Washington State Transportation Carbon Reduction Technical Report

Prepared by

WSDOT

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Contents

Acronyms

ACC II	California's Advanced Clean Cars II regulation
ACT	California's Advanced Clean Truck regulation
ACF	California's Advanced Clean Fleet regulation
BAU	Business-as-usual
CCA	Climate Commitment Act
CO_2e	Carbon dioxide equivalent
DOL	Washington State Department of Licensing
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle(s)
FHWA	U.S. Federal Highway Administration
FAF	Freight analysis framework
GHG(s)	Greenhouse gas(es)
HD	Heavy duty
HEAL	Washington State's Healthy Environments for All Act
HPMS	FHWA's Highway Performance Monitoring System
LD	Light duty
MD	Medium duty
MMT	Million metric tons
MOVES	Motor Vehicle Emissions Simulator model
PSRC	Puget Sound Regional Council
RTP	Regional Transportation Plan
RUC	Road usage charge
SC	Scenario
SEDS	U.S. EIA State Energy Data System
SIT	U.S. EPA's State Inventory and Projection Tool
TES	Washington State Transportation Electrification Strategy
TCRS	Washington State Transportation Carbon Reduction Strategy
VMT	Vehicle miles traveled
WA	Washington State
WSDOT	Washington State Department of Transportation
ZEV	Zero emission vehicle

Executive Summary

Introduction

The Washington State Transportation Carbon Reduction Strategy (TCRS) outlines the current policies in Washington to reduce transportation greenhouse (GHG) emissions. That strategy builds on the State Energy Strategy, describes the key roles of the Climate Commitment Act (CCA) and Healthy Environments for All Act (HEAL), and identifies other state policies and local strategies in progress across the state to reduce transportation emissions. The TCRS creates a baseline from which the state can expand transportation carbon emission reduction efforts. To do so, the state needs information to understand the likely effects of current efforts.

This scenario modeling report provides an initial examination of the effectiveness of current policies impacting transportation tailpipe emissions and includes a projection of emission reductions that could result from a range of transportation efficiency improvements. Four scenarios examine the effects of different policies related to zero emission vehicle (ZEV) sales requirements. The final scenario evaluates the potential implications of Washington adopting the medium- and heavy-duty vehicle sales requirements of the recent California Advanced Clean Fleets regulation (i.e., 100 percent sales by 2036).

Additionally, the report outlines potential emission reductions that could be achieved by improving transportation efficiency, subsequently reducing vehicle miles traveled (VMT). These analyses highlight where further research could assist the state in understanding the potential reductions from travel efficiency improvements and the interplay between such improvements and vehicle electrification efforts.

In addition to this look at on-road vehicles, a baseline analysis of non-road emissions (rail, marine, and aviation) identifies potential growth in these sectors and the associated emission trends.

Emission limits

This analysis looks at tailpipe emissions from transportation sources across the state. This approach captures emission changes from ZEV sales mandates and transportation efficiency improvements. The state has additional regulations in place to address the lifecycle emissions from transportation fuels through the Clean Fuels Standard.[1] However, the analysis presented here does not consider these effects as it focuses on tailpipe emissions. In addition, looking at tailpipe emissions allows for a direct comparison to emissions in the Washington State Greenhouse Gas Emissions Inventory[2] and the state's statutory emission reduction limits. The State of Washington has set limits to reduce greenhouse gas (GHG) emissions:[3]

- By 2030 – 45 percent reduction below 1990 levels
- By 2040 – 70 percent reduction
- By 2050 – 95 percent reduction and net zero emissions

In the absence of sector-specific emission limits, this analysis compares scenario estimates to proportional emissions reductions for the transportation sector. Throughout this report, the term "limit" refers to proportional limits within the transportation sector.

[1] https://ecology.wa.gov/air-climate/reducing-greenhouse-gas-emissions/clean-fuel-standard

[2] https://ecology.wa.gov/Air-Climate/Reducing-Greenhouse-Gas-Emissions/Tracking-greenhouse-gases/GHG-inventories

[3] Washington State Legislature, RCW 70A.45.020: Greenhouse gas emissions reductions—Reporting requirements. Available at: https://apps.leg.wa.gov/rcw/default.aspx?cite=70A.45.020

Policies considered

The analysis looks at four scenarios then adds VMT reductions from travel efficiency improvements. The scenarios are based on four vehicle electrification policies. Before describing the scenarios, it is important to understand each policy:

- **California's Advanced Clean Cars II (ACC II)**[4] – This ZEV standard requires all new light-duty (LD) vehicles of model year 2035 and later to be ZEVs.[5] The requirement phases in between 2026 and 2035 by requiring an increasing number of ZEVs be sold over that period. Non-ZEVs from model years 2034 and earlier may remain in use for the life of the vehicle. Washington adopted this regulation as part of the Motor Vehicle Emissions Standards – Zero-Emission Vehicles law.

- **California's Advanced Clean Truck (ACT)** – Manufacturers are required to sell an increasing percentage of ZEVs from 2025 to 2035. The standard applies percent sales targets by model year for Class 2b through Class 8 trucks; the percent sales target for ZEVs increases, on average, by 5 percent every model year until 2035. This modeling assumes that in 2035, 45 percent of Class 2b-5 vehicle sales and 40 percent of Class 6-8 vehicle sales in Washington will be ZEVs. Washington also adopted this regulation as part of the Motor Vehicle Emission Standards – Zero-Emissions Vehicles law.

- **Washington Clean Cars 2030 goal** – The Washington State 2022 transportation resources bill[6] established a state goal that all model year 2030 or later LD vehicles sold, purchased, or registered in Washington will be electric vehicles (EVs). This goal would have Washington achieve all new passenger vehicle sales as ZEVs five years earlier than currently required under the ACC II.

- **California's Advanced Clean Fleet (ACF)** – California recently adopted the Advanced Clean Fleet regulation that requires manufacturers to sell only zero emission medium- and heavy-duty (MD/HD) vehicles starting in 2036. Note that Washington State has not adopted this requirement; it is included in the analysis for illustrative purposes.

Zero Emission Vehicle scenarios

This analysis evaluates four scenarios to estimate potential emission reductions. Exhibit ES-1 summarizes the scenarios.

- **Scenario 1 – Business as usual (BAU):** This scenario provides a baseline, accounting only for EPA's 2021 GHG emissions standards for LD vehicles.[7]

- **Scenario 2 – BAU with ACC II and ACT:** This scenario overlays the BAU emissions baseline with the ACC II and ACT regulations, illustrating the GHG impacts of these two regulations that Washington has adopted into law.

- **Scenario 3 – Washington's Clean Cars 2030 goal:** This scenario replaces the ACC II regulation with Washington's goal of 100 percent LD vehicle sales being EVs beginning with model year 2030. This scenario keeps the ACT requirements in place for MD/HD vehicles.

- **Scenario 4 – Advanced Clean Fleets rule:** This scenario looks at how emissions would change if Washington State were to adopt the sales requirements in California's Advanced

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4 RCW 70A.30.010, https://app.leg.wa.gov/RCW/default.aspx?cite=70A.30.010.

5 WAC 173-423-075, https://apps.leg.wa.gov/wac/default.aspx?cite=173-423&full=true#173-423-075.

6 ESB 5974. https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/Senate/5974-S.SL.pdf?q=20231010091559.

7 https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-revise-existing-national-ghg-emissions

Clean Fleets regulation.[8] For LD vehicles, the scenario uses the Washington Clean Cars 2030 goal.

Exhibit ES-1. Scenarios (SC) modeled

Scenario	Light-duty policies	Medium- and heavy-duty policies
BAU	2021 Federal Emission Standards	Federal Standards
SC 2	ACC II	ACT
SC 3	WA Clean Cars 2030	ACT
SC 4	WA Clean Cars 2030	ACF

Zero emission vehicle results

Exhibit ES-2 compares 1990 emissions, 2021 (current) emissions, and the results of the four scenarios at the three time points corresponding to the state's GHG limits (2030, 2040, and 2050). GHG limits proportional to the on-road transportation emissions are shown for 2030, 2040, and 2050 as well. These results show that while current federal emission standards do reduce emissions between now and 2030, they are insufficient to meet 2030 limits. In addition, under the BAU scenario, emissions remain roughly at 2030 levels in 2040 and 2050.

Washington's adoption of the ACC II and ACT regulations will somewhat reduce emissions by 2030 but levels will remain significantly above the limit. By 2040 and 2050, the mandate for all LD vehicles to be zero emission noticeably impacts overall emissions, with medium- and heavy-duty vehicle emissions becoming dominant. Due to emissions from these vehicle classes, the state fails to meet its emission limits in both years.

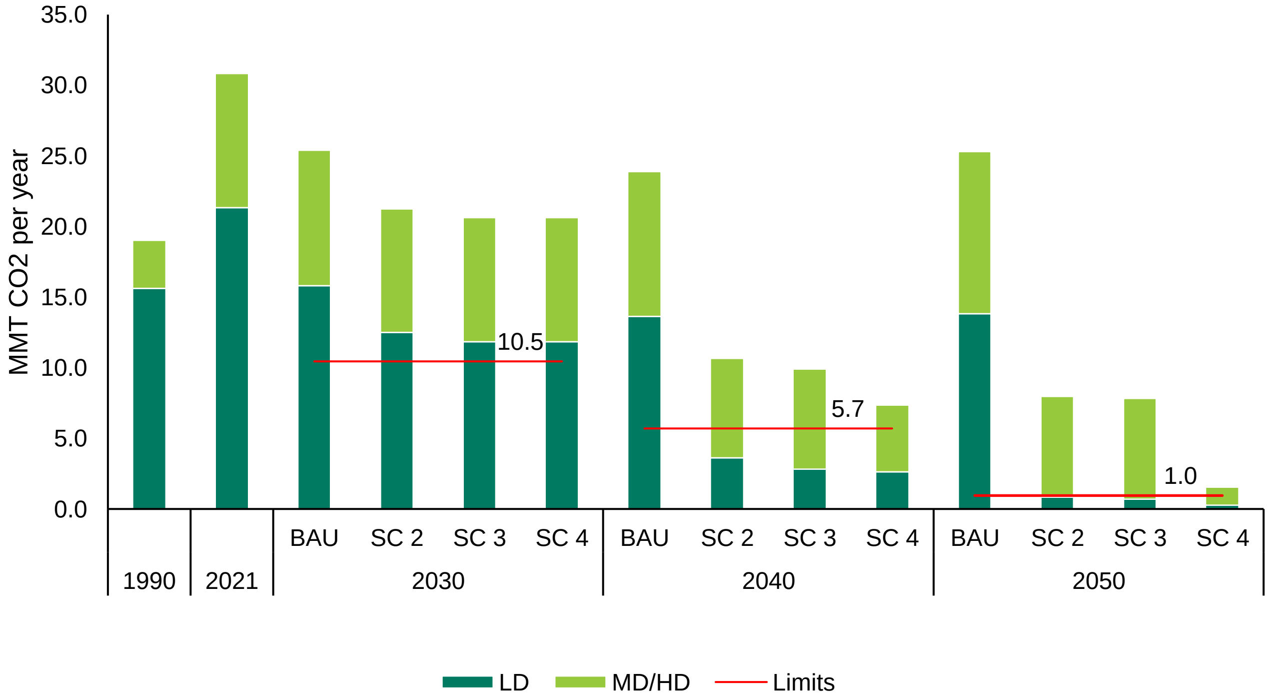
In Scenario 3, replacing the ACC II rule with the mandate for all model year 2030 and later LD vehicles to be zero emission slightly lowers the LD emissions, more so in 2040 than 2030 or 2050, due to the timelines for fleet turnover. This scenario does not affect MD/HD vehicle contributions.

The final ZEV scenario, Scenario 4, substitutes the ACT sales requirements with those from the California ACF rule. Although Washington State has not adopted this rule, the scenario showcases the potential impact of such a requirement on emissions. Since this rule does not come into full effect until 2036, its influence on 2040 emissions is modest. However, by 2050, its impact becomes more pronounced due to the extended time allowed for fleet turnover. By fully implementing these requirements for MD/HD vehicles and earlier zero emission requirements for LD vehicles – all new cars being zero emission by 2030 or 2035, at the latest – the state would be close to meeting a proportional 2050 GHG limit for on-road vehicle emissions.

Due to the nature of climate change, reducing emissions early is important. While electrification efforts reduce emissions over several decades, this analysis highlights the importance of early emission reductions from other on-road transportation strategies, such as improving transportation efficiency.

[8] https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets

Exhibit ES-2. Emissions under modeled scenarios



Transportation efficiency analysis

Additional analysis considered a range of potential emission reductions from transportation efficiency improvements that reduce VMT. The first part of the analysis included a comprehensive evaluation of the impacts of five categories of travel efficiency measures on reducing VMT from light-duty vehicles. These measures included pricing, telework, land use, transit, and active transportation.

This analysis is based on the information found during a literature review. Although information was found for all five of the categories of transportation efficiency measures considered, the literature did not provide sufficient detail for each individual measure within the categories to be included in the analysis. For example, within transit, one study provided sufficient detail on VMT reductions from transit speed improvements, but the literature review failed to identify other types of transit improvements (such as increased frequency or expanding service into areas not currently served) in sufficient detail to include in this analysis.

Although this analysis examined emissions at the state level, transportation efficiency measures are typically implemented at the local level. Different measures will vary in effectiveness across communities. Therefore, this analysis should be viewed as preliminary, offering a general estimate of the potential emission reductions attainable. While additional analysis is warranted, given the pressing nature of climate change and the significance of early emission reductions in achieving near-term limits, the state should not delay implementing improvements while awaiting further analysis.

To validate the findings from the literature review, they were compared to results in the Puget Sound Regional Council's (PSRC) 2030 GHG Analysis and Climate Implementation Strategy. To develop their strategy, PSRC conducted sophisticated travel demand modeling to assess the influence of diverse strategies, such as transit, pricing, and telework, on VMT reduction. Although the PSRC's analysis specifically pertained to the Puget Sound region, it serves as an invaluable benchmark.

