Smarter MODES Calculator User Guide & Methodology

Rocky Mountain Institute

Published February 15, 2024

Version 1.0

Contents

Overview of the Calculator 3

User Guide 3

- Inputs 4
- Outputs 6
- Tab Index 7
- Saving and Exporting Results 7

Methodology 8

- VMT model 9
  - Business-as-Usual (BAU) Forecast 9
  - Reduction 11
  - Avoided VMT 11
- LDV fuel model 12
- Operating cost model 12
- Emissions model 13
  - Method 1: Fuel and Charging 13
  - Method 2: VMT/GHG relationship from CDOT Analysis 14
- Co-benefits 15
  - Air Quality 15
  - Congestion 16
  - Safety 16
  - Physical Inactivity 17
- Key Assumptions 18
  - Monetary Assumptions: 18
  - Investments Assumption 18

Acknowledgements 19

Disclaimer 19

Overview of the Calculator

Decision makers in the United States are increasingly considering novel strategies to reduce climate pollution from the transportation sector. According to the US Environmental Protection Agency (EPA), [surface transportation constitutes the majority of transportation pollution](), primarily due to tailpipe emissions from light duty vehicles.

RMI's Smarter MODES (Mobility Options for Improved Decarbonization, Equity, and Safety) Calculator explores how various combinations of 1) light duty vehicle (LDV) electrification and 2) vehicle miles traveled (VMT) reduction can achieve emissions reductions from the transportation sector and additional co-benefits from improved health, safety, cost, and power generation outcomes as compared to business-as-usual policies in all 50 US states. The calculator can be run both at the state and national levels.

Given 1) a state, 2) an LDV electrification scenario, and 3) a VMT reduction scenario, the calculator outputs the following avoided events and associated costs:

- Avoided tailpipe and charging emissions
- Avoided automobile operations costs
- Safety benefits (i.e., avoided crash fatalities and injuries)
- Health benefit from physical activity (i.e., avoided inactivity fatalities)
- Health benefit from cleaner air (i.e., avoided air pollution fatalities)
- Avoided congestion time and costs

This calculator contains state — specific data and its outputs may be useful for long-term program planning, especially for developing "size-of-the-prize" estimates for achieving climate pollution reductions and expanding transportation options in a given state. However, the Calculator:

- Is not a travel demand or land use model
- Is not an individual, project-level planning tool
- Should be used in concert with other reputable analysis tools & models

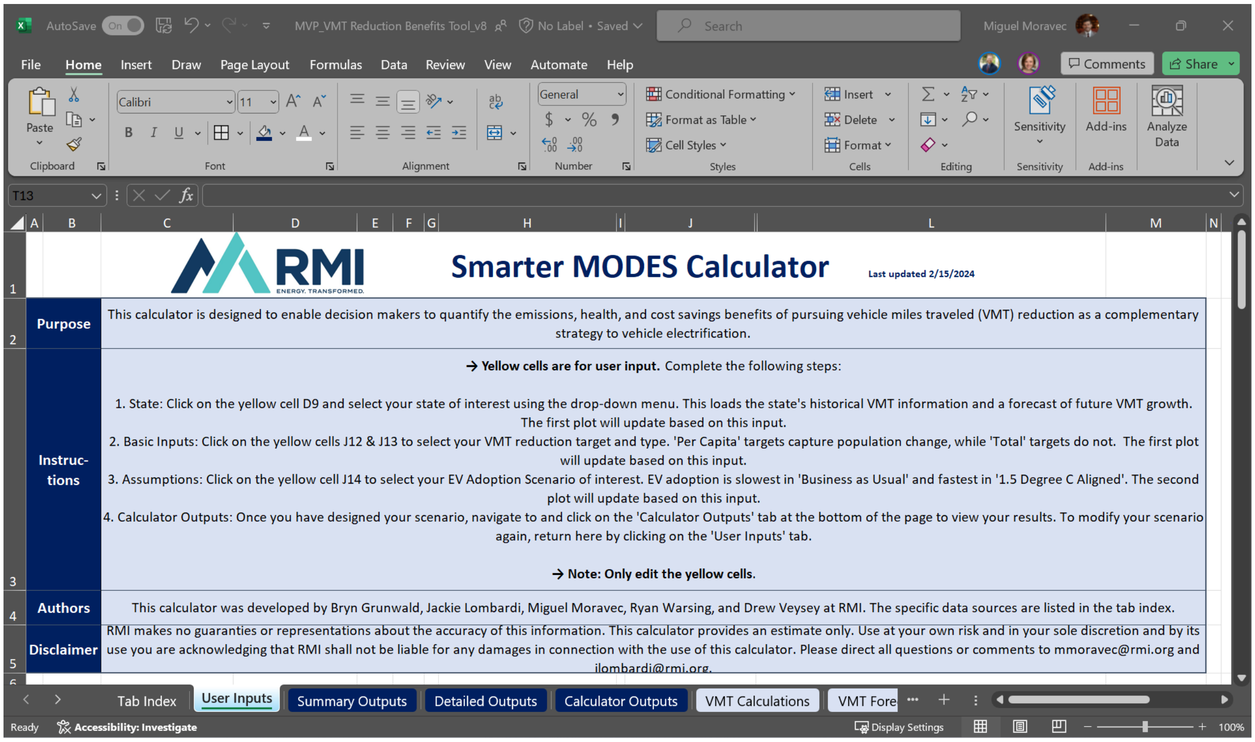
User Guide

The Calculator is a spreadsheet-based analysis Calculator contained in a single file, "RMI_Smarter _MODES_Calculator_V1.0.xlsx". Once the Calculator is open in Microsoft Excel, the user can dynamically select inputs to create a desired scenario and then view the outputs of said scenario.

