The Vermont Transportation Energy Profile

November 2019

VTrans Working to Get You There
Vermont Agency of Transportation

Acknowledgements

This VTrans report was prepared by Jonathan Dowds of the UVM Transportation Research Center. VTrans has commissioned the UVM Transportation Research Center to prepare the Vermont Transportation Energy Profile on a biennial basis since 2013.

Support from the Vermont Agency of Transportation and the Vermont Agency of Natural Resources was critical in accessing key data and information for this report.

Disclaimer

The Profile was developed and written as a collaborative project. The UVM Transportation Research Center is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the UVM Transportation Research Center or the Vermont Agency of Transportation. This Profile does not constitute a standard, specification, or regulation.

Table of Contents

List of Tables

List of Figures

Executive Summary

The transportation sector is responsible for 36% of the total energy consumed in Vermont (see Figure E-1), more than any other sector in the State. Petroleum-based fuels accounted for close to 95% of the total energy used in the transportation sector in Vermont in 2017. Transportation is also the largest source of greenhouse gas (GHG) emissions in the State, accounting for 43% GHGs in 2015.

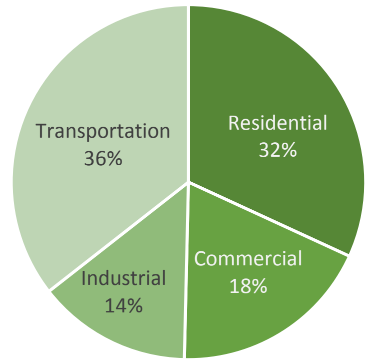


Figure E-1.Vermont Sectoral Energy Consumption, 2017 (U.S. EIA 2019)

Consequently, the 2016 Vermont Comprehensive Energy Plan (CEP) included three goals and nine supporting objectives related to reducing transportation sector energy consumption and greenhouse gas emissions (VDPS, 2016). The 2019 Vermont Transportation Energy Profile ("the Profile") is the fourth installment of a biennial reporting series that evaluates the State's progress toward achieving these transportation sector goals and objectives (together referred to as targets).

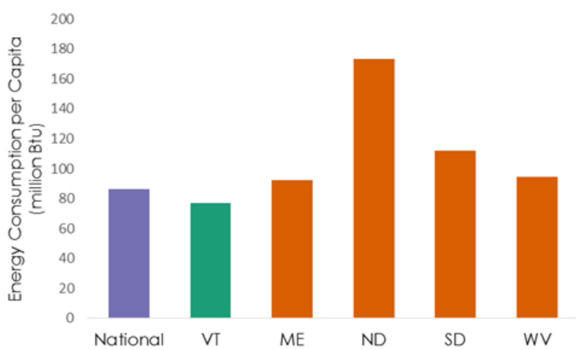


Figure E-2. Per Capita Transportation Sector Energy Consumption, 2017 (U.S. EIA 2019)

Vermont is one of 23 U.S. states that consumes more energy in the transportation than in any other sector (U.S. EIA, 2019). Nonetheless, as shown in Figure E-2, Vermont's per capita transportation sector energy use was below the national average in 2017 (77.2 vs 86.2 million Btus). In contrast, per capita levels seen in four rural comparison states, selected on the basis of similarities in population and development characteristics, all exceed the national average.

Near-term CEP transportation targets are presented in Table E-1. In order to assess the State's progress toward achieving these targets, the recent trend in each metric was extrapolated out to the target date and compared to the CEP goal for that date.[1] When the extrapolated value did not meet the CEP target, the State's progress was assessed as lagging behind the CEP target. For example, the CEP calls for the State to reduce transportation energy use from 49 trillion Btus to 39.2 trillion Btus by 2025. Extrapolating from the last five years of data, however, demonstrates that if

[1] Current trends are calculated based on the last five years of data using a least-squares, linear fitting process. This method finds the straight line that minimizes the sum of the squared residuals between the line and the empirical data points.

current trends continue transportation energy consumption will total 48.3 trillion Btus in 2025 and thus that energy reductions are currently lagging the CEP target.