Literature review results

The literature review identified 17 sources with relevant information on five categories of travel efficiency measures:

- **Land use** policies aim to create more compact, mixed-use, and walkable communities, reducing the distance between residential, commercial, employment, and recreational areas.
- **Telework** has the potential to reduce VMT by eliminating commuting trips; however, long-term effects of significant teleworking are unclear.[9]
- **Transit** includes buses, light rail, and commuter rail. Efforts to increase transit include network expansion and increasing service frequency.
- **Active transportation** replaces vehicle trips with non-vehicle modes, such as biking and walking. Opportunities can be improved by creating complete sidewalk networks, walking trails, and bike-friendly infrastructure.
- **Pricing** mechanisms such as cordon pricing, parking pricing, and VMT fees leverage financial mechanisms to influence travel behavior.

The range of VMT reductions associated with each type of strategy was determined based the literature available. Low and high ends of the range of feasibility were set at the 25th and 75th percentiles of the reductions found in the literature review, as illustrated in Exhibit ES-3.

Exhibit ES-3. Strategy effectiveness

Strategy	Low (25th percentile)	High (75th percentile)
Pricing	1.2%	15%
Telework	2%	4.5%
Land use	8.8%	30%
Transit	2.2%	2.2%
Active transportation (project level)	0.13%	0.68%

It is important to note that the combined effect of various VMT reduction strategies does not equate to the mere sum of their individual impacts. To determine a comprehensive VMT reduction factor for each year, the concurrent deployment of multiple strategies was mathematically combined to calculate a holistic VMT reduction value and avoid overestimating their collective impact on VMT reduction.

Exhibit ES-4 shows the results of combining the VMT reductions from multiple strategies and incorporating estimated strategy penetration, thereby creating a single low and high VMT reduction value for each analysis year. These reduction percentages were applied to LD vehicle emissions from the analysis above. It was assumed that VMT reduction took place evenly across all LD vehicles, i.e., a 5 percent reduction in VMT lead to a 5 percent reduction in light-duty vehicle emissions.

Once the strategies were mathematically combined, estimated strategy penetration was incorporated to create a single low and high VMT reduction value for each analysis year. Exhibit

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[9] Some data suggest that the ability to work remotely may encourage people to move further away from dense urban areas to less dense suburban or rural areas that typically require longer trips and limit mode choice. Careful consideration and planning are required to address these potential repercussions of increased telework.

ES-4 shows the results for each time point. These reduction percentages were applied to LD vehicle emissions from the analysis above.

Exhibit ES-4. Combined VMT reduction

Combined	2030	2040	2050
Low	4.4%	6.1%	7.8%
High	22.2%	27.1%	32.0%

PSRC's sensitivity analysis serves a point of reference against which to compare these results. As detailed in Appendix A, PSRC's sensitivity analysis illustrated that implementing a Road Use Charge (RUC) of $0.25 per mile combined with a 20 percent telework rate has the potential to result in 14 percent VMT reduction by 2030 from the baseline (i.e., 2022 PSRC Regional Transportation Plan (RTP) projections). In addition, the 2022 PSRC RTP land use strategies contributed an 11 percent reduction in VMT per capita. Extrapolating from this, if the same VMT per capita reduction from land use strategies were applied to the combined RUC and telework scenario, the cumulative VMT reduction could reach nearly 24 percent. Considering that such VMT reductions are specific to the Puget Sound region, the high VMT reduction estimate presented in Exhibit ES-4, although lower, seems to be a potentially feasible target for the state.

VMT reduction emission results

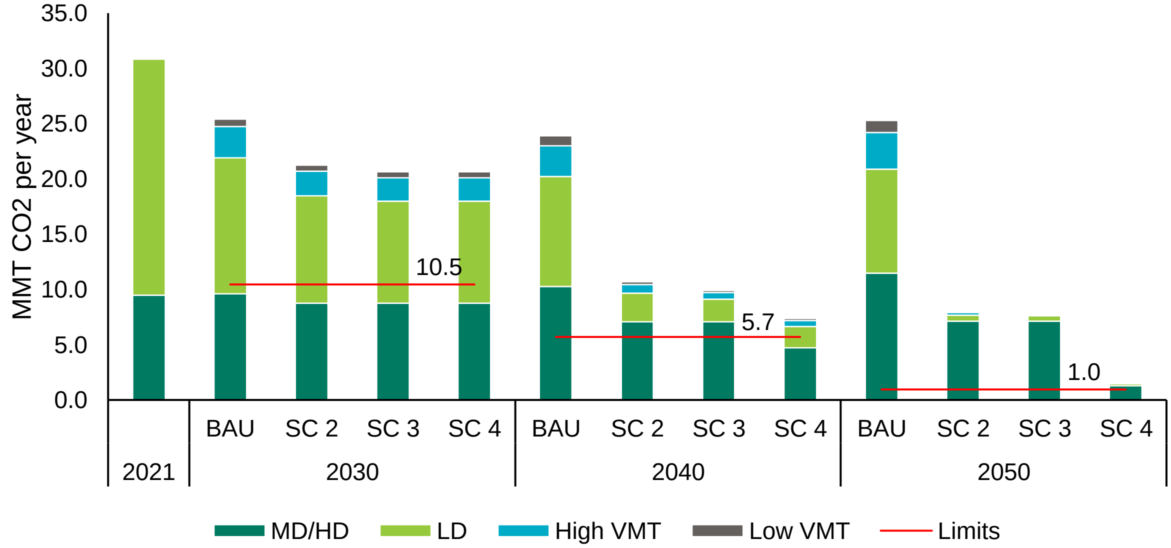
The simplified VMT reduction analysis completed for this report provides an initial estimate of the range of emission reductions that can be achieved though strategies that reduce the need to travel in single occupant vehicles.

Exhibit ES-5 adds the results of the VMT analysis to the figure showing emissions presented earlier. The LD Low VMT bar indicates the emissions that would be eliminated by achieving the low VMT reduction level. The LD High VMT bar indicates the additional emissions that would be eliminated by achieving the high VMT reduction level.

The addition of VMT reduction lowers LD emissions in all scenarios. Because VMT reduction affects a percentage of all LD emissions, in the scenarios with higher LD emissions, VMT reduction has a larger effect.

While VMT reduction strategies may not impact overall emissions to the same extent as electrification efforts, they remain crucial in reducing on-road emissions. Notably, short-term VMT reduction measures are vital for quickly cutting emissions and contribute to higher cumulative emissions reductions. In climate change mitigation, considering cumulative emissions is essential because the total accumulated GHG in the atmosphere, not just annual emissions, drives long-term climate change effects. These gases can persist for decades to centuries, intensifying global warming and exacerbating its associated impacts.

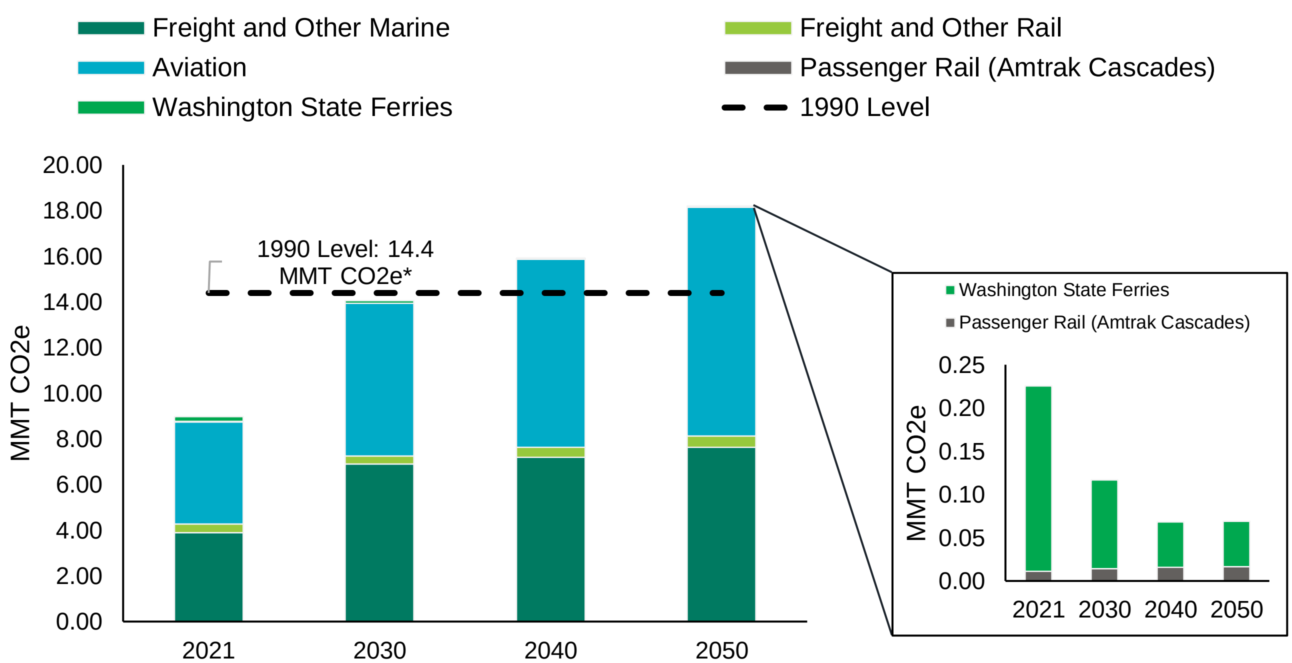
Exhibit ES-5. Impact of VMT reductions on State's on-road transportation under different ZEV adoption scenarios



Non-road emissions

In addition to on-road emissions, this analysis also evaluated emissions from the marine, aviation, and rail sectors. Given the limited information available for these sectors and the absence of comprehensive modeling tools, a more basic approach was employed to estimate these emissions. While there are ongoing efforts to curb emissions in these areas, such as pilot projects and grant programs, there are no specific regulations or policies to model the impact of these efforts. Therefore, this analysis anticipates likely growth in these sectors but does not assess scenarios for potential reduction effects, except for the Washington State Ferries, where the analysis leveraged vessel electrification plans. This brief analysis indicates that, without policy intervention, emissions from these sectors will rise in tandem with population and economic growth.

Exhibit ES-6. BAU projections of non-road emissions



Conclusion

Washington State has several regulations on the books that position the state to make meaningful reductions in on-road transportation emissions, especially for light-duty vehicles. This analysis shows that without similarly stringent requirements for MD/HD vehicles, the state cannot meet proportional on-road emission limits. However, with additional measures, such as the California Advanced Clean Fleets sales requirements, the on-road transportation sector can reduce emissions to levels close to proportional statutory limits by 2050. In the interim, particularly in the near term (by 2030), the state faces challenges in implementing changes robust enough to reduce on-road GHG emissions to meet set limits.

Simply establishing ZEV regulations is the beginning of the journey to cut emissions. For these vehicles to become widespread, a robust charging and fueling infrastructure that is accessible by all users must be developed. In addition, incentives to increase the appeal of these vehicles to drivers, particularly considering the higher initial costs compared to traditional internal combustion engine vehicles, are needed to support rapid adoption of the technology. Recognizing and seizing opportunities to expedite ZEV adoption is crucial in efforts to curb near-term emissions.

Alongside transitioning to ZEVs, enhancing travel efficiency and decreasing per capita LD VMT are crucial for reducing emissions. Although these measures alone cannot bridge the gap between current regulations and statutory limits, they play a significant role in emission reduction. Initiatives that can be deployed rapidly will have the greatest emission-reducing effect in the early years. This is particularly true in the near term when reducing VMT has a pronounced impact on emissions due to the higher presence of internal combustion engine vehicles on the road.

Initial analysis of non-road transportation emissions shows that, without intervention, emissions from rail, marine, and aviation are likely to increase.

Additional work to support strategic emission reduction implementation

Because of the importance of reducing VMT and improving travel efficiency in the state, towards the multiple goals of reducing GHG emissions, reducing the energy demand needed to electrify transportation, and achieving other state goals (e.g., health, equity, safety, etc.), the state would benefit from a **statewide multimodal transportation efficiency strategy** to accelerate transportation efficiency improvements**.** This work would identify preferred policies to reduce per capita VMT, meet GHG limits, minimize the need for transportation energy infrastructure investments, and improve equitable access. This strategy would need to be developed in close collaboration with partners and would support future legislative policy development and investment decisions.

The current analysis provides a high-level view of the effectiveness of strategies in place and potential additional strategies. However, more work is needed to better understand how the state can best meet emission limits. Closing these gaps will require additional analysis to provide a framework for making informed choices as the state continues to reduce emissions. Specific needs include:

- **Analysis of transportation efficiency improvements –** an analysis of transportation efficiency opportunities and measures is needed to support the development of a **statewide multimodal transportation efficiency strategy**. This analysis would identify how efficiency improvements contribute to emissions reductions and the support needed for their strategic implementation. This analysis must account for different types of communities (urban, suburban, small city, rural) and different types of travel (commutes, recreational, etc.).

- **Opportunities analysis for high-capacity inter-city transit and passenger rail –** identify the types of service that best meet traveler needs across the state and where they can be most efficiently implemented throughout the state, expanding beyond the central Puget Sound area and I-5 corridor. This analysis would evaluate efficiency improvements between communities: identifying demand, identifying service levels to meet that demand, and establishing priorities for implementation.

- **Freight analysis (rail, marine, aviation, and on-road freight) –** work with industry partners to characterize emissions and identify opportunities and challenges to improving efficiency from freight to inform the development of effective and efficient policies and programs that address freight-related emissions, specifically:

    - **Baseline emissions profile –** develop a baseline emissions profile of freight and non-road modes to characterize the emissions from these sectors.

    - **Opportunity analysis for freight efficiency improvements –** identify opportunities, challenges, and potential policy and programmatic supports to improve efficiency across all freight modes.

- **Evaluate the role of reducing VMT in lowering energy requirements and associated costs –** While it is generally understood that fewer miles traveled requires less energy, an analysis of the infrastructure and energy cost savings from improved transportation efficiency would support state vehicle electrification efforts and may help direct efforts for the most effective implementation.

Lastly, regardless of the status of any additional analysis or planning efforts, given the pressing nature of climate change and the significance of early emission reductions in achieving near-term limits, the state should not delay implementing improvements while awaiting further analysis.

1. Introduction

Source: WSDOT

The State of Washington is committed to tackling climate change and has set ambitious goals to reduce greenhouse gas (GHG) emissions. In 2020, the Washington Legislature set new limits to cut the state's GHG emissions 45 percent below 1990 levels by 2030, 70 percent below 1990 levels by 2040, and 95 percent below 1990 levels, with offsets for the remaining 5 percent, to achieve net zero emissions by 2050.