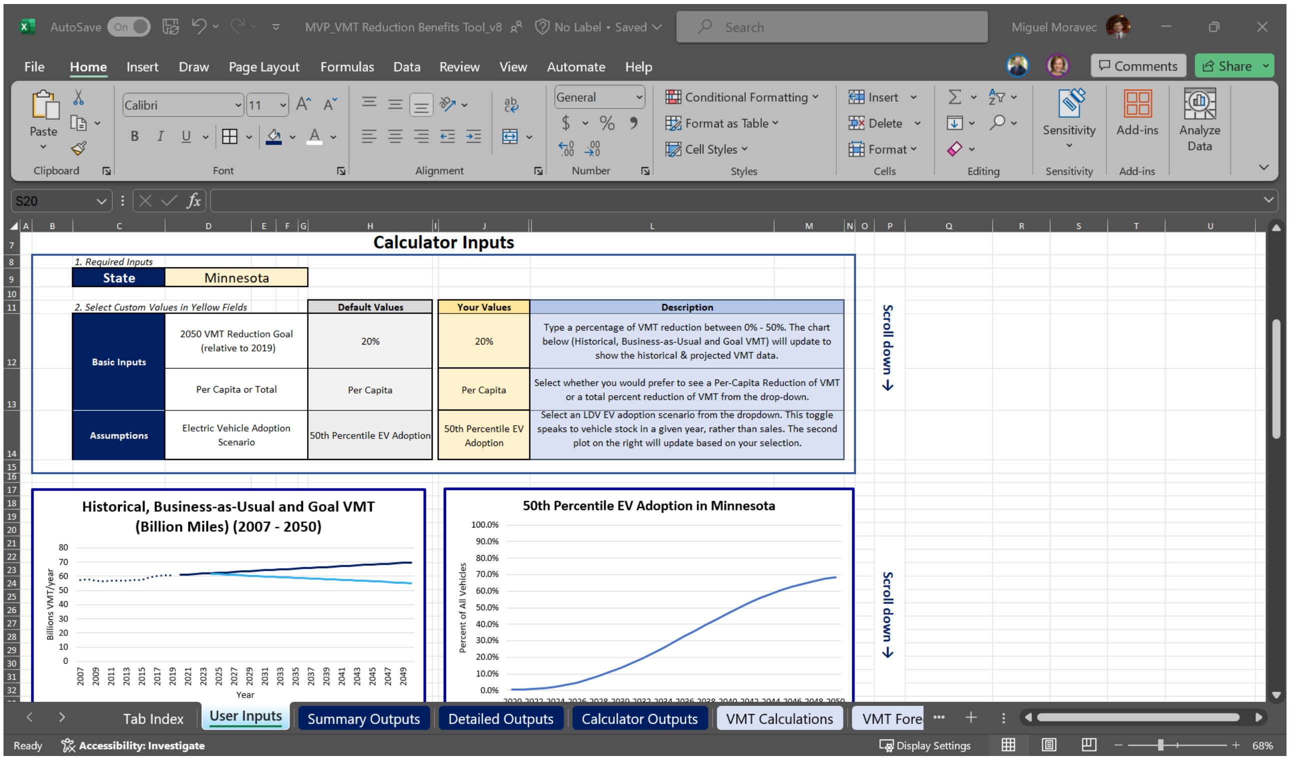
In most cases, the user should only need to interface with the 'User Inputs,' 'Summary Outputs,' and 'Detailed Outputs' tabs. Advanced users can refer to the 'Tab Index' tab and the 'Methodology' section of this document to learn about the supporting data and to unlock calculation tabs.

Inputs

After opening the Excel sheet associated with the Calculator, the user arrives at the 'User Inputs' tab, which resembles the image below:



The user should read the instructions, then scroll down to arrive at the inputs section, as observed in the image below.



The yellow cells are user input cells. The user should complete the following steps to create the desired scenario for analysis:

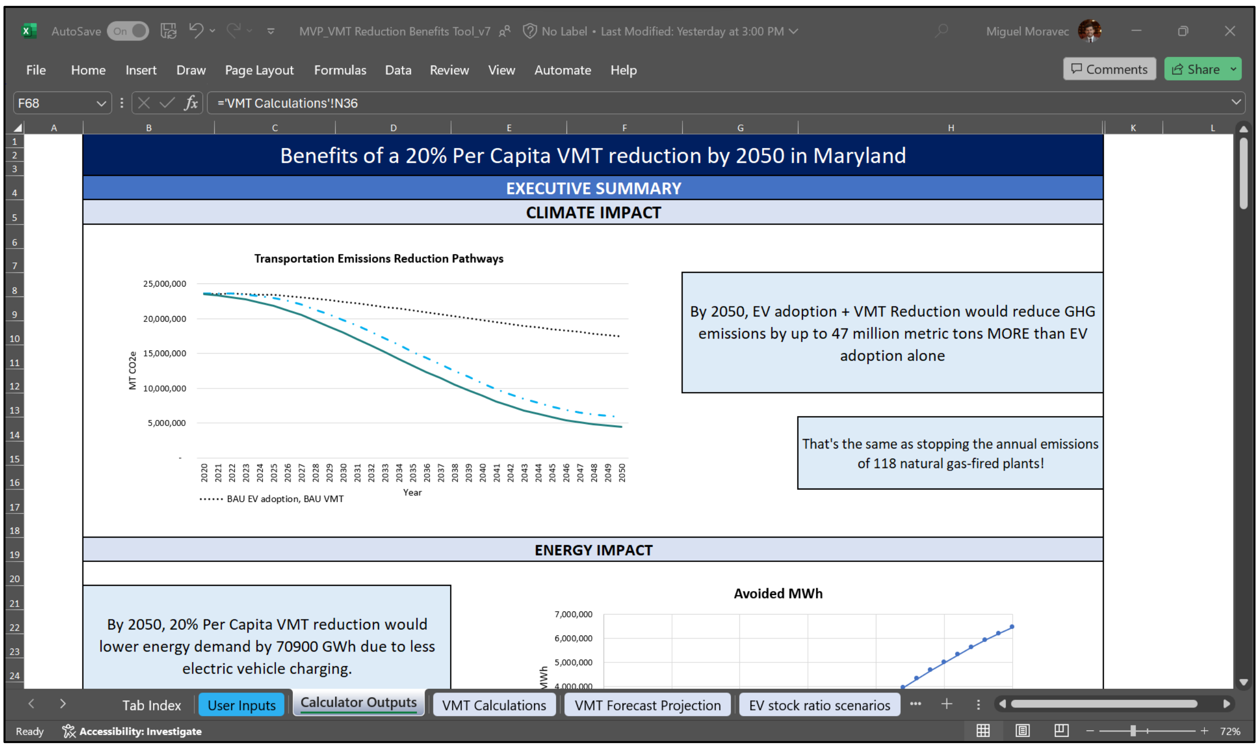
1. State:
    a. Click on the yellow cell D9 and select your state of interest using the drop-down menu. This loads the state's historical VMT information and a forecast of future VMT growth. The first plot on the left will update based on this input.
2. Basic Inputs:
    a. Click on the yellow cells J12 & J13 to input your VMT reduction target and select your VMT reduction target type. 'Per Capita' targets capture population change, while 'Total' targets do not. The first plot on the left will update based on this input.
3. Assumptions:
    a. Click on the yellow cell J14 to select your EV Adoption Scenario of interest.
        i. BAU EV Adoption
            1. Business as usual EV adoption. For most states, this will project a 40% EV stock by 2050.
        ii. 25th Percentile EV Adoption
            1. The 25th percentile between BAU and 100% adoption.
        iii. 50th Percentile EV Adoption
            1. The 50th percentile between BAU and 100% adoption.
        iv. 75th Percentile EV Adoption
            1. The 75th percentile between BAU and 100% adoption
        v. 100% EV Adoption by 2050
            1. The most aggressive EV adoption scenario, this assumes the selected state(s) reaches nearly full EV stock by 2050.

