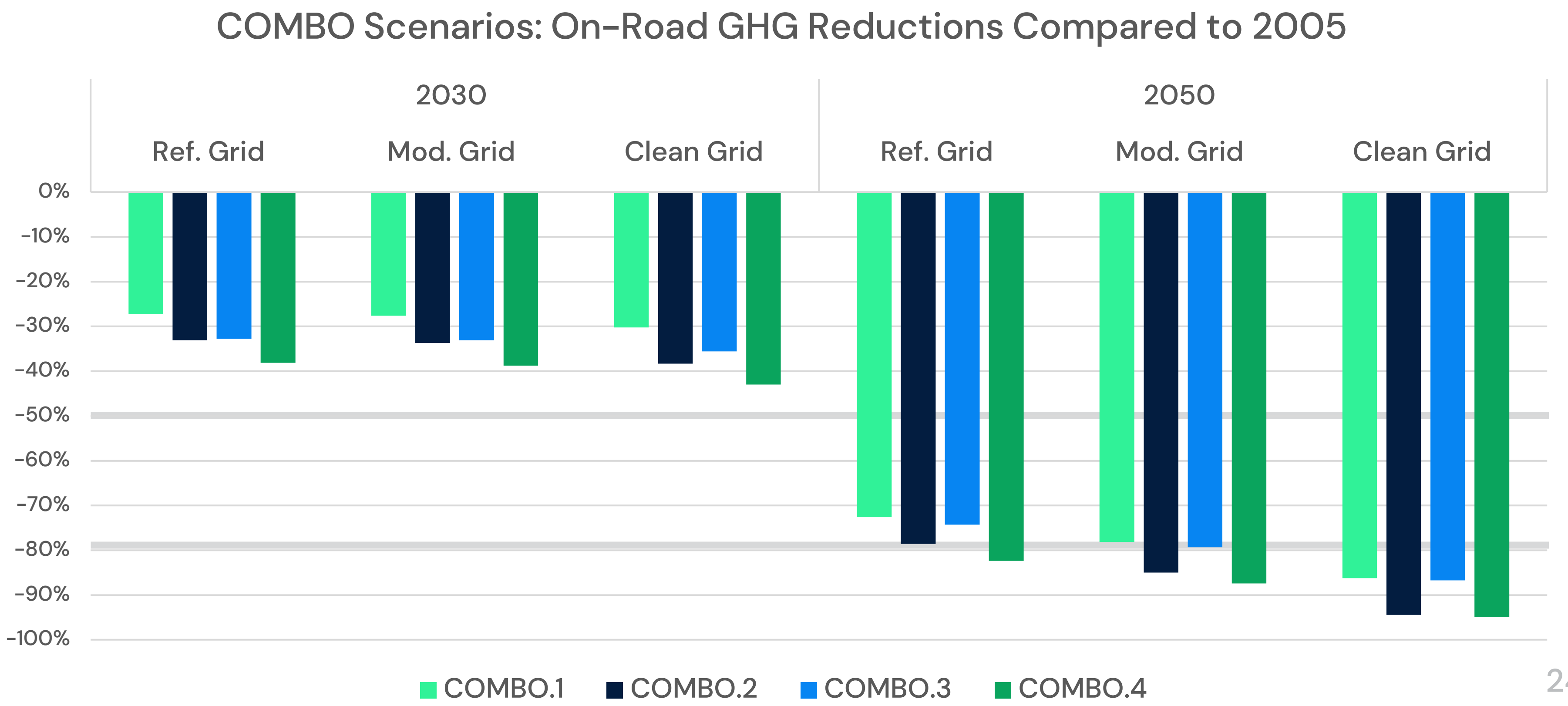
<u>Scenario Assumptions:</u>

- COMBO.1: All Pathways (VT.1 + MS.1 + TSMO)
- COMBO.2: More Aggressive Technology Emphasis (VT.2 + MS.1 + TSMO)
- COMBO.3: More Aggressive Mode Shift Emphasis (VT.1 + MS.3 + TSMO)
- COMBO.4: Most Aggressive Across All Pathways (VT.2 + MS.3 + TSMO + Shared CAVs*)

*Simulated as additional increases in vehicle occupancy and fuel economy

<u>Observations:</u>

- Combinations provide the largest benefits, particularly in the near-term (2030).
- By 2050, significant shifts to EVs mean that the power grid is more important in achieving the 80% reduction goal and MSTB strategies become relatively less important.