Historical emissions

The Washington State Department of Ecology (Ecology) publishes the statewide GHG emissions inventory every two years. In 2019,[10] the most recent inventory, the state's total annual GHG emissions climbed to 102.1 million metric tons (MMT) of carbon dioxide equivalent (CO_2e), representing a 9.3 percent increase above the 1990 baseline. In particular, the transportation sector is a substantial contributor to the state's emissions, accounting for about 39 percent of all GHG emissions. To achieve the state's emissions limits, Washington must move aggressively on multiple fronts, especially the transportation sector.

Exhibit 1 provides a summary of the state's GHG emissions inventories for the years 1990 and 2019, as well as future emission limits, under the assumption that each sector will achieve a proportional reduction in emissions.

The state's GHG emissions inventory represents only historical emissions – 1990 through 2019. While these data provide a crucial baseline for understanding past emissions, they do not predict future trends or account for future policy changes. This technical report evaluates future emissions through the lens of several scenarios.

Exhibit 1. Historic GHG emissions and future GHG emission limits

Category	Emissions (MMT CO_2e)			Emission Limits (MMT CO_2e)		
	1990	2019	Change since 1990	2030	2040	2050
Total State emissions	93.5	102.1	9.2%	51.4	28.1	4.7
Transportation Sector	35.5	40.3	13.5%	19.5	10.7	1.8
On-road Transportation	19.0	23.5	23.7%	10.5	5.7	1.0
Non-road Transportation	16.6	16.7	0.1%	9.1	5.0	0.8

Note: numbers may not add due to rounding.
[Source: generated from data in Ecology's GHG Emissions Inventory[Error! Bookmark not defined.]]

Future emissions

Forecasting future emissions and formulating reduction strategies in line with future requirements demand scenario modeling. This modeling must account for expected changes such as population growth, technological advances, and policy interventions. This technical report outlines the state's transportation tailpipe GHG emissions under a business-as-usual (BAU) scenario and assesses the effectiveness of various policies and strategies in achieving the state's GHG emission reduction limits. For the on-road sector, current zero emission vehicle (ZEV) policies and a potential policy that

[10] https://ecology.wa.gov/Air-Climate/Reducing-Greenhouse-Gas-Emissions/Tracking-greenhouse-gases/GHG-inventories

mirrors the sales requirement in the California's Advanced Clean Fleet regulation are evaluated for their efficacy in meeting state GHG limits. This analysis also estimates the potential emission savings from transportation efficiency enhancements and incorporates these with the reductions from ZEV policies for on-road vehicles. Given the limited state-level mandates for non-road sources, this analysis applies projected growth to forecast emissions from the non-road sector but does not consider reduction strategies.

The emissions estimates draw from the most current information concerning existing mandates, technology at hand, and current pricing structures. The influence of market dynamics on the adoption of novel technology due to fuel price fluctuations is not accounted for.

The modeling provides emission estimates for 2021, 2030, 2040, and 2050. The base year of 2021 is chosen due to the availability of VMT data, while the analysis years of 2030, 2040, and 2050 coincide with Washington's GHG emission limit milestones.

2. Methodology and Data Sources

Emissions modeling

This analysis quantifies only tailpipe emissions, excluding emissions associated with fuel or electricity production and distribution. While Washington's Clean Fuels Standard is expected to considerably reduce the state's carbon emissions from transportation fuels, the regulation is expected to mainly impact upstream emissions related to fuel production and distribution. As this modeling centers exclusively on tailpipe emissions, the Clean Fuels Standard is not explicitly factored into the analysis. Instead, the standard is implicitly incorporated through the assumptions of the state meeting its clean vehicle standards, as described below.

Policies considered

Four policies and regulations are considered in the scenarios modeled:

- **California's Advanced Clean Cars II (ACC II)**[11] – In 2020, the Washington State Motor Vehicle Emissions Standards – Zero-Emission Vehicles law directed Ecology to adopt California vehicle emission standards. ACC II requires all new light-duty (LD) vehicles of model year 2035 and later to be zero emission vehicles (ZEV).[12] The requirement phases in between 2026 and 2035 by requiring an increasing number of zero-emission vehicles be sold over that period. Non-ZEV vehicles from model years 2034 and earlier may remain in use for the life of the vehicle. Consequently, as older vehicles are phased out and replaced with newer models, the active vehicle fleet will progressively transition to ZEVs. The modeling assumes an average increase in ZEV sales of 7 percent for each model year from 2022 to 2035.

- **California's Advanced Clean Truck (ACT) –** As adopted in Washington,[13] manufacturers are required to sell an increasing percentage of medium- and heavy-duty (MD/HD) ZEVs from 2025 to 2035. The standard applies different percent sales targets by model year for Class 2b through Class 8 trucks.

  In alignment with the assumptions used for the Transportation Electrification Strategy (TES), the modeling assumes an average increase in ZEV sales of 5 percent for each model year reaching 45 percent of Class 2b - 5 ZEV sales by 2033 and 40 percent of Class 6 through 8 vehicle sales as ZEVs by 2032. The ZEV sales for post 2033 is assumed to remain at 45 percent for Class 2b-5 and at 40% for Class 6-8 vehicles.[14]

- **Washington's Clean Cars 2030 goal** – In 2022, Washington State established an additional state goal that all model year 2030 or later LD vehicles sold, purchased, or registered in Washington be electric vehicles.[15] This goal would have all new passenger vehicle sales be ZEVs five years earlier than currently required under the ACC II. This goal does not mandate manufacturers to meet sales requirements.

- **California's Advanced Clean Fleet (ACF)[16]** – California recently adopted an additional regulation to address MD/HD vehicle emissions. The Advanced Clean Fleet regulation includes requirements for specific fleets and sets a manufacturer sales mandate that beginning with model year 2036; they may sell only zero emission MD/HD vehicles. The

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[11] RCW 70A.30.010, https://app.leg.wa.gov/RCW/default.aspx?cite=70A.30.010.

[12] WAC 173-423-075, https://apps.leg.wa.gov/wac/default.aspx?cite=173-423&full=true#173-423-075.

[13] WAC 173-423-081, https://apps.leg.wa.gov/wac/default.aspx?cite=173-423&full=true#173-423-081.

[14] See FHWA for descriptions of vehicle classifications, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm

[15] ESB 5974. https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bills/Session%20Laws/Senate/5974-S.SL.pdf?q=20231010091559.

[16] https://ww2.arb.ca.gov/resources/fact-sheets/advanced-clean-fleets-regulation-overview

analysis only evaluates the manufacture sales mandate portion of this regulation. Note that Washington State has not adopted this requirement. It is included in the analysis for illustrative purposes.

Scenarios

Four scenarios estimate the effect of ZEV penetration in the Washington fleet with respect to on-road GHG emissions. Additional analysis assesses the magnitude of emission reductions, beyond those achievable through ZEV-related (e.g., electrification) measures, needed to meet the state's GHG emission reduction limits and considers the potential contribution transportation efficiency improvements can provide to reducing emissions. This assessment provides insight into potential strategies and pathways to achieve the state's emission limits in the transportation sector.

- **Scenario 1 – Business as Usual (BAU):** This scenario provides a baseline, accounting only for EPA's 2021 GHG emissions standards for LD vehicles and other federal policies impacting emissions from LD/HD vehicles that are already accounted for in the U.S. EPA MOVES models (e.g., Phase 2 GHG standards for MD/HD vehicles).

- **Scenario 2 – BAU with ACC II and ACT:** This scenario overlays the BAU emissions baseline with the ACC II and ACT regulations, illustrating the GHG impacts of these two regulations that Washington has adopted into law.

- **Scenario 3 – Washington's Clean Cars 2030 goal:** This scenario replaces the ACC II regulation with Washington's goal of 100 percent LD vehicle sales being electric vehicles (EV) beginning with model year 2030. This scenario keeps the ACT requirements in place for MD/HD vehicles.

- **Scenario 4 – Advanced Clean Fleets rule:** California's recently adopted the ACF[17] includes a mandate that, beginning with model year 2036, all MD/HD vehicles must be ZEVs. This scenario looks at how emissions would change if Washington State were to adopt this sales mandate. For LD vehicles, the scenario uses the Washington Clean Cars 2030 goal.

Analysis of feasible light-duty vehicle VMT reduction: This analysis explores the potential reductions in LD vehicle VMT that can be achieved through a suite of transportation efficiency improvement strategies, such as land use policies, telework, enhanced transit, improved active transportation infrastructure, and road pricing. The LD VMT reduction potentials are then added to the above scenarios to illustrate the combined effects of ZEV and LD VMT reductions on on-road emissions.

On-road modeling approach

Emissions from on-road sources were estimated using the Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator model (MOVES). Version 3.1 (the most current at the time of the analysis) was updated to reflect EPA's 2021 GHG emissions standards for LD vehicles. EPA's 2021 GHG standards may result in vehicle manufacturers offering a small percentage of their vehicle sales as electric vehicles (EVs); any EV adoption resulting from these standards are implicitly accounted for in the model's reflection of these standards.

Data sources used in the MOVES model included internal WSDOT data,[18] Federal Highway Administration's (FHWA) Freight Analysis Framework (FAF) version 5,[19] Washington State Department of Licensing (DOL) vehicle registration data, and data developed for the state's

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[17] https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/acf22/acffroa4.pdf

[18] WSDOT's VisionEval modeling outputs conducted as part of the State Highway System Plan.

[19] https://ops.fhwa.dot.gov/freight/freight_analysis/faf/

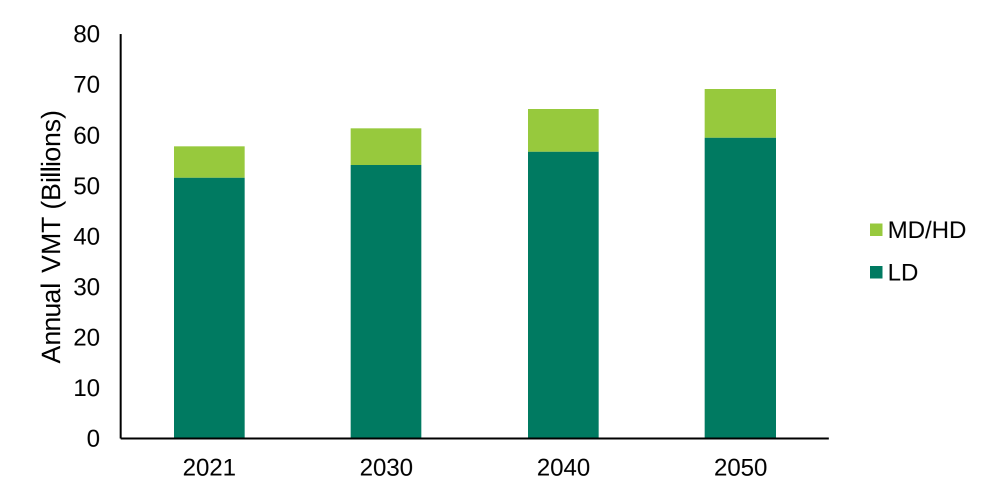
Transportation Electrification Strategy (TES). To ensure alignment, this analysis incorporates the same fleet turnover assumptions as the TES analysis.

The following data sources were used to develop the on-road emissions estimates calculated with the US EPA's MOVES model.

VMT by vehicle type: The base year (2021) VMT was sourced from the FHWA Highway Performance Monitoring System (HPMS). The total VMT for 2021 was apportioned among different vehicle classes using the VMT vehicle class fractions provided by HPMS.

For light-duty vehicles, future year VMT was projected by HPMS vehicle type using growth rate outputs from WSDOT's VisionEval modeling, which was conducted as part of the State Highway System Plan.[20] The HD vehicle VMT growth rate was derived from the Freight Analysis Framework's data on ton-mile growth rates for Washington. Exhibit 2 illustrates the resulting VMT values.

Exhibit 2. Estimated annual VMT for on-road vehicles[21]



Vehicle type population: DOL 2021 vehicle registration data, processed by Ecology, were used as the base year vehicle type data. Future year vehicle type populations were forecast using VisionEval for light-duty and FAF VMT growth rates for MD/HD vehicles.

Vehicle age distribution: For 2021, Ecology provided vehicle age distributions based on DOL data. For future years, Commerce provided forecasted vehicle age distribution data developed for the TES analysis (based on 2021 DOL data) out to 2035. Values for 2030 were used as provided. The 2035 age distribution was applied to the vehicles in 2040 and 2050.

Adjustment for EPA 2021 GHG emissions standards: MOVES3.1 includes the Safer Affordable Fuel-Efficient vehicle regulation,[22] which was repealed in December 2021. To reflect current vehicle standards, the modeling used adjusted GHG emissions outputs from MOVES based on the Regulatory Impact Analysis published by EPA as part of the 2021 GHG standards for light-duty vehicles.[23]

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[20] https://wsdot.wa.gov/construction-planning/statewide-plans/highway-system-plan

[21] Emissions and activity data presented in this report are aggregated over MOVES's source types. For simplicity, the project team combined light-duty vehicles and light-duty trucks into LD, Buses and Single Unit Trucks into MD, and Combination Trucks are considered as HD.

[22] The Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026. Link: https://www.epa.gov/regulations-emissions-vehicles-and-engines/safer-affordable-fuel-efficient-safe-vehicles-final-rule

[23] Regulatory Impact Analysis: Revised 2023 and Later Model Year Light Duty Vehicle GHG Emissions Standards (pdf) (EPA-420-R-21-028, December 2021). Link: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013ORN.pdf

Adoption rates for ZEV: This analysis used ZEV sales requirements (i.e., percent of new vehicles to be ZEV) by model year consistent with each scenario. Percent sales targets by model year were used to simulate proportional decreases in internal combustion engine vehicle emissions (e.g., 7 percent EV sales for model year 2022 decreases total vehicle emissions for model year 2022 vehicles by 7 percent).

Washington's Clean Fuel Standard: As discussed earlier, while Washington's Clean Fuel Standard plays a significant role in curbing carbon emissions from the transportation sector, these emission reductions occur during the "upstream" phase, particularly in fuel production. While important, these reductions are not captured in this tailpipe analysis. Similarly, for the purposes of this analysis, the Clean Fuel Standard support for increasing electric vehicles is assumed to be addressed through ZEV sales requirements. Thus, since this modeling specifically focuses on tailpipe emissions, it does not explicitly model impacts of the clean fuel standard. Consequently, the full, lifecycle reductions achieved through Washington's programs are not fully reflected in this analysis.