These instructions are also included in the Calculator for user convenience. Note: Default values are provided in the gray cells H12:H17. Users should not edit the 'Default Values' column.

After each input is selected, the spreadsheet instantaneously completes a new analysis. The full results are then available on the 'Detailed Outputs' tab, while summarized results are on the 'Summary Outputs' tab.

Outputs

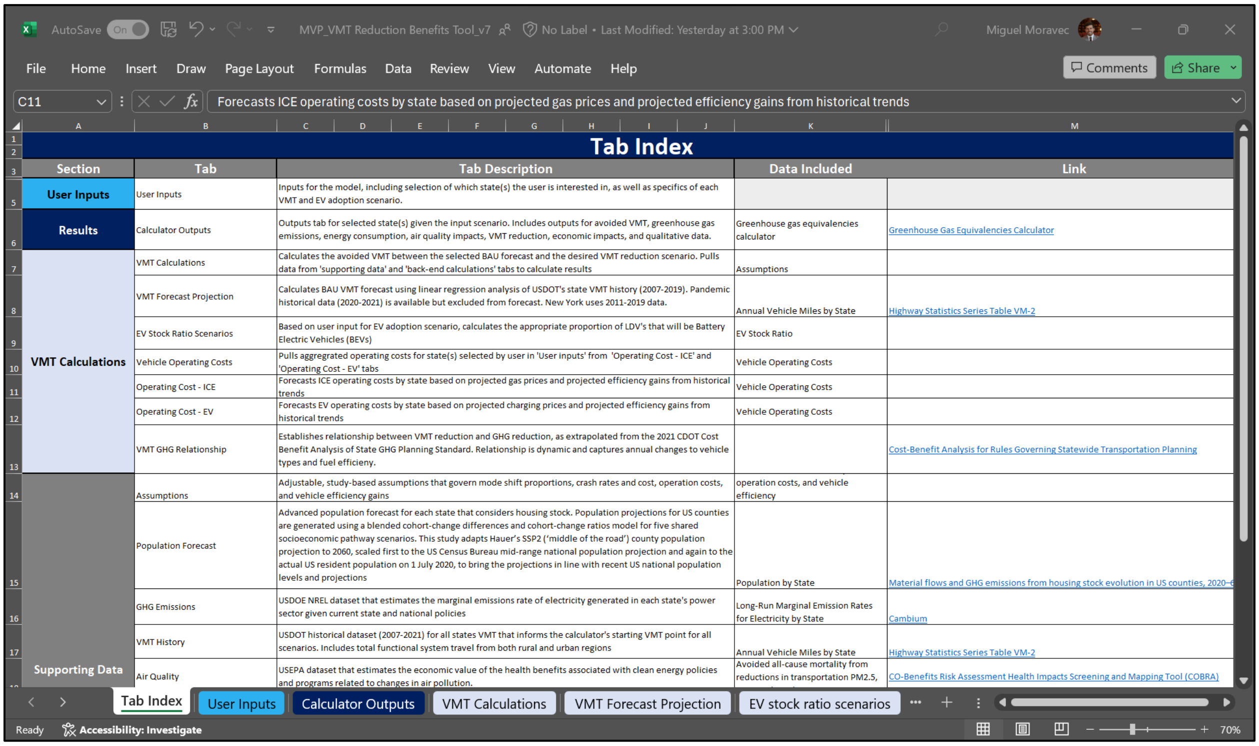
Once the user has designed their scenario using the desired inputs, the user should navigate to and click on the 'Summary Outputs' tab at the bottom of the page to view the executive Calculator results in 5 categories: Climate Impact, Household Savings, Road Safety, Public Health, and Energy Demand. The executive summary automatically contextualizes these findings with [US EPA greenhouse gas equivalencies]() where possible. **The user must scroll down to view the complete outputs from this section.** The 'Summary Outputs' tab should resemble the following image below:



For additional results from the calculator, the user should navigate to the 'Detailed Outputs' tab. This tab presents the same results from the summary tab and additional, more detailed values in a broader table. Generally, results are presented in both annual averages and cumulative scenario results form. Where possible, this section also automatically contextualizes the findings with [US EPA greenhouse gas equivalencies]().

Tab Index

The 'Tab Index' tab serves as a handy reference for advanced users to identify the location, description, and data behind the full set of tabs contained in the spreadsheet. In addition to the previously discussed 'User Inputs' and 'Calculator Outputs' tabs, the user is also able to read information about the 'VMT Calculations' and 'Supporting Data' set of tabs.