For many of these metrics, progress toward achieving the CEP target is likely to lag in the early years due to the necessity of upfront investments and the slow pace of behavior change. Progress may be particularly slow for metrics related to the vehicle fleet since cars and trucks typically have a long operating life. Thus, cases where the State is currently lagging in achieving a particular goal or objective should not be taken to mean that the target cannot be achieved.

Table E-1. Current Progress toward Achieving CEP Transportation Targets

	2016 CEP Transportation Targets	Baseline		Most Recent		Target Value	Projected Value
		Value[1]	Year	Value	Year		
Goals for 2025	1. Reduce energy use by 20%	49	2015	48.2	2017	39.2	48.2
	2. Increase the share of renewable energy to 10%	5.5%	2015	5.9%	2017	10%	6.3%
	3. Reduce GHGs emissions by 30% from 1990 levels	3.22	1990	4.34	2015	2.25	6.01
Supporting Objectives for 2025 and 2030	1. Hold VMT/capita stable	11,390	2011	11,888	2017	11,390	14,008
	2. Reduce the share of SOV commute trips by 20%	79.5%	2011	81.4%	2017	64%	85%
	3. Increase the share of bicycle/ pedestrian commute trips to 15.6%	7.2%	2011	6.8%	2017	15.6%	6.4%
	4. Increase state park-and-rides spaces to 3,426	1,142	2011	1,639	2019	3,426	2,357
	5. Increase annual transit ridership to 8.7 million trips	4.58	2011	4.74	2018	8.7	4.01
	6. Increase annual Vermont-based passenger-rail trips to 400,000	91,942	2011	921,935	2018	400,00	41,198
	7. Double the rail-freight tonnage in the state	6.6	2011	7.3	2014	12.2	N/A[2]
	8. Increase electric vehicle registrations to 10% of fleet	0.0%	2011	0.5%	2018	10%	1.1%
	9. Increase renewably powered heavy-duty vehicles to 10% of fleet	Since diesel vehicles can run on conventional diesel and biodiesel, this objective cannot be tracked without tracking biodiesel fuel sales					

[1] Units: Goal 1 - trillion Btu; Goal 3 - MMTCO2e; Obj. 5 - millions of riders; Obj. 7 - millions of tons
[2] Estimation of 2014 rail-freight tonnage relies on 2011 baseline data. Additional, independent data points are required to project a trend in rail-freight tonnage.

Glossary of Selected Abbreviations

AEV: All-Electric Vehicle – Any vehicle powered solely by an electric motor. Also referred to as an electric vehicle or battery electric vehicle, AEV is used throughout the profile to avoid confusion with plug-in hybrid electric vehicle (PHEV). As of July 2019, the Nissan Leaf is the most common AEV in Vermont.

ACS: American Community Survey – An annual survey conducted by the U.S. Census Bureau that collects demographic, economic, housing, and social information, including information about commuting behavior and vehicle ownership.

CEP: Comprehensive Energy Plan – A statutorily mandated framework for implementing state energy policy produced by the Vermont Department of Public Service in conjunction with other agencies and stakeholders. The most recent CEP was completed in 2016.

CNG: Compressed Natural Gas – An alternative fuel currently used primarily in heavy-duty fleets in Vermont. Compressed natural gas is pressurized to reduce the volume that it occupies and increase its energy density. Most natural gas is extracted from finite underground reserves that are not renewable, but natural gas can also be produced renewably from organic materials including from landfill and agricultural waste. Conventional natural gas offers modest greenhouse gas benefits relative to gasoline and diesel while renewable natural gas offers greater benefits.

CO_2 and CO_{2e}: Carbon Dioxide and Carbon Dioxide Equivalent – CO_2 is a greenhouse gas. CO_2 emissions are the most significant transportation-sector contributor to climate change. CO_{2e} express the climate impacts of different greenhouse gases in terms of their climate impact relative to CO_2. It allows for the consistent comparison of different greenhouses in a manner that accounts for their differential impacts on climate change.

HEV: Hybrid Electric Vehicles – Any vehicle with both an internal combustion engine and an electric motor that *cannot* be plugged into an external source. HEVs have significant fuel efficiency advantages over conventional internal combustion engine vehicles.

ICEV: Internal Combustion Engine Vehicle – Any vehicle powered solely by the combustion of fuel in an engine. Also referred to as conventional vehicles or combustion vehicles, ICEVs can use a variety of liquid and gaseous fuels including gasoline, diesel, natural gas and biofuels.