In addition, the state GHG limits are based on the state's GHG emissions inventory, which is based on tailpipe emissions. This means that the analysis methods used here, focused on tailpipe emissions, can be directly compared to the state's proportional limits.

Non-road modeling approach

In Washington State, there is currently no model to project emissions for non-road transportation modes. Therefore, this analysis assumed that emissions from these sources would grow in proportion to their respective activity levels. Although this was the best approach available within the scope of the current effort, this method does introduce several uncertainties. While concerns about market trends, future regulatory actions, and technological advancements are relevant to the on-road analysis, their potential impact to non-road emissions is likely greater. Activity increases are not necessarily directly proportional to emission increases for some modes, such as passenger rail travel. In addition, this approach does not account for efficiency improvements or the use of alternative fuels that may become available.

Non-road data sources

Non-road emissions used a base year of 2019 emissions because 2021 data were not available, and 2020 data were highly influenced by the COVID-19 pandemic.[24] Using 2019 instead of 2020 data, should prevent significant underestimation of future emissions.

Base year, 2019, emissions were estimated using EPA's State Inventory and Projection Tool[25] (SIT) based on work from Ecology.[26] Future year emissions were estimated by applying sector specific growth rates to 2019 data. Where data was available, passenger and freight travel were addressed separately.

This analysis excludes international bunker fuels. The EPA SIT uses fuel consumption from the Energy Information Administration's (EIA) State Energy Data System (SEDS). Specifically for the marine sector, the SEDS draws upon the historical sales of fuel into or within each state. Consequently, the EIA's state-level consumption estimates mirror the volume of fuel sold within a state and not necessarily where the fuel has been used. While this might not be a significant concern for sectors like rail or ferries, it does pose implications when estimating GHG emissions related to marine and aviation sectors. This is primarily because a substantial fraction of the fuel consumed in these sectors is used in international and inter-state operations. Given that both

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[24] The decision to use 2021 data for on-road emissions was based on the availability of actual VMT data for that year, ensuring a more accurate representation of on-road emission levels.

[25] US EPA SIT tool. Link: https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool#:~:text=What%20is%20the%20State%20Inventory,or%20complete%20a%20new%20inventory. Last accessed: June 16, 2023

[26] https://ecology.wa.gov/Air-Climate/Reducing-Greenhouse-Gas-Emissions/Tracking-greenhouse-gases/GHG-inventories

state and national GHG inventories exclude international bunker fuels,[27] this analysis also excluded international bunker fuel (as estimated by the EPA) from the total fuel usage reported by the EIA. Excluding emissions associated with international bunker fuel provides a clearer representation of emissions that are within the direct influence of Washington State's policy measures. In the meantime, it is important to underline that the remaining fuel estimates still encompass any fuel intended for inter-state operations, provided that this fuel is sold and delivered to end users in Washington.

Marine: Washington State Ferries emission estimates used projected fuel use that was developed for the Ferries 2040 plan and vessel electrification planning. In the case of other marine categories, which predominantly include freight (as well as cruise ships, recreational watercraft, and commercial harbor craft, but excluding state ferries), emission projections used FAF data.

Rail: For intercity passenger rail, passenger-mile data from Amtrak Cascades along with average fuel efficiency (gallons per passenger-mile traveled[28]) were used to estimate fuel use and associated emissions for 2019. Although ridership is not necessarily directly correlated to rail activity and fuel use, this analysis used the Washington State Rail Plan's[29] baseline ridership data to estimate future emissions for intercity passenger rail. This approach assumes that an increase in ridership directly correlates with an increase in fuel consumption and emissions.[30] The Washington State Rail Plan baseline ridership growth rates are 33 percent in 2030, 45 percent in 2040, and 55 percent in 2050, relative to 2019. Although the state has previously invested in more fuel-efficient locomotives, for the purpose of BAU projections, no fuel efficiency improvements were anticipated.

To estimate emissions for other rail categories, Amtrak Cascades rail fuel consumption was subtracted from the total fuel consumption provided by the SIT. After calculating the emissions data for the base year of 2019, projections were made using FAF data to forecast emissions in future years.

Aviation: For commercial passenger, cargo, military, and general aviation emissions, Federal Aviation Administration Terminal Area Forecast[31] data were used to estimate future emissions. Due to the lack of precise data for any subcategory of aviation, the aviation sector was not separated among categories.

VMT reduction estimates

Consistent with the 2021 State Energy Strategy's recommendation to improve travel efficiency, potential VMT reduction values for five categories of strategies were calculated for 2030, 2040, and 2050. These were overlaid on the ZEV emission reduction scenarios.

These strategies are:

- **Land use** policies aim to create more compact, mixed-use, and walkable communities, reducing the distance between residential, commercial, employment, and recreational areas.

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[27] International bunkering refers to the provision of fuel for use in ships or aircraft that are engaged in international transportation; the bunkered fuel is the fuel taken onboard in Washington but used in international travel.

[28] Oak Ridge National Laboratory, Transportation Energy Data Book 40. 2022,Table 2.13. Also available at: https://afdc.energy.gov/data/10311

[29] Projected ridership data were extracted from Exhibit 4-10 of the Washington State Rail Plan 2019 -2040. Link: https://wsdot.wa.gov/sites/default/files/2021-10/2019-2040-State-Rail-Plan.pdf

[30] This approach offers a conservative estimate as the projected increase in ridership could also be attributed to a higher utilization of the rail system, meaning more passengers per train, rather than just an increase in overall rail activity. However, after careful consideration of planned intercity rail expansion, staff decided to use ridership as a surrogate.

[31] https://www.faa.gov/data_research/aviation/taf

- **Telework** has the potential to reduce VMT by eliminating commuting trips. At the time of this report, the long-term effects of significant teleworking are unclear. Some data suggest that the ability to work remotely may encourage people to move further away from dense urban areas to less dense suburban or rural areas that typically require longer trips and limit mode choice. Careful consideration and planning are required to address potential repercussions of increased telework.

- **Transit** includes buses, light rail, and commuter rail. Efforts to increase transit use include network expansion and increasing service frequency.

- **Active transportation** replaces vehicle trips with non-vehicle modes, such as biking and walking. Opportunities can be improved by creating complete sidewalk networks, shared-use trails, and bike-friendly infrastructure.

- **Pricing** mechanisms such as cordon pricing, parking pricing, and VMT fees leverage financial mechanisms to influence travel behavior.

Literature review and analysis

This analysis examined the range of potential VMT reductions available through a comprehensive literature review of studies exploring the efficacy of VMT reduction strategies. The literature review found 17 sources that provided information on unique strategies or combinations of strategies. Another 14 sources provided only elasticity information rather than a complete range or a single estimate for VMT reduction. Exhibit 4 illustrates the number of data points collected from literature for each unique strategy.

Exhibit 4. Literature review strategy datapoints by category

Strategy Category	# of Data points
Pricing	17
Transit	10
Telework	9
Active transportation	7
Land-use policies	7

Translating literature review results into VMT reduction estimates

The 25th and the 75th percentiles were used as the lower and upper limits of potential VMT reductions.

The combined effect of various VMT reduction strategies does not equate to the mere sum of their individual impacts. Equation 1 was used to combine strategy-specific estimates into a comprehensive VMT reduction factor for each time point. Because synergies exist between transit, land use, and active transportation, only the highest VMT reduction value among these strategies was taken at each point. This methodology captures the holistic VMT reduction that would transpire from the concurrent deployment of multiple strategies and avoids overestimating their collective impact on VMT reduction. This calculation was completed for both the low and high reduction estimates, at each time point.

Equation 1. Combined VMT reduction equation for each year and percentile level

$$\{(100\% - Pricing_{per}) * (100\% - Telework_{per}) * (100\% - [Max(Transit_{per}, Land\ Use_{per}, Active\ Transport_{per})])\} - 100\%$$

Where:

- $Pricing_{per}$ – The VMT reduction effect of pricing at the specified year and percentile level
- $Telework_{per}$ – The VMT reduction effect of telework at the specified year and percentile level
- $Max(Transit_{per}, Land\ Use_{per}, Active\ Transport_{per})$ – The highest VMT reduction effect from transit, land use, and active transportation strategies at the specified year and percentile level

Scaling VMT reductions implementation by year

To scale the VMT reduction potential for each strategy to specific time points (2030, 2040, and 2050), the penetration of each strategy was taken into account. The extent to which a strategy is deployed varies over time. Exhibit 5 describes the scaling factors used for each of the five strategies.

The combined potential VMT reduction estimates are outlined in Exhibit 6, which illustrates that these strategies could lead to a percentage decrease in VMT of approximately 4 - 8 percent at the low end and 22 - 32 percent at the high end over the 2030 - 2050 timeframe, compared to the VMT projected under the business-as-usual scenario.

Exhibit 5. Scaling strategy effects to 2030, 2040, and 2050

Strategy	Scaling – 2030, 2040, and 2050
Pricing	Since pricing strategies can be implemented in the near-term, the pricing effect was applied at 100 percent in 2030, 2040, and 2050.
Telework	Similar to pricing, telework policies can be implemented in the near-term with immediate effects; the effect was applied at 100 percent in 2030, 2040, and 2050. Note that the level of effect will depend widely on (1) the portion of the population teleworking and (2) their teleworking frequency. The study referenced to develop estimates here assumed 40 percent of the population teleworked, and that no changes to non-work VMT occurred. A caveat to consider is how non-work travel changes as a result of telework.
Land use	Land-use strategies at a regional or state scale take longer to implement and subsequently shift behavior more slowly than telework or pricing. For this study, it was assumed it would take 50 years from the present day to shift the development patterns for increased density. By this assumption, the change would be 14 percent of the way along by 2030, 34 percent by 2040, and 54 percent by 2050. Land-use effects on VMT were scaled the same. Because of synergies that exist between transit, land use, and active transportation, only the highest VMT reduction value between these strategies was taken at each combined measure point. In all cases, this led to using the land use values.
Transit	Changes in transit service (frequency, coverage, etc.) were assumed to reach 100 percent effectiveness by 2050, first hitting 50 percent in 2030 and 75 percent in 2040. Because of synergies that exist between transit, land use, and active transportation, only the highest VMT reduction value between these three strategies was taken.
Active transportation	Although active transportation was considered and scaled to 100 percent by 2050 (from 30 percent in 2030 and 60 percent in 2040), its effect was always less than 1

Strategy	Scaling – 2030, 2040, and 2050
	percent. Because of synergies that exist between transit, land use, and active transportation, only the highest VMT reduction value between these strategies was taken. The active transportation effect was never higher than land use or transit taken alone, and so its individual measurement was not factored in. However, changes in the active transportation system are still likely embedded in larger land use shifts.

Exhibit 6. Estimated combined strategy VMT reduction results

Strategy	VMT Reduction	2030	2040	2050
Pricing		100%	100%	100%
Low	1.2%	1.20%	1.20%	1.20%
High	15%	15.00%	15.00%	15.00%
Telework		100%	100%	100%
Low	2%	2.00%	2.0%	2.0%
High	4.5%	4.5%	4.50%	4.50%
Land use		14%	34%	54%
Low	8.8%	1.23%	2.99%	4.75%
High	30%	4.20%	10.20%	16.20%
Transit		50%	75%	100%
Low	2.2%	1.10%	1.65%	2.20%
High	2.2%	1.10%	1.65%	2.20%
Active transportation (Project Level)		30%	60%	100%
Low	0.13%	0.04%	0.08%	0.13%
High	0.68%	0.20%	0.41%	0.68%
Combined				
Low		4.4%	6.1%	7.8%
High		22.2%	27.1%	32.0%

An examination of PSRCs 2030 GHG Analysis and Climate Implementation Strategy was used to validate the findings derived from the literature review. Within this strategy, PSRC conducted sophisticated travel demand modeling for LD vehicles, aiming to assess the influence of diverse strategies such as transit, pricing, and telework on VMT reduction. Although the PSRC's analysis specifically pertained to the Puget Sound region, it serves as an invaluable benchmark.

As detailed in Appendix A, PSRC’s sensitivity analysis illustrated that a $0.25 per mile road use charge (RUC) combined with a 20 percent telework rate has the potential to reduce LD VMT by 14 percent compared to the 2022 regional transportation plan (RTP) projection. While PSRC's study did not encompass a sensitivity test on land use, PSRC’s 2022 RTP’s land use strategies were estimated to provide an 11 percent reduction in LD per capita VMT.

Extrapolating from this, if the same LD VMT per capita reduction from land use strategies were applied to the combined RUC and telework scenario, the cumulative VMT reduction could reach nearly 24 percent. Considering that such VMT reductions are specific to the Puget Sound region, the high VMT reduction estimate presented in Exhibit 6, although lower, appears to be a potentially feasible target for the state.