Key Conclusions

- Achieving a 50% reduction in on-road GHG emissions (from the 2005 level) by 2030 is extremely ambitious.
  - None of the scenarios were estimated to achieve this goal. Only 9 years away, there is very little time to get to the level of vehicle technology adoption and VMT reduction to meet this goal.
  - On-road transportation, however, can contribute substantial GHG reductions to help support the region's goal. Several scenarios (generally with a combination of strategies) achieve the level of on-road GHG reductions in COG's multisector 2030 CEAP.
- Achieving an 80% reduction in on-road GHG emissions (from the 2005 level) by 2050 is more attainable with vehicle technology advancements and a clean electric grid.
  - The goal is only met with the most aggressive scenario under the reference case electric grid.
  - However, the goal can be achieved under other scenarios with vehicle technology/fuels strategies and a cleaner electric grid.
  - Mode shift and travel behavior strategies provide supporting GHG reductions but are less important when nearly all on-road vehicles are EVs and the electric grid is carbon neutral.

Study Limitations

- Limited assessments of potential secondary effects
  - Increased telework might encourage changes in locations of businesses.
  - Reducing VMT may have additional benefits on improving traffic flow, but the improved flow may also encourage some mode shifts back to driving as travel time is reduced.
  - Shifts to EVs might induce additional driving if the cost of driving is reduced.
- Uncertainties regarding effects of significant changes in pricing
  - Sketch models rely on price elasticities, which may not be accurate for large changes in price.
- Implementation considerations for getting to scenario results
  - Questions about how to get to level of transit service improvement, level of EV adoption in scenarios.
- Implications for GHG emissions in other sectors not considered
  - Increasing housing in the region may increase building energy consumption, yet more dense multifamily housing reduces energy use per person. Telework may increase energy use from the building sector.

Implementation Considerations

Co-Benefits of Strategies

- Accessibility and Mobility
  - Expanding transit and active transportation options; bicycle, pedestrian, micromobility → access to jobs, education, healthcare, etc.
- Reliability
  - Transit enhancements, TSMO → improved reliability.
- Safety
  - TSMO strategies and active transportation enhancements → improved safety.
- Improved Air Quality and Public Health
  - Increase in bicycle/pedestrian activity → reduction in vehicle emissions, increased physical activity.
  - Increase in electric vehicles → reduction in vehicle tailpipe emissions.
- Economic Benefits
  - Improved access to businesses, more efficient freight movement.
  - Increase in teleworking → improvements in efficiency/productivity.
  - Vehicle electrification → lower cost of vehicle ownership; local economic opportunities for the installation and maintenance of private and public EV charging infrastructure.

Equity Considerations

Potential Concerns

- Vehicle electrification:
  - Access to EVs and charging infrastructure might be difficult for some population segments (medium- and low-income, multifamily residents, and renters) → role of low-interest loans and vouchers to lower costs; municipal zoning to advance EV readiness.
- Teleworking:
  - Not applicable for workers in many service industries.
  - Potential impacts on businesses with low-income workers (restaurants, services), particularly in downtown areas.
- Parking pricing, cordon pricing, and VMT fees:
  - Costs can disproportionately affect low-income households and may be regressive.
  - Fees can be designed with equity in mind, accounting for factors such as household income (e.g., credits for low-income households), and use of funds for transit and equity-focused services.

Opportunities

- Land use, transit, and bicycle/pedestrian/micromobility:
  - Can support more affordable housing and transit costs, ability to access places without a private motor vehicle.

Implementation Considerations

- Role of Federal Government
  - Potential Federal policies to spur deployment of EVs, a clean power grid, or to advance road pricing.
- Role of the Private Sector
  - Vehicle manufacturers (EVs); developers (land use); private employers (telework).
- Intergovernmental Cooperation
  - State and local coordination to agree on policies; multi-state agreements.
- Transportation Revenues and Expenditures
  - Reducing transit fares, shifts to EVs → loss of traditional revenue sources for transportation.
  - Transit enhancements require significant, long-term spending.
  - Upfront costs for widespread vehicle electrification → role of incentive programs and policies.
  - Costs associated with education and awareness programming for each strategy.
- Social and Economic Effects
  - Potential social and economic costs of teleworking.
  - Potential implications on regional competitiveness (positive or negative).
  - Costs of pricing strategies (road pricing, parking pricing) on households.