GHG: Greenhouse gas – Any of several gases that contribute to climate change by trapping heat in the atmosphere. Carbon dioxide emissions from the combustion of fossil fuels are the largest contributor to climate change in the transportation sector.

LRTPS: Long Range Transportation Planning Survey – A survey commissioned by VTrans, conducted in 2016, to gather public opinion on transportation issues to inform updates to the State's Long-Range Transportation Plan.

LNG: Liquefied Natural Gas – An alternative fuel currently used exclusively in heavy-duty fleets in Vermont. Liquefied natural gas is cooled until it reaches a liquid state to reduce the volume that it occupies and increase its energy density. Most natural gas is extracted from finite underground reserves that are not renewable, but natural gas can also be produced renewably from organic materials including from landfill and agricultural waste. Conventional natural gas offers modest greenhouse gas benefits relative to gasoline and diesel while renewable natural gas offers greater benefits.

LCA: Life Cycle Assessment – A technique used to evaluate the environmental impacts of a product comprehensively, including the impacts related to producing, operating, and decommissioning the product.

MPG and MPGe: Miles per Gallon and Miles per Gallon Equivalent – MPG is the measure of the distance a vehicle can travel on a gallon of fuel. MPGe is the measure of the distance a vehicle can travel using the equivalent energy that is in a gallon of gasoline. MPGe is used to compare the fuel efficiency of vehicles that use different energy sources (e.g. gasoline and electricity).

PEV: Plug-in Electric Vehicle – Any vehicle with an electric motor that plugs into an external power source to charge. This includes plug-in hybrid electric vehicles (PHEVs), which use a combination of gasoline and electricity, and all-electric vehicles (AEVs), which use electricity exclusively.

PHEV: Plug-in Hybrid Electric Vehicle – Any vehicle with both an internal combustion engine and an electric motor that can be plugged into an external power source to charge.

NHTS: National Household Travel Survey – A national survey conducted on a periodic basis (generally every 6 – 8 years) by the U.S. Department of Transportation. The most recent NHTS was completed in 2017. Unlike the 2009 NHTS, the 2017 NHTS sample size in Vermont is not large enough to make state level estimates of travel behavior in Vermont. Data for New England are provided for the 2009 and 2017 NHTs for indications of trends that may be occurring in Vermont.

RFS: Renewable Fuel Standard – A regulatory mechanism that mandates sales of specific renewable fuels. The U.S. RFS was established in 2005 and updated in 2007 and mandates sales volumes for biomass-based diesel, cellulosic biofuel, advanced biofuel, and total renewable fuel.

SOV: Single Occupancy Vehicle – Any vehicle occupied only by the driver. SOV trips have lower energy efficiency per passenger mile than trips which include passengers. Reducing SOV trips is one strategy for reducing transportation sector energy consumption.

VMT: Vehicle Miles Traveled – The total on-road distance driven by all vehicles within a given jurisdiction. Reducing VMT is one strategy for reducing transportation sector energy consumption.

"To measure is to know. If you cannot measure it, you cannot improve it."

—Lord Kelvin

1 Introduction

The transportation sector is vital to the physical, social, and economic well-being of Vermonters, but it is also responsible for 36% of the total energy consumed in the State (U.S. EIA, 2019) and 43% of total greenhouse gas (GHG) emissions (VT ANR, 2018), both the highest of any sector. The 2019 Vermont Transportation Energy Profile ("the Profile"), the fourth edition of this biennial reporting series, documents a wide range of data and trends related to transportation energy consumption and GHG emissions. The Profile is intended to inform transportation-related policymaking generally and to directly track the State's progress toward achieving the transportation-sector goals and objectives articulated in the State's Comprehensive Energy Plan (CEP).

The 2016 CEP was a multi-agency effort led by the Vermont Public Service Department that provides a framework for achieving the State's vision of an efficient, reliable, and heavily renewable energy future. Near-term goals in the 2016 CEP include reducing per-capita energy consumption by 15% by 2025, meeting 25% of the State's remaining 2025 energy needs with renewable sources, and reducing GHG emissions by 40% by 2030.[2] To support these economy-wide goals, the CEP quantified three specific goals for the transportation sector:

1. Reduce total transportation energy use by 20% from 2015 levels by 2025;
2. Increase the share of renewable energy in all transportation to 10% by 2025 and 80% by 2050;
3. Reduce transportation-emitted GHGs by 30% from 1990 levels by 2025.