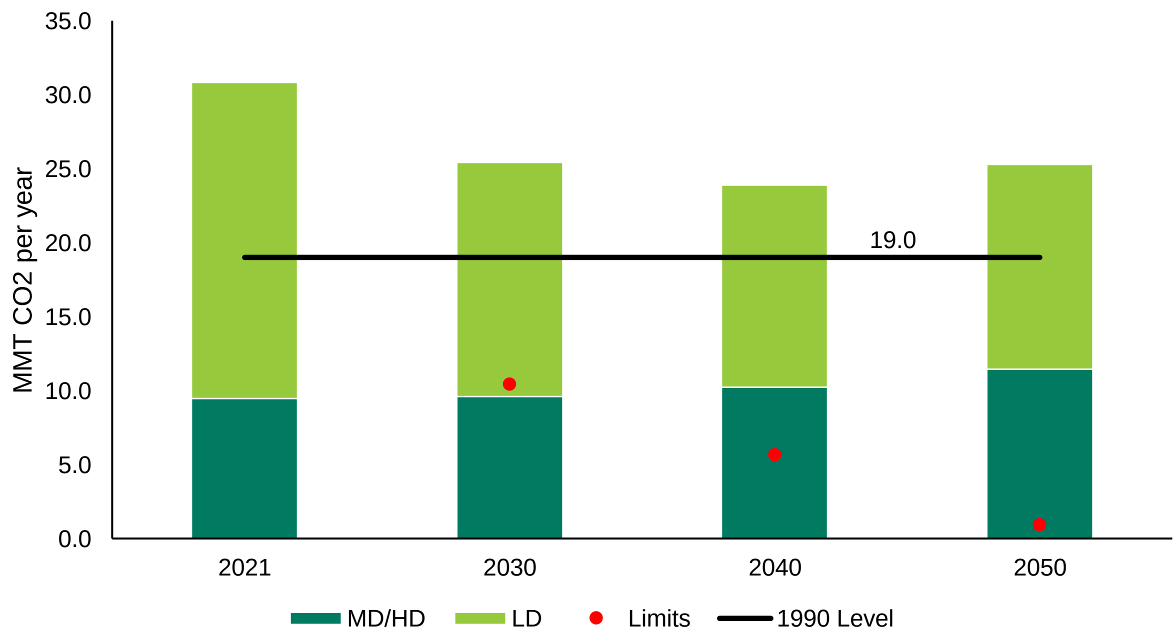
3. On-Road Results

Scenario 1 – Business as usual baseline

Exhibit 7 presents the carbon dioxide equivalent (CO_2e) emissions by year and vehicle class under Scenario 1 – the current federal emission standards with no additional state requirements (i.e., no ACC II, no ACT).

LD emissions decrease from 2021 to 2030 and 2040 but increase between 2040 and 2050. Reductions are due to the EPA light-duty vehicle GHG standards for model years 2023 and newer. However, by 2050 increases in VMT outpace the emission reductions. MD and HD vehicle emissions decrease slightly by 2030 – as a results of Federal Phase 1 and 2 GHG emission standards – but increase in 2040 and 2050. For all modeled years, Washington's on-road emissions not only exceed limits, but also exceed the 1990 level of 19 million metric tons of CO_2e (MMT CO_2e).

Exhibit 7. Baseline on-road BAU GHG emissions under Scenario 1 (without ACC II & ACT)



Note: "Limits" refer to proportional GHG emissions limits for the on-road sector. For example, the limit in 2030 (10.5 MMTCO2), is 45 percent reduction below 1990 emission levels (19 MMTCO2).

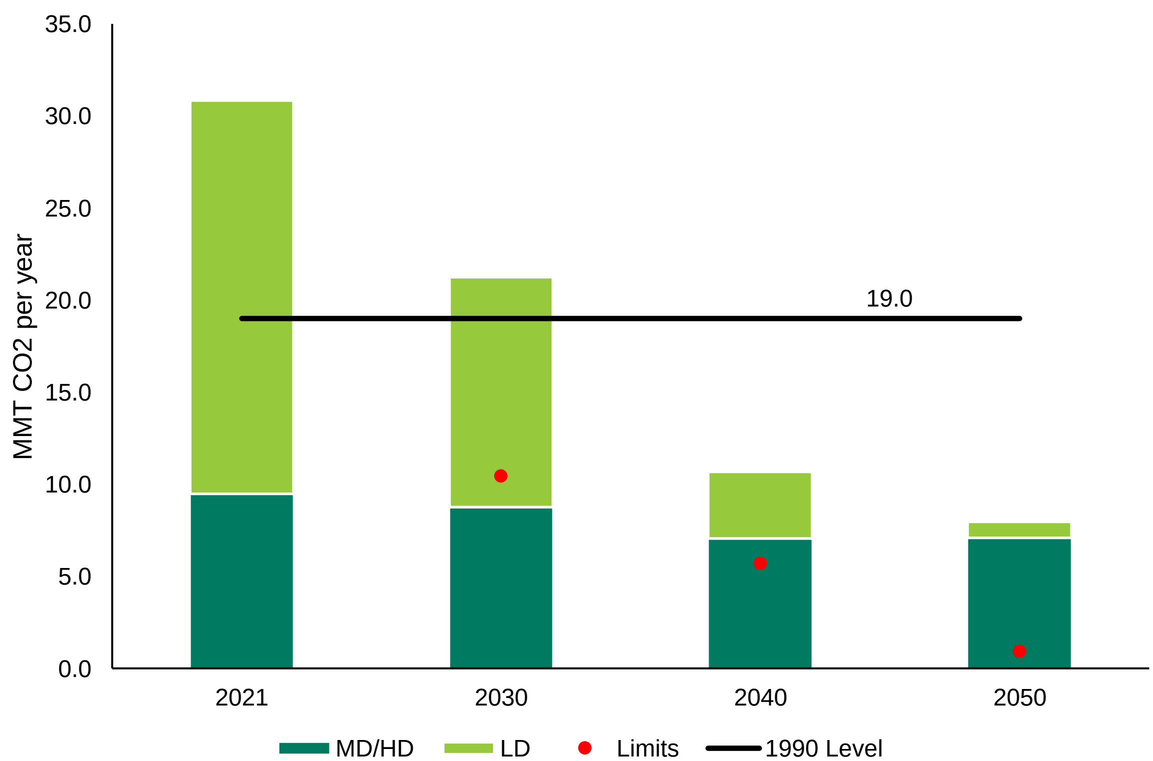
Scenario 2 – BAU with ACC II and ACT

Scenario 2 adds the Advanced Clean Cars II (ACC II) and Advanced Clean Trucks (ACT) requirements to the BAU case. Washington has adopted both requirements as state law. Exhibit 8 illustrates the emissions effects of these two regulations.

Under this scenario, 2030 emissions are more than 16 percent lower than in the BAU scenario, however, they remain well above the proportional 2030 limit. By 2040, fleet turnover leads to significantly more LD electric vehicles on the road and emissions drop further, although total on-road emissions are still above the proportional 2040 limit. In 2050, LD emissions are reduced even further leaving MD and HD emissions as the dominate source of on-road emissions. While 2050 total on-road emissions are down slightly from 2040, emissions totals are still well above the proportional statutory limit.

This scenario demonstrates that while the policies already adopted by the state are a significant step in reducing emissions, ACC II and ACT alone will not meet proportional statutory limits in 2030, 2040, or 2050. In particular, MD and HD emissions dominate on-road emissions in 2040 and 2050.

Exhibit 8. BAU on-road GHG emissions under Scenario 2 (with ACC II & ACT)



Scenario 3 – Washington Clean Cars 2030 goal (with ACT)

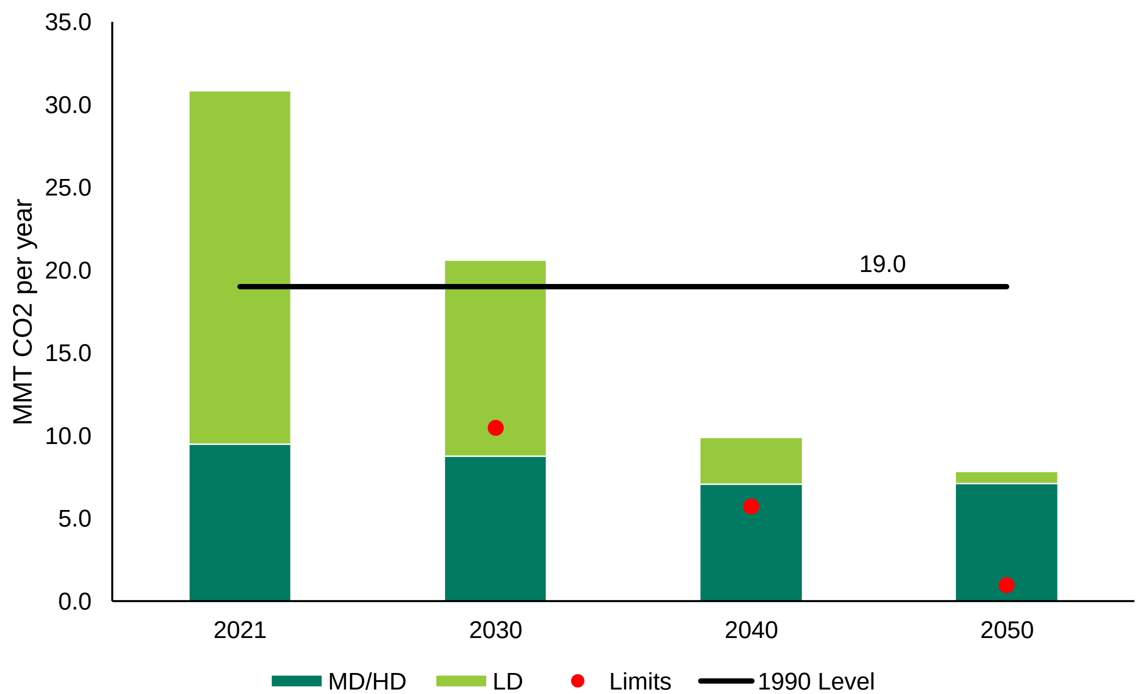
Washington State's Clean Cars 2030 sets a goal for all new model year 2030 and later LD vehicles to be EVs. In Scenario 3, this clean car goal replaces the ACC II requirements while the ACT remains the same as in Scenario 2.

In 2030, total emissions are about 3 percent below Scenario 2 emissions due to expedited LD EV sales. Note that while the legislation only sets a goal for 2030 and future years, it is assumed that the EV adoption rates will be impacted in earlier years as well – expediting the ramp up of EV sales.

However, as Exhibit 9 shows, emissions remain well above the proportional 2030 limit. Similar to Scenario 2, emissions drop further in 2040, but still remain above the proportional limit. And in 2050, MD and HD vehicles again are the dominate source of on-road emissions.

Despite bringing Washington closer to its GHG limits, the mandates of 100 percent LD EV sales by 2030 and ACT still fall short of meeting the proportional statutory limits as the Clean Cars 2030 goal only affects LD emissions without addressing the MD and HD sector.

Exhibit 9. On-road GHG emissions under Scenario 3 (LD 100% ZEV by 2030 and ACT)



Scenario 4 – Advanced Clean Fleets rule

Despite the accelerated electrification of vehicles under Washington's Clean Cars 2030 goal and the ACT rule, on-road transportation emissions still fall significantly short of meeting their proportional statutory limits. As Scenarios 2 and 3 illustrate, this result is primarily due to MD and HD vehicle emissions in 2040 and 2050.

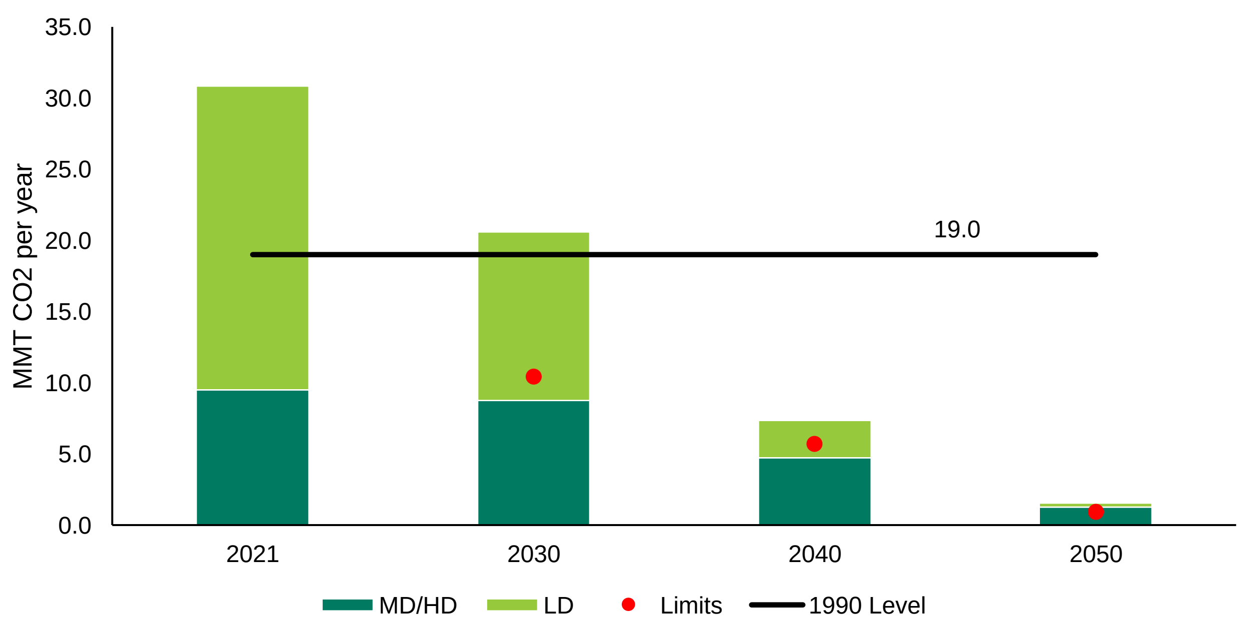
While Washington State has not adopted the California Advanced Clean Fleet (ACF) regulation, Scenario 4 examines the potential impact that the vehicle sales requirement (rather than the fleet requirement) of this regulation might have on emissions. This scenario serves to highlight the potential effect such a policy could have on meeting the proportional statutory limits.

The ACF rule requires all new Class 2b through 8 vehicles (vehicles with a gross vehicle weight above 8,500 pounds) sold after 2036 to be ZEV. For years prior to 2036, ZEV sales requirements follow the ACT rule. This scenario uses the Washington Clean Cars 2030 goal for LD emissions.

As depicted in Exhibit 10, the implementation of the ACF sales requirements for MD and HD vehicles would yield significant reductions in transportation emissions by 2040 and 2050. Because the mandate only affects model year 2036 and newer vehicles, this scenario has no impact on emissions in 2030.

While this scenario does not achieve the proportional statutory emissions limits, it illustrates that the state can come close to reaching the proportional 2050 GHG reduction limit through aggressive electrification.