Tab Index

Section	Tab	Tab Description	Data Included	Link
User Inputs	User Inputs	Inputs for the model, including selection of which state(s) the user is interested in, as well as specifics of each VMT and EV adoption scenario.		
Results	Calculator Outputs	Outputs tab for selected state(s) given the input scenario. Includes outputs for avoided VMT, greenhouse gas emissions, energy consumption, air quality impacts, VMT reduction, economic impacts, and qualitative data.	Greenhouse gas equivalencies calculator	Greenhouse Gas Equivalencies Calculator
VMT Calculations	VMT Calculations	Calculates the avoided VMT between the selected BAU forecast and the desired VMT reduction scenario. Pulls data from 'supporting data' and 'back-end calculations' tabs to calculate results	Assumptions	
	VMT Forecast Projection	Calculates BAU VMT forecast using linear regression analysis of USDOT's state VMT history (2007-2019). Pandemic historical data (2020-2021) is available but excluded from forecast. New York uses 2011-2019 data.	Annual Vehicle Miles by State	Highway Statistics Series Table VM-2
	EV Stock Ratio Scenarios	Based on user input for EV adoption scenario, calculates the appropriate proportion of LDV's that will be Battery Electric Vehicles (BEVs)	EV Stock Ratio	
	Vehicle Operating Costs	Pulls aggregrated operating costs for state(s) selected by user in 'User inputs' from 'Operating Cost - ICE' and 'Operating Cost - EV' tabs	Vehicle Operating Costs	
	Operating Cost - ICE	Forecasts ICE operating costs by state based on projected gas prices and projected efficiency gains from historical trends	Vehicle Operating Costs	
	Operating Cost - EV	Forecasts EV operating costs by state based on projected charging prices and projected efficiency gains from historical trends	Vehicle Operating Costs	
	VMT GHG Relationship	Establishes relationship between VMT reduction and GHG reduction, as extrapolated from the 2021 CDOT Cost Benefit Analysis of State GHG Planning Standard. Relationship is dynamic and captures annual changes to vehicle types and fuel efficieny.		Cost-Benefit Analysis for Rules Governing Statewide Transportation Planning
Supporting Data	Assumptions	Adjustable, study-based assumptions that govern mode shift proportions, crash rates and cost, operation costs, and vehicle efficiency gains	operation costs, and vehicle efficiency	
	Population Forecast	Advanced population forecast for each state that considers housing stock. Population projections for US counties are generated using a blended cohort-change differences and cohort-change ratios model for five shared socioeconomic pathway scenarios. This study adapts Hauer's SSP2 ('middle of the road') county population projection to 2060, scaled first to the US Census Bureau mid-range national population projection and again to the actual US resident population on 1 July 2020, to bring the projections in line with recent US national population levels and projections	Population by State	Material flows and GHG emissions from housing stock evolution in US counties, 2020–
	GHG Emissions	USDOE NREL dataset that estimates the marginal emissions rate of electricity generated in each state's power sector given current state and national policies	Long-Run Marginal Emission Rates for Electricity by State	Cambium
	VMT History	USDOT historical dataset (2007-2021) for all states VMT that informs the calculator's starting VMT point for all scenarios. Includes total functional system travel from both rural and urban regions	Annual Vehicle Miles by State	Highway Statistics Series Table VM-2
	Air Quality	USEPA dataset that estimates the economic value of the health benefits associated with clean energy policies and programs related to changes in air pollution.	Avoided all-cause mortality from reductions in transportation PM2.5,	CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)

The 'Supporting Data' set of tabs contains state and country-specific data from open-source repositories, as described in the 'Tab Index'.

The 'VMT Calculations' set of tabs pull information from the 'Supporting Data' tabs and reformats and/or models it as described in the methodology and in the 'Tab Index'. The results of this modeling are available in the 'Calculator outputs' tab as discussed in the previous section.

For the Calculator to work as designed, users should not modify the 'Supporting Data' or 'VMT Calculations' set of tabs.

Saving and Exporting Results

The Calculator does not automatically save or export the outputs generated by user inputs. Thus, a user who wants to preserve the results of a given scenario can either:

1) Save the spreadsheet as a new file using the "save as" function in Excel, or
2) Manually transcribe the results to a new, separate Excel sheet, Word document, or other file.

In both cases, the user should consider naming the new file to represent the unique user inputs that generated the scenario.

In addition, the user can preserve the results of a given Calculator run by using the "print" function in Excel. When viewing either the 'Summary Outputs' or 'Detailed Outputs' tab, the user can press

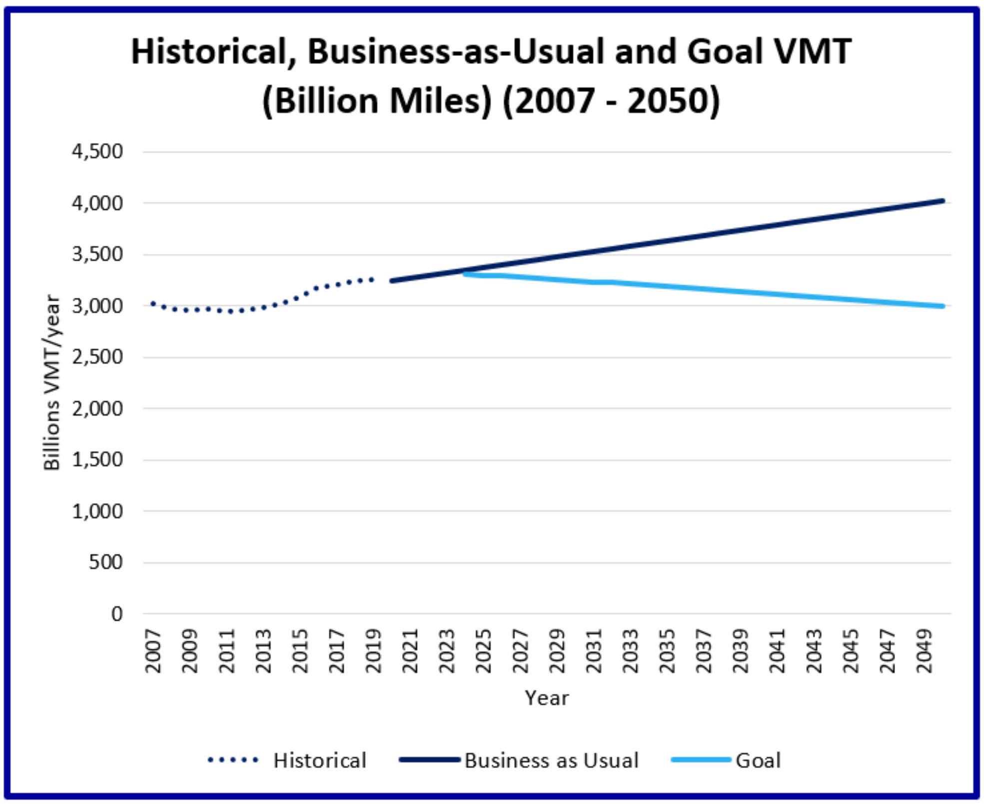
Methodology

The Calculator works by modeling the impacts of avoided automobile VMT between two scenarios that occur between the years 2020 and 2050:

1) a business-as-usual (BAU) VMT and LDV electrification case, and;

2) a user-defined VMT and LDV electrification case.