The CEP also provided 9 supporting objectives for these goals. As shown in Table 1-1, these objectives relate to controlling the increase in vehicle miles traveled (VMT)—an estimate of the total on-road distance driven by all vehicles in Vermont,

2016 CEP STRATEGIES FOR TRANSPORTATION

Light-Duty Vehicles

- Increase the fuel efficiency of light-duty vehicles registered in Vermont.
- Increase registrations of electric vehicles in Vermont to 10% by 2025 by promoting consumer awareness, incentivizing purchase, and deploying charging infrastructure.

Heavy-Duty Vehicles

- Increase the fuel efficiency of heavy-duty vehicles registered in Vermont.
- Increase the use of renewable fuels such as advanced liquid or gaseous biofuels.

Travel Modes

- Provide more efficient alternatives to single-occupancy vehicle trips.
- Promote transit, walking, biking, carpooling, and teleworking.

Smart Land Use

- Maintain historical settlement patterns, emphasizing compact centers.

[2] Per capita energy reduction goals are relative to a 2015 baseline while GHG emissions reductions goals are relative to a 1990 baseline.

increasing the percent of trips taken using lower-energy-intensity travel modes such as walking and public transit, and increasing renewable fuel usage for vehicle trips.

Table 1-1. 2016 CEP Supporting Transportation Objectives

Control Vehicle Miles Traveled:

1. Hold per capita VMT to 2011 levels.

Increase the Share of Travel Modes with Lower Energy Intensities:

2. Reduce the share of SOV commute trips by 20%.
3. Double the share of bicycle and pedestrian commute trips to 15.6%.
4. Triple the number of state park-and-ride spaces to 3,426.
5. Increase public transit ridership by 110% to 8.7 million trips annually.
6. Quadruple Vermont-based passenger-rail trips to 400,000 trips annually.
7. Double the rail-freight tonnage in the state.

Increase Renewable Fuel Usage:

8. Increase the number of electric vehicles registered in Vermont to 10% of the fleet by 2025.[3]
9. Increase the number of heavy-duty vehicles that are renewably powered to 10% by 2025.

Note: All objectives are for 2030 and relative to a 2011 baseline except where indicated otherwise.

As articulated in the CEP, achieving the goals of reducing transportation energy use and GHG emissions while also increasing renewable energy use in the transportation sector will require a multifaceted approach that reduces VMT, improves fuel economy, and reduces GHG emissions per mile traveled. Currently, none of the eight objectives that can be assessed quantitatively (all but Objective 9) are on pace to achieve the CEP targets. Additional policy initiatives that accelerate mode shifts and vehicle electrification may be needed to succeed in meeting the vision put forth in the 2016 CEP.

Sections 2 through 6 of the Profile provide the data needed to evaluate the CEP transportation objectives in a broader transportation context. Progress toward achieving each of the three goals and nine supporting objectives are evaluated in Section 7. Overall conclusions are provided in Section 9.

1.1 Vermont in Context

In order to provide context for the data outlined in this Profile, national data are provided alongside Vermont data whenever possible. In addition, since transportation demand is closely tied to development patterns, Vermont data are juxtaposed with four comparison states: Maine, North Dakota, South Dakota, and West Virginia. These four states, shown in Figure 1-1, were selected based on similarities in terms of (1) the proportion of each state that is rural versus urban, (2) residential density distribution, (3) household size distribution, (4) the distribution of the number of workers in each household, and (5) overall population. In addition, potential comparison states were limited to states that experience significant winter weather and its associated impact on travel. The same set of

[3] Throughout the Profile, "the fleet" is assumed to refer to all on-road vehicles registered in Vermont unless specifically indicated otherwise. Thus, achieving this objective would require that the number of electric vehicles registered in Vermont equal 10% of all on-road vehicle registrations by 2025.

comparison states have been used since the 2015 edition of the Profile to provide a consistent basis for comparison.