Exhibit 10. On-road GHG emissions under Scenario 4 (LD 100% ZEV by 2030, ACT, & ACF)

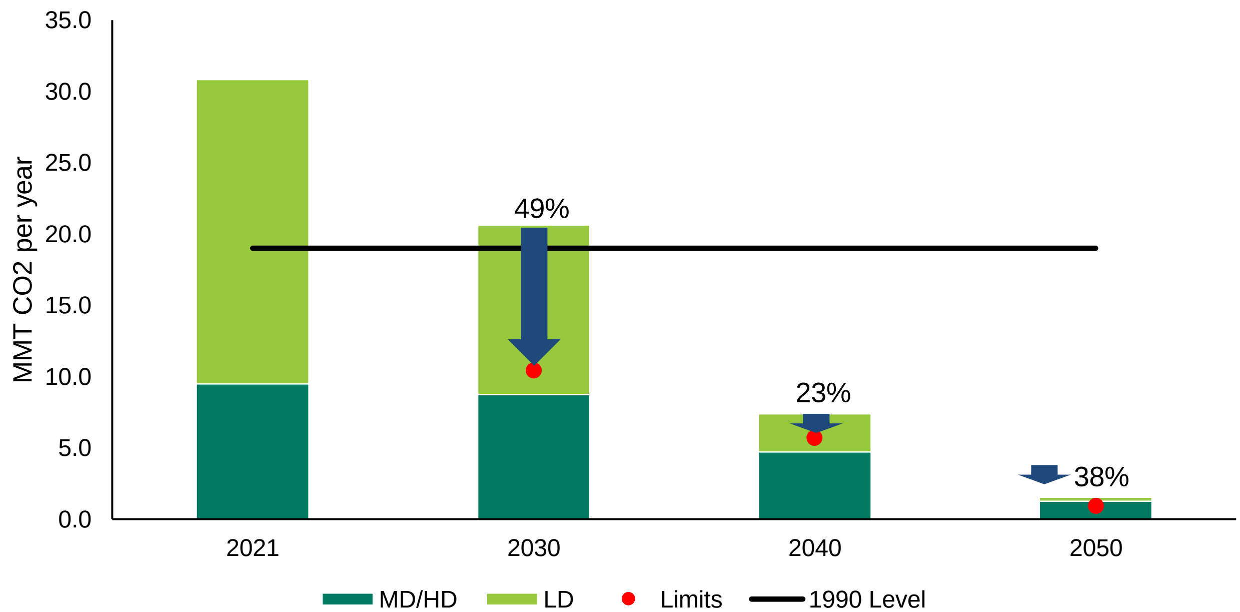


Additional reductions needed beyond electrification to meet state emission limits

Exhibit 11 illustrates the additional GHG emission reductions needed to reach the proportional GHG limits for on-road sources beyond Scenario 4, after meeting Washington's Clean Cars 2030 goal and hypothetically adopting California's ACF sales requirements.

According to the analysis, an additional 49 percent reduction would be needed to meet the 2030 limit, 23 percent to meet 2040 limits, and an additional 38 percent reduction would be needed to meet the 2050 limit.

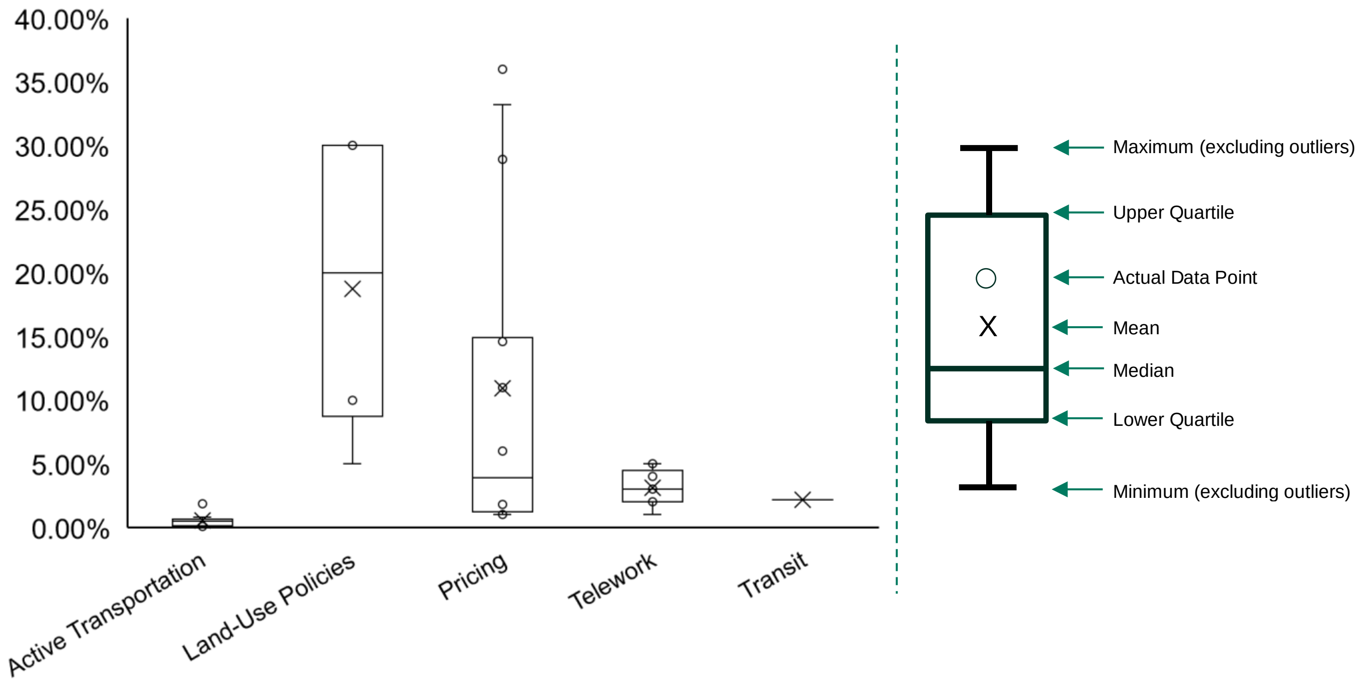
Exhibit 11. Additional on-road GHG emission reductions required to meet GHG reduction limits



Light-duty VMT reduction potential

Exhibit 12 illustrates the VMT reduction potential identified in the literature review. The results comprise a total of 33 data points: 7 for active transportation, 4 for land use strategies, 14 for pricing strategies, 7 for telework, and 1 for transit. It is important to note that all data points for active transportation were reported only at project and community level scales, while for other strategies, data at city, county, regional, state, and national levels were used.

Exhibit 12. Boxplot of total VMT reduction results for individual strategies at larger scales



While pricing offers the greatest overall range (1-36 percent, with a median of 4 percent) and the highest potential for VMT reduction, the inner quartiles range from 1 to 15 percent. The lowest and highest data points originate from a recent city-level study by FHWA, which analyzed the citywide VMT reduction across nine cities under five different parking cash-out scenarios.[32] Depending on the city and scenario, the VMT reduction results varied between 1 percent and 36 percent.

Another pricing study assessed the national impact of a combination of gas and VMT taxes.[33] Those results varied from 1 percent to 33 percent. The low end resulted from a 31.2 cent per gallon gas tax or a 1.54 cent per mile VMT tax. The high end resulted from a 39.3 cent per gallon gas tax and a 21.8 cent per urban mile and 3.8 cent per rural mile VMT tax (all in 2013 dollars). This scenario assumes that over the long run, the fleet average fuel economy will improve by 40 percent, which reduces the operational cost of the vehicles and thereby the sensitivity of consumer behavior to VMT fees.

The range of results for land use is also wide and has the largest range in the middle quartiles. This broad range highlights the role the scale of analysis plays in evaluating the effectiveness of land use changes on transportation greenhouse gas emissions. At larger, regional scales, changes typically are a smaller percentage of the travel than the same changes show when evaluated at a smaller scale. Smaller scale changes can also yield VMT changes on a faster timeline. This is not to say that

[32] FHWA. 2023. “An Assessment of the Expected Impacts of City-Level Parking Cash-Out and Commuter Benefits Ordinances - FHWA Operations.” https://ops.fhwa.dot.gov/publications/fhwahop23023/index.htm#toc.

[33] Langer, Ashley, Vikram Maheshri, and Clifford Winston. 2017. “From Gallons to Miles: A Disaggregate Analysis of Automobile Travel and Externality Taxes.” Journal of Public Economics 152 (August): 34–46. https://doi.org/10.1016/j.jpubeco.2017.05.003.

large scale changes are not important; they are critical to reducing the need for individual vehicles. These changes, however, will require more time to become evident.

The impacts of telework are relatively small, ranging from 1 to 5 percent. The effects of telework on a region's or state's total VMT depends on multiple factors including the proportion of workers teleworking, the frequency of telework, the commute distance and travel modes of teleworkers, and the potential changes in travel patterns resulting from telework. For instance, an analysis of telework in Dane County, WI, found that total annual VMT could be reduced by 1 to 5 percent, assuming that 40 percent of all workers telework at least one day per week (1 percent if 40 percent of workers telework one day per week and 5 percent if 40 percent of all workers telework 5 days per week).[34] It is worth noting that these VMT reduction impacts are based on the assumption that workers' travel for other purposes will not increase. However, current research[35] on telework is revealing mixed results about its overall impact on VMT, given shifts in workers' travel for other purposes.

The transit study reviewed estimated that a 5 percent improvement in transit speeds over a 30-year period (from 2000 to 2030)[36] provides a 2 percent reduction in VMT related to all car trips. The literature review failed to identify VMT reduction results for additional types of transit improvements (such as increased frequency or expanding service into areas not currently served) that provided the level of detail needed for this analysis. Still, these limited findings are consistent with PSRC's 2030 GHG Analysis and Climate Implementation Strategy where the impact of transit improvement in 2030 were relatively small as compared to other strategies.

For active transportation, the literature identified VMT reductions only at a project level or within specific plans or communities. Even at these smaller scales, the estimated VMT reduction impacts are minimal, ranging from less than 1 percent to just under 2 percent.

Light-duty VMT reduction effects

Combining the VMT reduction percentages developed out of the literature review (Exhibit 13) with the emissions reductions in Scenarios 1 through 4 shows the combined effect of electrification and travel efficiency improvements. As discussed in Section 2, to corroborate these combined VMT reduction assumptions, WSDOT reviewed the analysis conducted as part of the PSRC's 2030 GHG Analysis and Climate Implementation Strategy and demonstrated that the estimated level of VMT reduction derived from the literature are within reasonable ranges.

Exhibit 13. Estimated combined VMT reduction results

VMT Reduction	2030	2040	2050
Low end	4.4%	6.1%	7.8%
High End	22.2%	27.1%	32.0%

Exhibit 14 illustrates that the addition of VMT reduction lowers LD emissions in all scenarios. Because VMT reduction affects a percentage of all LD emissions, in the scenarios with higher LD emissions, VMT reduction has a larger effect.

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[34] Sustain Dane, and Greater Madison Metropolitan Planning Organization. 2021. "Telework in Dane County." https://daneclimateaction.org/documents/Admin-PDFs/Telework-Report-1.17.21-Final.pdf.

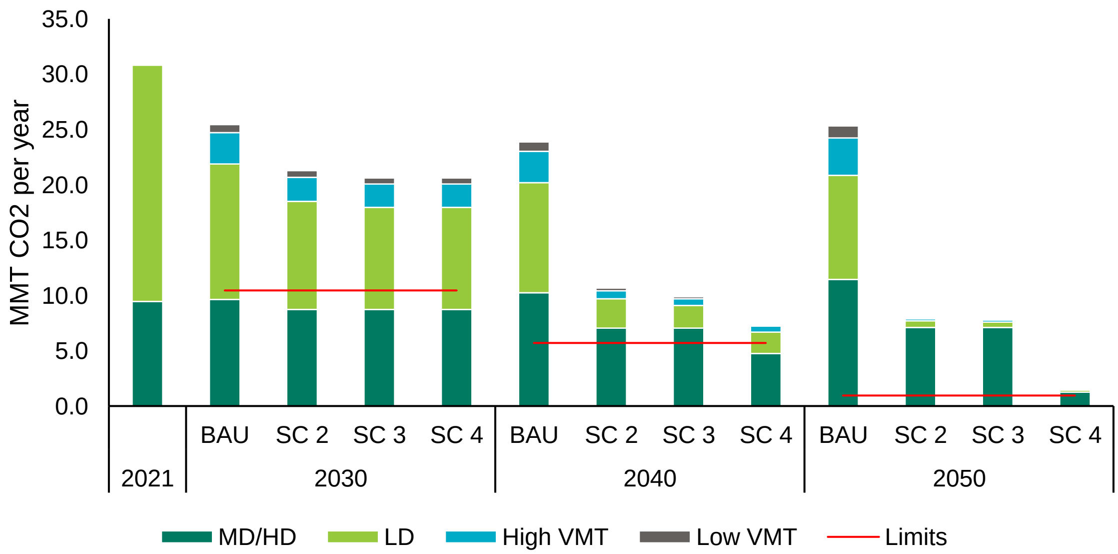
[35] Wöhner, F. (2022). Work flexibly, travel less? The impact of telework and flextime on mobility behavior in Switzerland. Journal of transport geography, 102, 103390.

[36] Anas, Alex. 2015. "Why Are Urban Travel Times so Stable?" Journal of Regional Science 55 (2): 230–61. https://doi.org/10.1111/jors.12142

While VMT reduction strategies may not impact overall emissions to the same extent as electrification efforts, they remain crucial in reducing on-road emissions. Notably, short-term VMT reduction measures are vital for quickly cutting emissions and result in higher cumulative emissions reductions. In climate change mitigation, considering cumulative emissions is essential because the total accumulated GHG in the atmosphere, not just annual emissions, drive long-term climate change effects.

Moreover, this analysis does not consider the economic advantages of reducing "electrified miles," or the miles not driven by electric vehicles. The energy conserved from undriven miles decreases the demand for energy and the cost of energy infrastructure.