Get in touch with:
Michael Grant

Vice President, Transportation
(202) 862-1211
Michael.Grant@icf.com

linkedin.com/company/icf-international/

twitter.com/icf

https://www.facebook.com/ThisIsICF/

icf.com

About ICF

ICF (NASDAQ:ICFI) is a global consulting and digital services company with over 7,000 full- and part-time employees, but we are not your typical consultants. At ICF, business analysts and policy specialists work together with digital strategists, data scientists and creatives. We combine unmatched industry expertise with cutting-edge engagement capabilities to help organizations solve their most complex challenges. Since 1969, public and private sector clients have worked with ICF to navigate change and shape the future.

Summary of GHG Reductions Estimated for Scenarios: % Reductions from 2030 and 2050 Baseline Forecast, Respectively

- Vehicle technology benefits increase substantially over time as EV adoption takes off.
- Mode shift and travel behavior strategies' benefits increase over time but at a much more modest level.
- TSMO strategy benefits are small and incorporate assumptions about CAVs.

**Note: Baseline forecast assumes Reference Grid; cleaner electric grid assumptions yield some emissions benefits beyond the effects of scenario strategies. Figures are rounded to nearest percent.*

Scenario	Key Components	2030			2050		
		Ref. Grid	Mod. Grid	Clean Grid	Ref. Grid	Mod. Grid	Clean Grid
VT.1	50% of new LD vehicle sales are EVs in 2030, with 100% by 2040; 30% of new M/HD truck sales are EVs in 2030, with 100% by 2050; 50% of buses on the road are EVs in 2030, 100% in 2050; biofuels/renewable diesel make up 10% of diesel fuel use in 2030 and 20% in 2050	-8%	-8%	-11%	-64%	-71%	-81%
VT.2	100% of new LD vehicle sales are EVs in 2030; 50% of new M/HD truck sales are EVs in 2030, with 100% by 2040; 100% of buses on the road are EVs by 2030; biofuels/renewable diesel make up 20% of diesel fuel use in 2030 and 30% in 2050	-16%	-17%	-23%	-72%	-81%	-92%
MS.1	Land use changes, including new housing in the region; transit fares reduced 50% by 2030 and 75% in 2050; all workplace parking in activity centers priced by 2030; 10% reduction in transit travel time by 2030 and 20% by 2050; 25% telework; increased bike/ped/micromobility	-6%	-6%	-7%	-9%	-9%	-10%
MS.2	MS.1 + DC core cordon pricing + VMT-fees of $0.05 per mile in 2030 and $0.10 per mile in 2050 (analyzed for passenger vehicles)	-9%	-9%	-10%	-13%	-13%	-14%
MS.3	MS.2 with amplified strategies, including free transit; all workplace parking priced by 2050 (not just in activity centers), 15% reduction in transit travel time by 2030 and 30% by 2050; 40% telework	-13%	-13%	-14%	-16%	-16%	-17%
TSMO	Optimized ITS/TSMO, with benefits from connected/automated vehicles (CAVs) by 2050	-1%	-2%	-2%	-3%	-4%	-5%
COMBO.1	Combined scenario: VT.1+ MS.1 + TSMO	-15%	-15%	-19%	-68%	-75%	-84%
COMBO.2	Combined scenario with more aggressive technology emphasis: VT.2 + MS.1 + TSMO	-22%	-23%	-28%	-75%	-83%	-94%
COMBO.3	Combined scenario with more aggressive mode shift emphasis: VT.1 + MS.3 + TSMO	-21%	-22%	-25%	-70%	-76%	-85%
COMBO.4	Combined scenario with aggressive actions across all pathways and shared CAV future: VT.2+MS.3+TSMO+additional sharing in 2050	-28%	-28%	-33%	-80%	-85%	-94%

KEY:

- Less than 5% reduction
- 5 – 10% reduction
- 11 – 25% reduction
- 26 – 50% reduction
- 51 – 75% reduction
- Over 75% reduction

ICF