The two scenarios are represented by the diverging, solid lines in the plot below. The BAU case shows more VMT growth, while the user-defined case shows equal or less VMT growth.



The Calculator considers Federal Highway Administration (FHWA) historical state VMT data (represented by dotted line) and [RMI Energy Policy Simulator (EPS)] vehicle stock data to forecast the VMT and Electrification cases for both scenarios. The Calculator also uses state and national data to model the impacts of the avoided VMT.

The Calculator largely does not determine *how* automobile VMT is avoided, but rather captures the impacts of *if* the automobile VMT is avoided. The Calculator makes light assumptions about avoided VMT being shifted to walking and biking, but otherwise does not make additional assumptions about whether` avoided automobile VMT is shifted to other modes or avoided entirely through shorter or fewer trips.

VMT model

Business-as-Usual (BAU) Forecast

Historical VMT data is collected for all 50 states from a period that spans 2007 to 2019 from the US Department of Transportation (USDOT) Highway Statistics Series Table VM-2. Historical VMT data is truncated to exclude the COVID19 pandemic years of 2020-2021, which are considered outliers due disruptions in travel associated with the global pandemic. USDOT has not since published more recent Table VM-2 data. This historical data is analyzed using linear regression, and the resulting trend line is the basis of the BAU forecast of VMT growth for each state through 2050. The reliance on historical VMT trends to project future VMT may not capture potential changes in travel behavior or policy shifts.

In the national context, our regression model forecasts a 0.63% year-over-year increase in VMT for all motor vehicles in the ’50 State Combined Scenario.’ This is consistent with the latest official USDOT forecast, which states, “FHWA’s Spring 2023 long-term forecast of National Vehicle Miles of Traveled has total VMT increasing at an average annual rate of 0.6% between 2019 and 2049.” USDOT does not forecast individual state VMT.

Alternative approaches were considered but not implemented due to the complexity of these methods compared to the simple regression approach that could be applied to all 50 states with open-source data.

Similar cost-benefit analyses use state-specific Travel Demand Models (TDM’s) to forecast VMT growth. However, such tools are expensive to operate and not available uniformly across all 50 states.

Others use the Department of Energy’s (DOE) National Energy Modeling System (NEMS) national VMT forecasts and downscale the forecasts to states based on state population projections. The advantage of the regression analysis compared to this NEMS approach is that it is less contrived, as recent state population trends are captured in recent historical VMT trends. The disadvantage of the regression approach compared to downscaling NEMS data is that our regression approach assumes VMT from all vehicle types change at the same rate, while NEMS outputs specific forecasts for each vehicle type. Thus, this approach could exclude shifts in vehicle usage patterns, especially as policies change and urban landscapes evolve.

However, historical data from USDOT Table VM-1 suggests that LDV VMT has remained stable at approximately ~89% percent of total motor vehicle VMT for the most recent 14 years of VMT data is available. Thus, for the purposes of this analysis, we assume LDV VMT will remain ~89% of the total motor vehicle VMT, even as VMT reductions are accomplished.

Year	LDV VMT	All Motor Vehicle VMT	LDV Share of Total VMT
2021	2,768,999	3,132,411	88.40%
2020	2,572,988	2,903,622	88.61%
2019	2,924,053	3,261,772	89.65%
2018	2,897,083	3,240,327	89.41%
2017	2,877,378	3,212,347	89.57%
2016	2,849,718	3,174,408	89.77%
2015	2,779,693	3,095,373	89.80%
2014	2,710,556	3,025,656	89.59%
2013	2,677,730	2,988,280	89.61%
2012	2,664,060	2,969,433	89.72%
2011	2,650,458	2,950,402	89.83%
2010	2,648,456	2,967,266	89.26%
2009	2,633,248	2,956,764	89.06%
2008	2,630,213	2,976,528	88.37%
2007	2,691,034	3,031,124	88.78%

USDOT Table VM-1

As a final "gut-check," the outputs of the linear regression model were compared to State DOT VMT BAU forecasts where available. Many State DOTs do not publicly release State VMT forecasts, however our linear regression results were comparable to the forecasts of six of the seven State DOT's that we identified had recently published such forecasts.

The exception to this result was related to New York state. In its 2021 Clean Transportation Roadmap Report, NYSDOT projects VMT to grow between 0.77% to 1.29% per year across all motor vehicles between 2020 and 2050. However, linear regression of historical VMT data from New York from 2007 to 2019 suggests a negative trendline and therefore a decrease in VMT year over year through 2050. This discrepancy is in part due to a 2011 change in how NYSDOT calculates VMT, which abruptly modified historical VMT trends in New York. Thus, in the case of New York only, we truncate the training data for the linear regression model to only include VMT from 2011-2019.

Though the user may still choose to use the RMI linear regression model BAU forecast, in deference to State DOT's official projections, the Calculator automatically substitutes official State DOT forecasts for BAU VMT for the seven State DOT's who released such projections:

- California
- Colorado
- DC
- Maryland
- Massachusetts
- Minnesota
- New York
- Washington
-

Reduction

The VMT Reduction forecast is calculated from a 2019 baseline through 2050.

In the case that a user selects the "Total" reduction option on the 'User Inputs' tab, the Calculator calculates the 2050 goal VMT based on the user's selected reduction target of the 2019 value, then determines a linear year-over-year reduction rate that produces the appropriate outcome.

In the case that a user selects the "Per Capita" reduction option on the 'User Inputs' tab, the Calculator incorporates state population data into its calculation. This Calculator uses an [advanced population forecast]() that is based on US Census mid-range projections and available housing stock in each state's counties. Using this population data, 2019 VMT per capita is calculated. Then, the Calculator calculates the 2050 goal VMT per capita and resultant total VMT based on the state's projected 2050 population. Finally, the Calculator determines a linear year-over-year reduction rate to achieve the appropriate 2050 goal VMT.