Exhibit 14. WA transportaton GHG emissions under various ZEV and VMT reduction scenarios



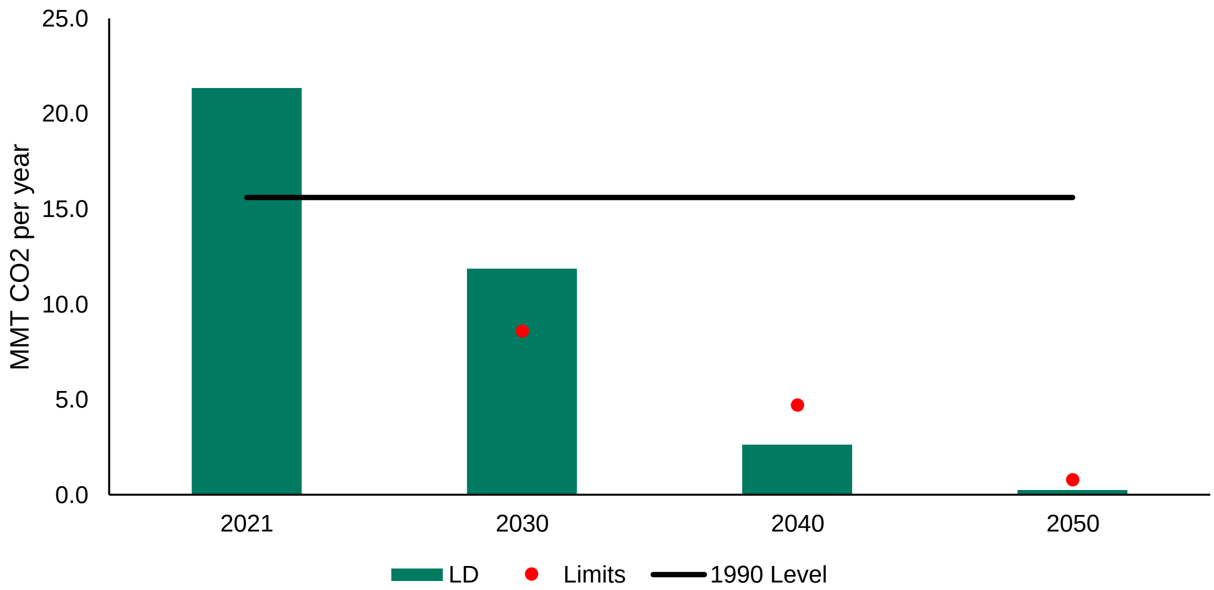
Light-duty vehicle fleet emissions and VMT reductions

Evaluating the LD vehicle emissions in isolation from the MD and HD vehicles provides additional insight into this portion of on-road emissions. Exhibit 15 shows Scenario 4 emissions from only the LD fleet and the corresponding proportional reduction limits.

For 2040 and 2050, the swift electrification of LD vehicles through Advanced Clean Cars II or the Washington's Clean Cars 2030 goal would enable this portion of the on-road fleet to meet and surpass proportional GHG emission reduction limits. However, despite the extensive electrification requirements for this portion of the vehicle fleet, an additional 28 percent emissions reduction is needed beyond the Clean Cars 2030 goal to meet a proportional 2030 LD GHG limit.

The 2030 VMT reduction range identified above, 4.4 to 22.2 percent, means it is possible to for this subsector of the transportation emissions to come close to meeting the 2030 limit. Doing so will require the implementation of all strategies available, expanding transit, enhancing walking and biking opportunities, introducing a mileage-based road use charge, engaging in land use planning that supports compact communities, and reducing trips through telework and related policies.

Exhibit 15. Scenario 4 light-duty vehicle GHG emissions[37]



Note: In this chart, "Limits" refer to proportional GHG emissions limits for the on-road light-duty sector. For example, the limit in 2030 (8.2 MMTCO2), is 45 percent reduction below 1990 emission levels for this subsector (14.9 MMTCO2).

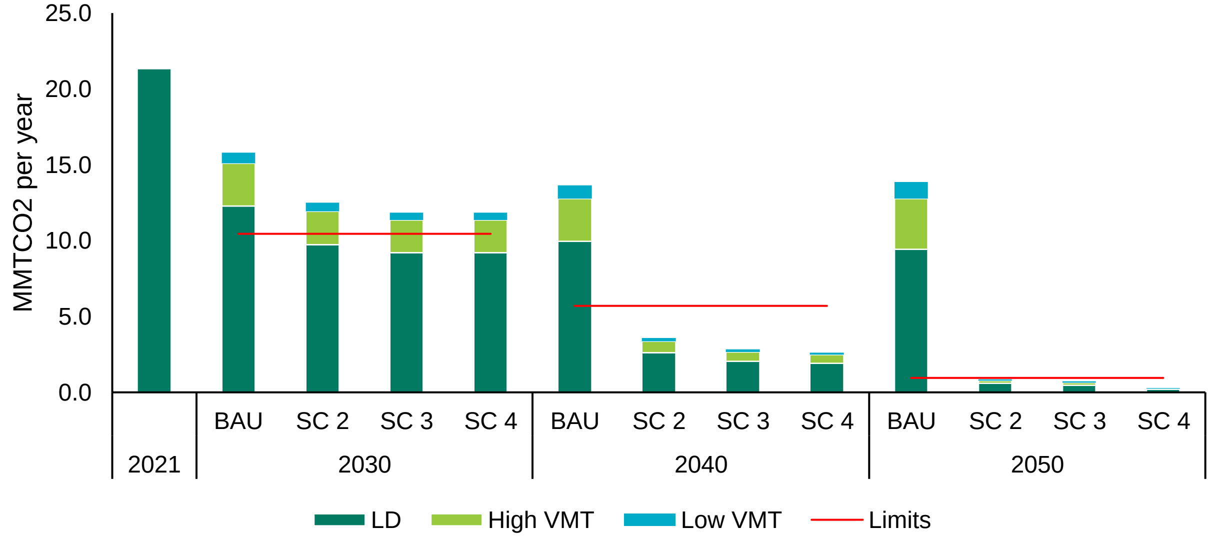
Light-duty emission reductions – electrification and efficiency

Exhibit 16 provides a visual representation of the impact of both the lower and higher estimates of VMT reduction on the GHG emissions from LD vehicles in the state. In this figure, the high and low VMT reductions (see Exhibit 13) are applied to the emissions from LD vehicles under Scenario 4. The reduced emissions are assumed equal to the reduced VMT, implying that the entire fleet undergoes the same VMT reduction, i.e., a 5 percent reduction would result in a 5 percent reduction in GHG emissions.

In 2030, the estimated VMT reductions could lower GHG emissions from the LD vehicle sector to close to the proportional 2030 limit for LD vehicles. However, it is crucial to underscore that to come close to this limit, the state must achieve the high end of VMT reductions, up to 22 percent from a combination of strategies – all potential VMT reduction categories must be implemented concurrently. While VMT reductions do reduce LD emissions and with aggressive implementation could bring the state close to meeting the limits for this subsector, overall, LD VMT reductions cannot sufficiently address the remaining emissions gap for all on-road sources.

[37] Note that the 1990 level GHG emissions and "limits" shown in this figure represent light-duty vehicles only. The limits here are determined by applying proportional reductions to the 1990 level light-duty emissions only.

Exhibit 16. On-road light-duty vehicle GHG emissions under and potential VMT reductions

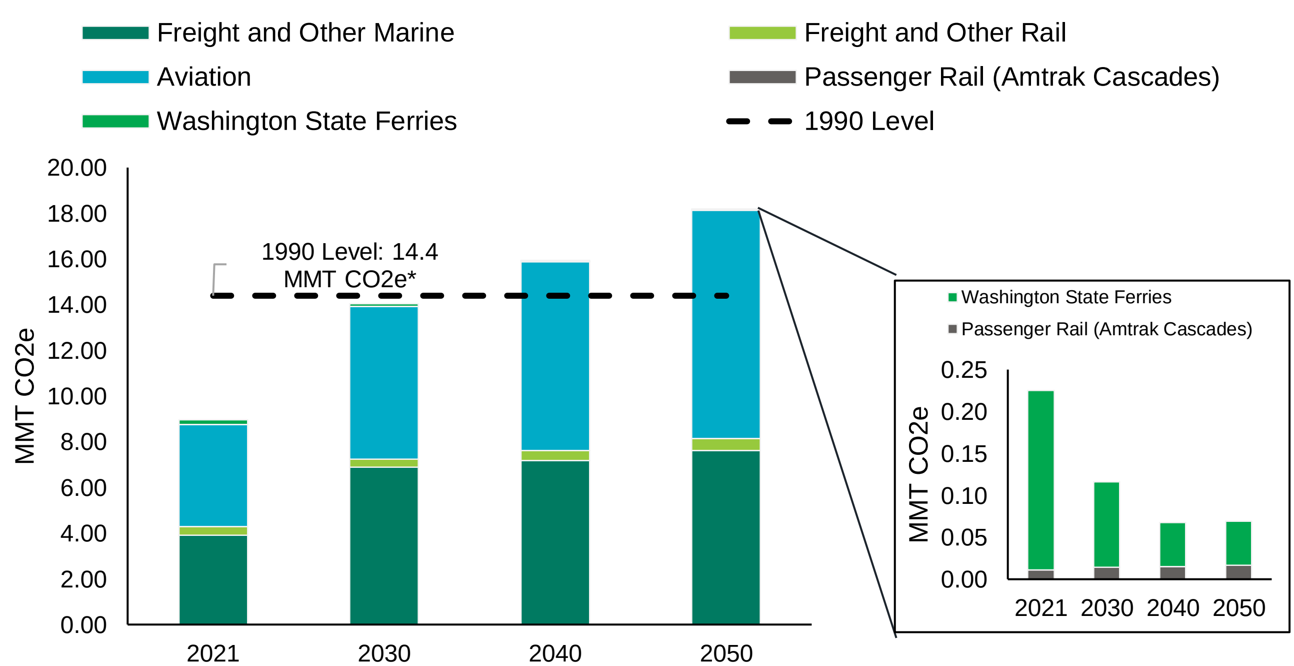


4. Non-Road Results

Non-road emissions, specifically the aviation, marine, and rail sectors, also contribute to the transportation sector. Because the types of vehicles, equipment, and vessels that make up these sectors and the nature of their use require different data sources for analysis and different considerations for reducing emissions, they are analyzed separately. Currently, the data and tools available for this analysis are rudimentary. Nonetheless, this analysis provides a starting point to considering the need to address these sectors.

Exhibit 17 shows that emissions from non-road sources are currently below 1990 levels.[38] However, significant projected growth in both freight and passenger travel (especially air passenger) results in an increase in emissions, forecasting that they surpass the 1990 levels by 2040. This projected rise underscores the urgency of adopting measures aimed at increasing fuel efficiency and switching to zero emission technologies for these modes of transport. This transition will require on-going monitoring and advancements in both regulation and technology to ensure that sectors keep pace with the state's broader goals for reducing GHG emissions.

Exhibit 17. Projected non-road emissions (rail, aviation, marine)[39]



As shown in Exhibit 17, emissions from Amtrak Cascades and Washington State Ferries are minor compared to other non-road sectors. For this reason, emissions from these sectors are magnified for a closer look. As illustrated, the state anticipates a substantial reduction in emissions from Washington State Ferries due to the vessel electrification over the next two decades. At this time, ferries planning extends to 2040; future plans will extend further.

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[38] In 2018, the Energy Information Administration (EIA) revised jet fuel data dating back to 2010, leading to a noticeable reduction in the reported values from 2010 onwards; data prior to 2010 are no longer directly comparable to data collected afterward. [US Energy Information Administration - EIA - Independent Statistics and Analysis]

[39] In the context of the analysis, water transportation other than Washington State Ferries falls under the category of "freight and other marine." This includes various forms of commercial water transportation such as cargo ships, cruise ships, recreational watercraft, and commercial harbor crafts. Similarly, any rail transportation apart from Amtrak Cascades is categorized as "freight and other rail." This encompasses the movement of freight and other types of rail transportation that do not fall within the scope of Amtrak Cascades.

5. Conclusion

Photo by Josh Hild on Unsplash

While notable strides have been made in recent years towards establishing policies to mitigate transportation emissions, significant work remains. This analysis underscores the necessity of further substantial reductions in emissions to achieve Washington's GHG emission reduction limits. Meeting these limits will require a multifaceted approach that leverages a range of strategies and technological advancements.

Accelerating the adoption of cleaner technologies is key to meeting the state’s GHG limits. ZEVs, powered by electricity or hydrogen, are pivotal in this transition. By replacing traditional internal combustion engine vehicles with these alternatives, Washington can dramatically curtail tailpipe emissions. This switch, however, needs to extend beyond personal vehicles to encompass commercial fleets, public transportation systems, and freight transport to truly transform the transportation sector.

The move to ZEVs needs to happen rapidly. Even under the most aggressive scenario modeled here, Washington is not on track to meet the 2030 greenhouse gas limits. It is imperative to quickly transition light-duty vehicles away from fossil fuels. While regulations require ZEV sales, supplementary programs, such as incentives and charging infrastructure, are essential to support the rapid influx of electric vehicles. Encouraging drivers, especially high-mileage drivers and those with older, less efficient vehicles, to switch to EVs can yield important early emission benefits.

Similarly, the medium- and heavy-duty vehicle fleets need to transition to low or no carbon fuels: electricity, hydrogen, or other low carbon fuels. If these segments are not addressed, they will remain roughly at current levels and dominate on-road sector emissions. This analysis showed that adopting the sales requirements in California’s Advanced Clean Fleets rule could significantly reduce MD and HD emissions in 2040 and 2050. Although electrification for these vehicles needs to be expedited, it is likely to take longer than for LD vehicles; in the interim, low carbon fuels, such as renewable diesel, biodiesel, and renewable natural gas, may provide a bridge.

In addition to on-road emissions, the current analysis looked at marine, aviation, and rail emissions. With less information available about these sectors and fewer robust modeling tools readily available, a more rudimentary approach was used to estimate these emissions. And while there are efforts underway to reduce emissions in these segments, there are no clear rules or policies to model the effects of. This brief analysis shows that without intervention, the emissions from these sectors will continue to increase as population and the economy grow.

Alongside these technological shifts, there is an urgent need to enhance the overall efficiency of the state's transportation systems. This involves rethinking land use patterns and how passenger and freight transportation are managed. Implementing measures that encourage more efficient travel including expanding active transportation networks, public transportation, ridesharing, while reducing travel distances and the need for travel. These changes will lead to reductions in VMT and associated emissions reductions.

Importantly, having ZEV requirements on the books is just the first step to reducing emissions. These vehicles need supports to get on the roads – incentives to encourage drivers to make the switch to electric vehicles, particularly given the higher upfront cost compared to internal combustion engine vehicles, as well as sufficient charging infrastructure. Additionally, these efforts should recognize that opportunities for accelerating ZEV adoption are an important tool to reducing near-term emissions.