In both cases, the user can confirm the final year-over-year reduction rate used by the Calculator for a given scenario in the 'VMT Calculations' tab under the 'VMT YoY Changes' section. This section resembles the image below, with the value of interest in the final row.

VMT YoY Changes	
If per capita reduction, use this math:	
2019 VMT per capita	9,899.63
2050 Goal reduced VMT per capit	7,919.71
2050 Goal VMT (if per capita)	3,050,935,299,582.58
Effective VMT Reduction by 2050	5.94%
YoY VMT % Change Per Capita	0.19%
If true reduction, use this math:	
YoY VMT % Change if Total	0.65%
2050 Goal VMT (if total)	2,594,962,617,341.49
Final YoY Value:	
This Scenario: YoY VMT%	0.19%

Avoided VMT

The annual 'avoided VMT' values are calculated by taking the annual difference between the BAU and Reduction VMT scenario forecasts. These values are the basis for many of the subsequent health, safety, cost, and energy consumption outcomes.

LDV fuel model

LDV fuel type forecasts were retrieved from RMI's Energy Policy Simulator (EPS) for 2020-2050. The EPS is an open-source model for estimating the environmental, economic, and human health impacts of hundreds of climate and energy policies, including EV-sales related policies and their effects on transportation vehicle stock by fuel type. EPS models are available for 48 states and the United States as a whole. For the two states that do not have a specific EPS model (Alaska and Hawaii), national vehicle stock trends are used.

Each state and national EPS model offers a 'BAU' scenario and an 'NDC Aligned' scenario of EV adoption and stock. The 'NDC Aligned' scenario represents ambitious decarbonization efforts that would achieve the 'Nationally Determined Contribution' of emissions reductions committed to by the United States as part of the Paris Agreement, such as adopting the 'Advanced Clean Cars II' policy. The 'BAU' scenario assumes significantly less EV adoption as a result of a policy environment that features less EV-related incentives, mandates, and subsidies. In addition to EV adoption and stock, each EPS scenario also projects the associated stock of Internal Combustion Engine (ICE) vehicles.

For each state, an annual ratio of EV to ICE LDVs is calculated given the EV adoption scenario the user selects in the 'User Inputs' tab. To represent that states may achieve EV adoption between BAU and NDC-alignment, additional mid-range scenarios are generated using the percentile feature of Excel, representing EV adoption that is 25%, 50%, and 75% of the NDC scenario compared to the BAU scenario.

While EPS also projects alternative and hybrid fuel LDV stock, for the purposes of this Calculator these fuel types are not considered in the EV/ICE ratio. According to DOE, the vast majority (86%) of hybrid LDV stock on the road today is non-plug-in hybrid, meaning that the onboard battery is charged primarily by the ICE engine. While this improves the fuel efficiency of the vehicle, the vehicle still produces tailpipe greenhouse gas emissions and incurs fuel charges at the pump rather than at home or at charging stations. The effect of hybrid vehicles on state ICE fuel efficiency is thus largely captured in state average fueling costs.

Future iterations of the Calculator may incorporate the fuel efficiency of alternative LDV fuels, including diesel. According to DOE, diesel LDV vehicles represent less than 1% of current LDV stock. Unlike EVs, the proportion of diesel LDV stock is not projected to change drastically according to EIA.

Operating cost model

A model is created to forecast annual average fuel and charging costs per mile by state. The model considers state data on 1) historical gasoline costs and 2) historical residential electricity rates to project future costs for these services if they were to continue following historical trends. Then, the model uses state data on contemporary LDV vehicle sizes (pickup truck, SUV, sedan, hatchback) and their respective fuel efficiencies to determine an average fuel and charging cost per mile in each state. The model also assumes that vehicle fuel efficiency improves based on projected efficiency gains for ICE and EV LDVs from the Bloomberg New Energy Finance terminal. The results of this modeling are available in the

'Vehicle Operating Costs' tab. Avoided costs associated with new power generation, grid expansion, and upgrade are not accounted for.

National maintenance costs per mile for both EV and ICE vehicles are retrieved from Kelly Blue Book. National depreciation costs per mile are retrieved from the American Automobile Association. Unlike fuel and electricity rates, which in this Calculator increase based on historically derived trends, maintenance and depreciation costs are assumed to increase with inflation from the contemporary value. See the 'Key Assumptions' section for more on assumed inflation.

The output annual fuel, charging, maintenance, and depreciation costs per mile from this model are applied to the 'avoided VMT' values to produce total estimated cost savings. US Census data on households is retrieved to determine cost savings per household per state.

This approach may underestimate cost savings due to its assumption that avoided VMT represents only reduced LDV fuel or charging costs. Medium Duty Vehicle (MDV) and Heavy Duty Vehicle (HDV) trips incur larger fuel/charging costs per mile than LDVs. USDOT projects that national truck (MDV and HDV) VMT will increase at 2 to 4 times the rate of LDV VMT across all economic scenarios over the next 20-30 years. However, this version of the calculator does not contain MDV and HDV fuel cost information.

Emissions model

The Calculator uses two unique and independent methods of calculating emissions reductions to verify the magnitude of expected climate pollution reduction benefit. The results from both methods are available in the 'Detailed Outputs' tab. In the 'Summary Outputs' tab, the results refer to output from Method 1.

Method 1: Fuel and Charging

Using the fuel efficiencies from the 'Operating cost model,' annual averages for 1) avoided gallons of gasoline consumed per mile and 2) electricity consumption per mile are calculated for each given state.

While the emissions associated with the consumption of a gallon of gasoline are held constant, the emissions from electricity consumption are dynamic and based on a state's changing electricity generation portfolio.

To address the unique emissions associated with the dynamic nature of state electricity generation, data is retrieved from the US DOE Cambium dataset. This dataset estimates the marginal emissions rate of electricity generated in each state's power sector given state and national policies as of 2022. For this model, we use the Cambium Emission intensities (kg/MWh) of the Mid Case Long-Run Marginal Emissions Rate scenario.

Since AK and HI were not included in Cambium's dataset, AK and HI emission intensity was determined using AKGD and HIOA eGRID 2019 data. From this data, it's estimated that Alaska's marginal emission rate would decrease by 60% by 2050 given the Cambium state average. For Hawaii, a 95% marginal emission rate reduction by 2050 is assumed given the state's current Renewable Portfolio Standard (RPS). Since DC was not included in Cambium's dataset, its marginal emissions rate is estimated by averaging the MD and VA Cambium data for each year. The absence of specific EPS models for Alaska and Hawaii and the use of national vehicle stock trends for these states may not accurately reflect their unique transportation profiles.