Additional work to support strategic emission reduction implementation

Because of the importance of reducing VMT and improving travel efficiency in the state, towards the multiple goals of reducing greenhouse gas emissions, reducing the energy demand needed to electrify transportation, and achieving other state goals (e.g., health, equity, safety etc.), the state would benefit from a **statewide multimodal transportation efficiency strategy** to accelerate transportation efficiency improvements**.** This work would identify preferred policies to reduce per capita vehicle miles traveled (VMT), meet greenhouse gas (GHG) limits, minimize the need for transportation energy infrastructure investments, and improve equitable access. This strategy would need to be developed in close collaboration with partners and would support future legislative policy development and investment decisions.

The current analysis provides a high-level view of the effectiveness of strategies in place and potential additional strategies. However, more work is needed to better understand how the state can best meet emission limits. Closing these gaps will require additional analysis to provide a framework for making informed choices as the state continues to reduce emissions. Specific needs include:

- **Analysis of transportation efficiency improvements** – an analysis of transportation efficiency opportunities and measures is needed to support the development of a statewide multimodal transportation efficiency strategy. This analysis would identify how efficiency improvements contribute to emissions reductions and the support needed for their strategic implementation. This analysis must account for different types of communities (urban, suburban, small city, rural) and different types of travel (commutes, recreational, etc.).

- **Opportunities analysis for high-capacity inter-city transit and passenger rail** – identify the types of service that best meet traveler needs across the state and where they can be most efficiently implemented throughout the state, expanding beyond the central Puget Sound area and I-5 corridor. This analysis would evaluate efficiency improvements between communities: identifying demand, identifying service levels to meet that demand, and establishing priorities for implementation.

- **Freight analysis (rail, marine, aviation, and on-road freight)** – work with industry partners to characterize emissions and identify opportunities and challenges to improving efficiency from freight to inform the development of effective and efficient policies and programs that address freight-related emissions, specifically:

    - **Baseline emissions profile –** develop a baseline emissions profile of freight and non-road modes to characterize the emissions from these sectors.

    - **Opportunity analysis for freight efficiency improvements –** identify opportunities, challenges, and potential policy and programmatic supports to improve efficiency across all freight modes.

- **Evaluate the role of reducing VMT in lowering energy requirements and associated costs –** While it is generally understood that fewer miles traveled requires less energy, an analysis of the infrastructure and energy cost savings from improved transportation efficiency would support state vehicle electrification efforts and may help direct efforts for the most effective implementation.

Lastly, regardless of the status of any additional analysis or planning efforts, given the pressing nature of climate change and the significance of early emission reductions in achieving near-term limits, the state should not delay implementing improvements while awaiting further analysis.

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Appendix A: PSRC's 2030 GHG Analysis and Climate Implementation Strategy

Since 2010, Puget Sound Regional Council (PSRC) has maintained a Four-Part Greenhouse Gas (GHG) Strategy to curbing the GHG emissions from transportation in the region. This multi-faceted approach comprises land use, travel choices, user fees, and technology. Firstly, the land use component emphasizes compact, mixed-use developments to reduce trips as well as travel distances. The travel choices element promotes alternative modes of transportation like walking, cycling, and public transit, providing residents with options beyond single-occupancy vehicles. User fees, such as road usage charges (RUC), are introduced to influence driving behavior and fund alternatives to driving alone. Lastly, the technology facet focuses on adopting cleaner fuel technologies and facilitating the shift to low- and zero-emission vehicle technologies.

PSRC's 2022 Regional Transportation Plan[40] (RTP) reflects the growth in population and employment expected by 2030, in line with the VISION 2050 Regional Growth Strategy. Aiming for a sustainable and efficient multimodal transportation system, the plan envisions an expanded high-capacity transit system across all four counties, including 21 bus rapid transit routes, 7 ferry routes, and 50 light rail stations. The RTP also calls for significant bicycle, pedestrian, and other alternative modes of transportation investments. The RTP also proposes transitioning to a RUC system by 2030 as a sustainable revenue model and demand management tool, differing from the rates currently considered by the Washington State Transportation Commission. In the meantime, there are a total of 135 roadway capacity projects in the 2030 RTP which add approximately 530 centerline miles to the regional system, a change of approximately 2%.

PSRC conducted a detailed sensitivity analysis evaluating the impact on VMT and GHG of various strategies beyond the assumptions in the RTP: transit expansion, pricing mechanisms, and telework. The target year for this analysis is 2030, although PSRC has also conducted a limited number of sensitivity analyses for 2050 as well. This appendix briefly describes these scenarios and provides an overview of the outcomes derived from the sensitivity analyses conducted by PSRC.

Land use

As described earlier, PSRC's RTP bases its land use assumptions on the VISION 2050 Regional Growth Strategy. The region expects to add 700,000 people and 362,000 jobs between 2018 and 2030, with 65 percent of the population growth and 75 percent of job growth centered near planned high-capacity transit stations. The PSRC modeling suggests that even with a 19 percent increase in population by 2030, investments in the plan and anticipated growth will reduce the overall increase in VMT to 7%. This translates to a nearly 11 percent reduction in per capita VMT from 2018 to 2030.

[40] https://www.psrc.org/planning-2050/regional-transportation-plan

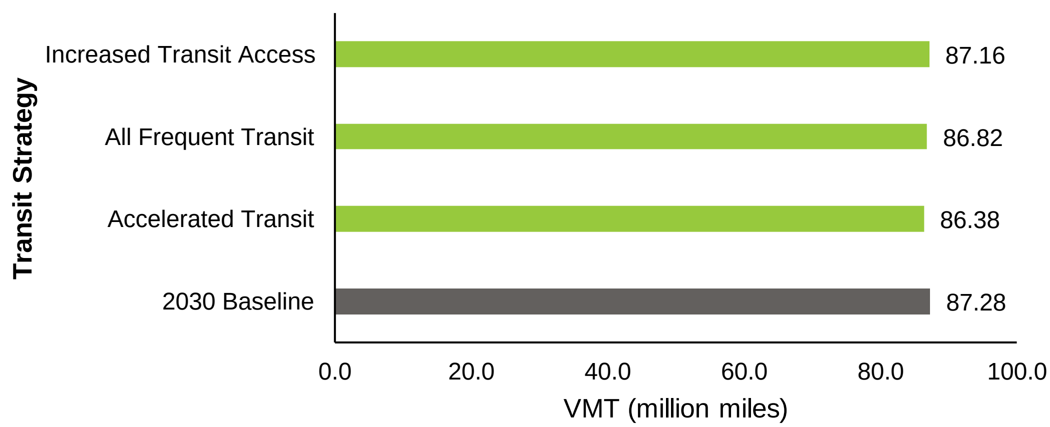
Transit

As part of this sensitivity analysis, PSRC modeled three scenarios reflecting enhanced transit within the region:

- **Accelerated transit** – Accelerating the 2050 high-capacity transit network to 2030. This scenario brings forward the expanded network of transit expected by 2050 to 2030 and assess its impact on VMT and transit ridership in 2030.
- **All frequent transit** – Increasing the frequency of all non-high-capacity transit service
- **Increased transit access** – Increased transit network access to high-capacity transit stations through additional active transportation facilities and local transit service.

PSRC's modeling suggests that while the acceleration of transit alternatives and increased frequencies will significantly increase transit boardings by 2030, the effect on VMT and emissions will be limited (less than 1 percent), especially in 2030. See Exhibit A-1. The reason for this is the growth coming to the region, which is greater and more impactful by 2050 and relatively modest by 2030.

Exhibit A-1. Impact of transit strategies on 2030 light-duty vehicle VMT



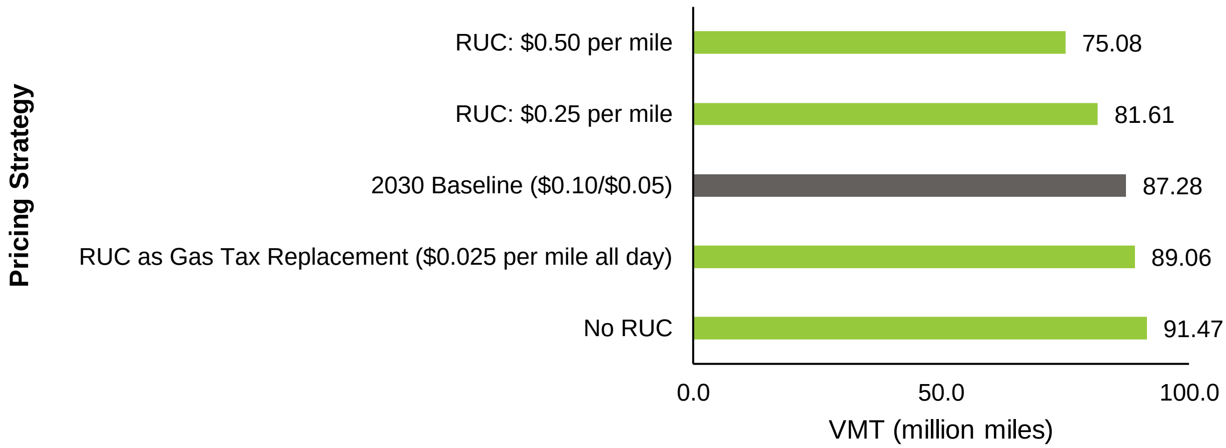
Pricing

PSRC tested various road use charge (RUC) rates for sensitivity, including a state-level RUC of 2.5 cents per mile, a regional 25 cents per mile RUC, a high-level regional RUC of 50 cents per mile, and a no-RUC scenario. The sensitivity analysis revealed that the 50 cents per mile RUC could decrease VMT in 2030 by approximately 17.9 percent, reducing it from 91.47 million miles to 75.08 million miles.

The current PSRC RTP presumes a RUC rate of 10 cents per mile during peak periods and 5 cents per mile during non-peak periods. This RUC rate is projected to lower the VMT from 91.47 million miles to 87.28 million miles, a 5 percent reduction.

Exhibit A-2 shows the effects of differing RUC levels.

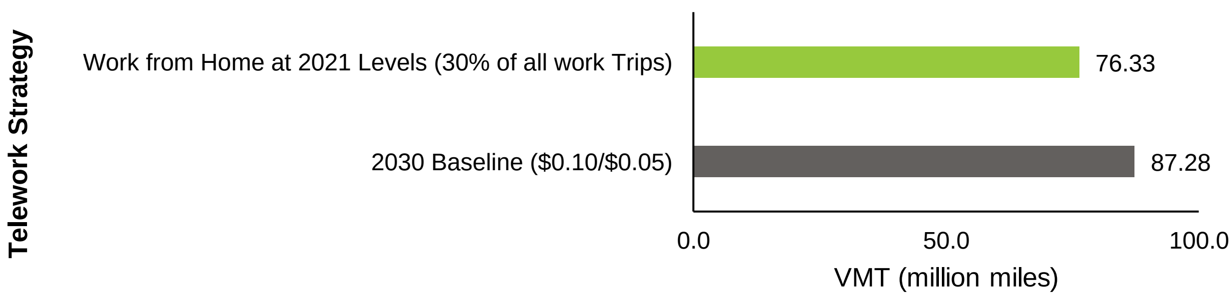
Exhibit A-2. Impact of pricing strategies on 2030 light-duty vehicle VMT



Telework

PSRC evaluated a scenario assuming a significant increase in work-from-home levels to 30 percent (up from the 10 percent assumed under the RTP). This 30 percent level mirrors what was observed during the 2021 pandemic. Such an uptick in remote work is anticipated to decrease the overall VMT by roughly 13 percent, as illustrated in Exhibit A-3. However, PSRC highlights that the option to work from home is not feasible for all sectors and locations.

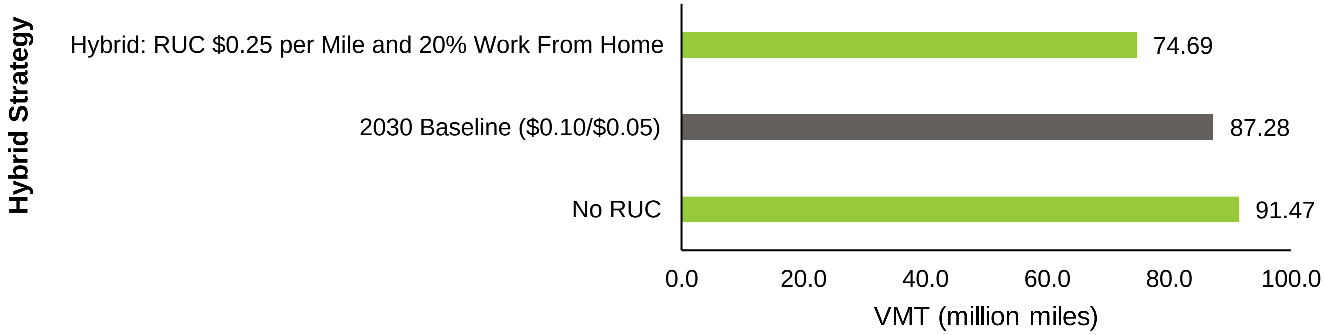
Exhibit A-3. Impact of telework strategy on 2030 light-duty vehicle VMT



RUC and telework

PSRC also conducted a combined scenario to evaluate the potential VMT reduction when two strategies are implemented concurrently: a RUC of $0.25 per mile and a 20 percent work-from-home policy. This approach allows for a comprehensive assessment of how simultaneous interventions in both pricing mechanisms and telework policies might amplify VMT reductions, compared to implementing each strategy independently. In the combined scenario analysis, PSRC discovered that by concurrently implementing the two strategies at mid-level stringencies, there is potential for a 14.4 percent VMT reduction compared to the baseline scenario (i.e., that assumed in the current PSRC RTP). Compared to the no-RUC scenario, the combined scenario results in an 18.3 percent reduction in VMT.

Exhibit A4. Impact of combined telework and RUC strategies on 2030 light-duty vehicle VMT



Combined total

Although the PSRC analysis does not encompass a sensitivity test on land use, the land use strategies outlined in the 2022 RTP, along with other measures such as transit expansion, combine to an 11 percent reduction in VMT per capita between 2018 and 2050. Extrapolating from this, if the same VMT per capita reduction from land use strategies were applied to the combined RUC and telework scenario, the cumulative VMT reduction could reach nearly 24 percent.[41]

[41] This deduction is derived from the formula: 1−(1−14%) * (1−11%) = 24%, showcasing the compounding effects of these strategies when implemented together.