The values for the marginal emissions rate of electricity generated in each state's power sector are available in the 'GHG Emissions' tab.

The output gasoline and electricity consumption values per mile from this model are applied to the 'avoided VMT' values to produce total estimated avoided emissions in each state.

This approach may underestimate emissions savings due to its assumption that avoided VMT represents only reduced LDV energy consumption and associated emissions. Medium Duty Vehicle (MDV) and Heavy Duty Vehicle (HDV) trips consume more energy per mile than LDVs. USDOT projects that national truck (MDV and HDV) VMT will increase at 2 to 4 times the rate of LDV VMT across all economic scenarios over the next 20-30 years. This could be significant for states with large rural areas or extensive freight transportation. However, this version of the calculator does not contain MDV and HDV energy consumption information.

Method 2: VMT/GHG relationship from CDOT Analysis

To ground-truth and improve upon results from the Method 1 emissions model, a second methodology was developed based on data from a 2021 Cost-Benefit Analysis commissioned by the Colorado Department of Transportation.

This CDOT analysis estimated the net outcomes on GHG and VMT in Colorado if the state pursued a suite of expanded travel choice, transit, and land use strategies with the explicit goal of meeting a new GHG standard. These strategies were considered additional to Colorado's goal to adopt EVs in line with the Advanced Clean Cars II standard. The analysis of the impact of these policies was made possible in part due to the state's unique, activity-based travel demand model, which is inclusive of multimodal forms of transportation.

Tables A.11 and A.15, below, represent the net results of these strategies on state GHG emissions and VMT:

Table A.11
VMT by Year, Light-Duty Vehicles

	Vehicle-Miles of Travel (millions)		
Scenario	**2030**	**2040**	**2050**
Baseline VMT Estimate	63,551	71,069	78,587
Change from Baseline			
Proposed Rule Implementation: Travel Choices + Transit + Land Use	(6,943)	(8,378)	(9,814)
Alternative 1: Travel Choices	(5,876)	(6,197)	(6,146)
Alternative 2: Travel Choices + Transit	(6,633)	(7,593)	(8,138)

Table A.15
GHG Emissions Change from Baseline Forecast by Year

	GHG Emissions Change in Year (million metric tons)		
Scenario	2030	2040	2050
Proposed Rule Implementation: Travel Choices + Transit + Land Use	(1.70)	(1.20)	(0.70)
Alternative 1: Travel Choices	(1.43)	(0.88)	(0.44)
Alternative 2: Travel Choices + Transit	(1.62)	(1.09)	(0.59)

The method 2 model assumes that a state pursues the same travel choice, transit, and land use strategies that Colorado did, and that there is a dynamic relationship between VMT reduction and GHG reductions as a result of these strategies.

For the years provided in the analysis (2030, 2040, and 2050), the model calculates the relationship between each million miles of VMT decreased and each million metric tons of GHG decreased, as compared to the baseline scenario. The values for this relationship in intermittent years are calculated using extrapolation.

The output 'GHG per VMT' reduction values are applied to the 'avoided VMT' values to estimate net total avoided emissions in each state. As expected, this 'net' measure generates lower emissions outcomes than the alternative model from Method 1, which calculates only avoided fuel and energy consumption from LDVs and does not consider new energy consumption from other modes (transit, rail, etc).

This method may understate the benefits of VMT reduction for states with less EV adoption than Colorado (note that the benefit of VMT reduction decreases with time in Colorado due to aggressive electrification). In addition, the results from this method depend on states deploying a similar suite of strategies as Colorado to reduce emissions, which may or may not be possible.

Co-benefits

The methodologies for estimating congestion, safety and physical activity co-benefits draw from the Georgetown Climate Center's Transportation Investment Strategy Tool Documentation, prepared by Cambridge Systematics.

Air Quality

The air quality averted fatalities were calculated using data retrieved from the EPA's Co-Benefits Risk Assessment Health Impacts Screening and Mapping Calculator (COBRA) for the Energy Policy Simulator (EPS).

Avoided all-cause mortality from NO_x, and SO_2 in each state's transportation sector were normalized and assumed to be reduced in proportion to the share of 'avoided VMT' that comes from ICE vehicles, using the LDV model EV/ICE ratio.

Avoided all-cause mortality from $PM_{2.5}$ in each state's transportation sector was normalized and assumed to be reduced in proportion to the share of 'avoided VMT' that comes from *both* ICE and EV vehicles. This assumption was made due to research from the Organization for Economic Co-operation and Development (OECD) that suggests EVs emit approximately the same $PM_{2.5}$ as ICE vehicles as a result of non-exhaust pollution from tires.

The latest 2021 US DOT guidance for the statistical value of life is used to calculate savings from averted deaths.

Future versions of the Calculator may more directly model air quality benefits by calculating the avoided pollutants generated per avoided mile, rather than assuming air quality fatality outcomes improve in proportion to system VMT reductions. This would allow non-fatal health outcomes and damages, such as the occurrence of asthma, to be addressed.

Congestion

Roadway congestion leads to longer travel times for official business trips and freight movements, as well as longer personal errands and commuter trips, adversely affecting economic outcomes. National studies from the Texas Transportation Institute suggest that transit expansion and other mitigation measures that reduce VMT are associated with congestion relief and therefore time savings.

Based on this research, the Calculator retrieves the following relationship from the 2021 CDOT Cost Benefit Analysis, which values time savings at 0.015 hours per mile of vehicle travel reduced. This value represents a weighted average across Colorado metro area sizes and is conservative compared to national averages, which may value time savings as high as 0.02 hours of delay reduced per VMT reduced.

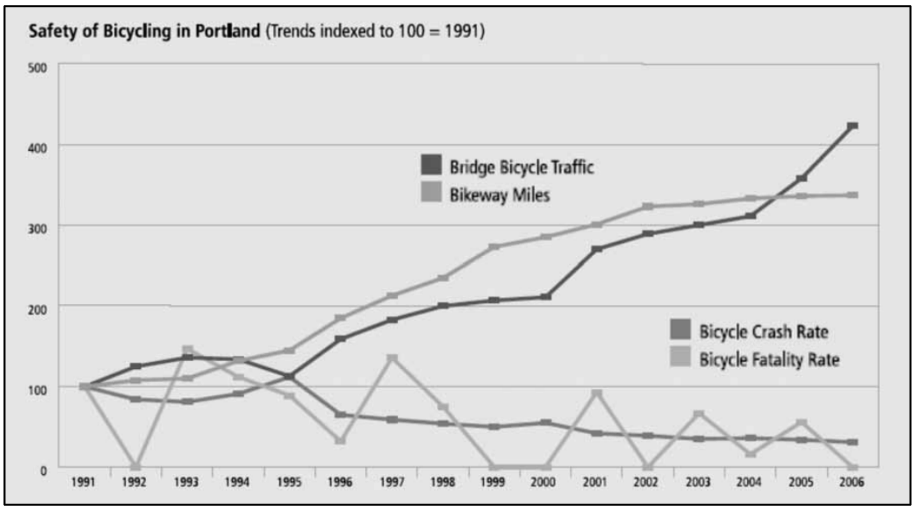
This value is applied to the 'avoided VMT' model output to estimate total congestion relief outcomes. Delay savings are valued at $16.50 per hour based on U.S. DOT 2021 Benefit-Cost Analysis Guidance.

Fuel and charging costs from avoided congestion relief are not calculated, as they are considered captured by the achievement of larger VMT reduction outcomes.

Safety

To estimate the cost savings from avoided automobile crash fatalities and injuries, crashes are assumed to be reduced in proportion to VMT reduction. Average million vehicle-mile crash rates are used from Fatality Analysis Reporting System (FARS) fatality data from 2000-2009 and injury rates reported by the Bureau of Transportation Statistics (BTS) in National Transportation Statistics (Table 2-17: "Motor Vehicle Safety Data"). The latest 2021 U.S. DOT guidance for the statistical value of life is used to monetize the cost of traffic fatalities, while injuries are valued using data from 2021 official Federal Transit Administration reporting templates.

Presumably, reduced light duty vehicle (LDV) VMT represents shorter trips, avoided trips, or trips shifted to other modes. For the purposes of this Calculator, fatalities associated with increased trips on other modes are considered marginal and are not examined. According to the National Safety Council, the US fatality rates on buses and trains are ten and seventeen times smaller, respectively, than the LDV fatality rate per *passenger* mile. Published research literature also describes a "safety in numbers" effect in which increases in biking and walking are associated with no change or decreases in the fatality rate per person mile traveled (PMT). For example, according to a study, the city of Portland saw a three-fold increase in biking PMT between 1991 and 2006. In the same time period, the number of bike-related fatalities and crashes decreased in total.



We therefore assume that state transportation systems would see neither an increase or decrease in pedestrian and bicyclist fatality events, although we acknowledge that this outcome would be most likely when mode shift is paired with increased investments in safety infrastructure.

Physical Inactivity

Active transportation health benefits are calculated based on two key assumptions. First, the Calculator assumes that for every 10 miles of reduced LDV VMT, 1 mile shifts to new biking PMT (person mile traveled) and 1 mile shifts to new walking PMT compared to BAU. Second, the Calculator uses the medium rate of avoided fatalities per PMT from biking and walking active transportation health benefits as measured in a 2020 Harvard study evaluating the impacts of mode shift in 12 US states.

These rates are applied to the 'Avoided VMT' model output, generating total annual avoided pre-mature fatalities. These averted fatalities are considered indirect and are *not* included in the direct monetized cost savings, since the magnitude of averted fatalities could be quite large but the impact is indirect and thus more uncertain than the other direct health benefits which are monetized.

Key Assumptions

Monetary Assumptions:

Annual inflation is assumed to occur at a rate of 3.20% per year. The inflation rate is applied to all values except refueling and charging costs, which are forecast to increase based on historical trends rather than inflation. A discount rate of 2.22% is applied to all cost savings.

Future versions of the calculator may apply unique inflation and discount rates to avoided fatalities to better align with federal guidance on the value of avoided fatalities.

Investments Assumption

The Calculator assumes that 'net-neutral' state investments into the transportation system can produce the desired reduced VMT reduction outcome. In other words, the Calculator assumes that the revenue needed to develop and maintain VMT-reducing infrastructure would be reprioritized from other planned projects that increase VMT and/or emissions in a manner that is incompatible with desired outcomes. This assumption was also used in the 2021 CDOT cost benefit analysis of its GHG standard, which found that the state would be able to meet its GHG target by gradually shifting up to 28% of its investment into transportation options that reduced VMT. A table of this investment shift is available below.

Table 1
Net Neutral Investment Levels and Dollars Shifted to Multimodal Transportation and other Environmentally Beneficial Transportation Investments
(net present value, millions of 2021 dollars)

Years	Total RTPs + 10-Year Plan	Total Shift to Mitigation	Percent Shift
2022-2025	$3,842.07	$417.90	11%
2026-2030	$4,802.59	$974.90	21%
2031-2040	$9,605.17	$2,655.80	28%

[1]

States that would similarly desire to achieve the reduction target in a net-neutral manner may need to evaluate the flexibility of their transportation revenue streams to fund different kinds of projects. Many federal program dollars can be flexed across programs and modes.

Acknowledgements

RMI would like to thank the following organizations for reviewing the calculator and providing valuable input and feedback:

- Ecology Center
- Georgetown Climate Center
- Institute for Transportation and Development Policy (ITDP)
- Move LA
- National Caucus of Environmental Legislators (NCEL)
- Natural Resources Defense Council (NRDC)
- NextGen Policy
- Rails to Trails Conservancy
- Sierra Club
- Southwest Energy Efficiency Project (SWEEP)
- Southern Environmental Law Center
- State Smart Transportation Initiative (SSTI)
- TransitCenter
- Transportation for America
- Union of Concerned Scientists (UCS)
- Victoria Transport Policy Institute

Disclaimer

RMI makes no guarantees or representations about the accuracy of this information. This calculator provides an estimate only. Use at your own risk and in your sole discretion and by its use you are acknowledging that RMI shall not be liable for any damages in connection with the use of this calculator. Please direct all questions or comments to mmoravec@rmi.org and jlombardi@rmi.org.