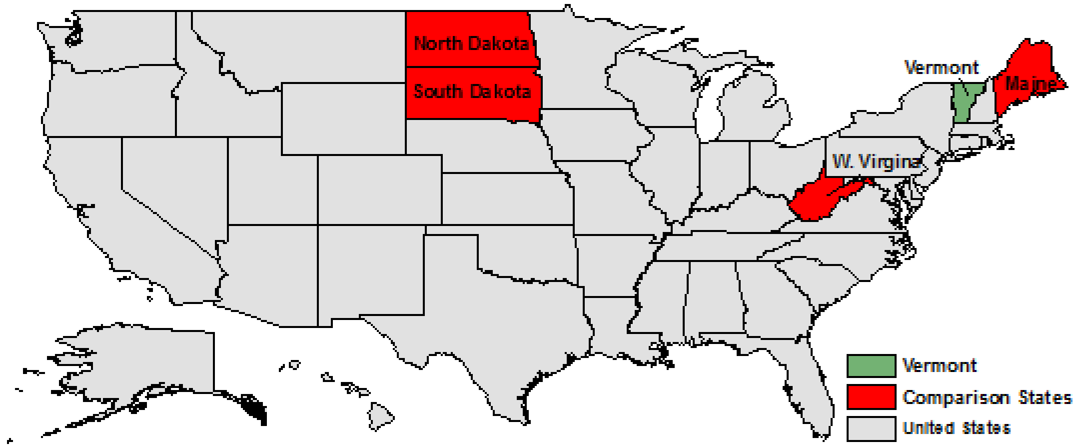


Figure 1-1. Vermont and Comparison States

1.2 Data Sets Used in the Energy Profile

This report draws on a variety of data sets to illustrate trends in Vermonters' travel behavior, vehicle fleet composition, and fuel sources that are relevant to CEP metrics and broader transportation policy-making initiatives. These data sources are expected to be available at regular intervals in the future. They include but are not limited to:

- American Community Survey (ACS), U.S. Census Bureau
  - Data Collection Cycle: Annual
  - Most Recent Data Available: 2017
- Highway Statistics Series, Federal Highway Administration (FHWA)
  - Data Collection Cycle: Annual
  - Most Recent Data Available: 2017
- National Household Travel Survey (NHTS)
  - Data Collection Cycle: Six- to eight-years
  - Most Recent Data Available: 2017
- State Energy Data System, U.S. Energy Information Administration (EIA)
  - Data Collection Cycle: Annual
  - Most Recent Data Available: 2017
- Vermont Department of Motor Vehicles (VDMV) licensing/vehicle registration
  - Data Collection Cycle: Annual
  - Most Recent Data Available: 2018
- Vermont Greenhouse Gas Emissions Inventory, Agency of Natural Resources
  - Data Collection Cycle: Annual
  - Most Recent Data Available :2015

- Vermont Legislative Joint Fiscal Office (JFO) gasoline/diesel sales
  - Data Collection Cycle: Monthly
  - Most Recent Data Available: 2019

- VTrans Public Transit Route Performance Reviews
  - Data Collection Cycle: Annual
  - Most Recent Data Available: State Fiscal Year (SFY) 2018

The NHTS is the single most comprehensive source of U.S. travel behavior data. The survey includes a travel diary, where all members of a participating household log their travel on a specified study day. The information collected in the diary includes information on travel mode (household vehicle, transit, bicycle, etc.), trip purpose, and number of travelers for each reported trip. Because of this, the NHTS can be used to calculate mode share, vehicle occupancy, travel patterns, rates of biking and walking, and many other variables. For the 2009 NHTS, VTrans, the Chittenden County Regional Planning Committee (CCRPC), and the University of Vermont purchased an "add-on" sample which over-sampled Vermonters relative to the national population, enabling variables to be calculated at the state level.

Due to rising costs, the State did not opt to purchase an add-on for the 2017 NHTS. Consequently, the 2017 NHTS sample size in Vermont is not large enough to make state-level estimates of travel behavior in Vermont. Data for New England are provided for the 2009 and 2017 NHTS for indications of trends that may be occurring in Vermont. While not required to track the 2016 CEP targets, the NHTS has provided a great deal of context for this Profile and transportation decision-makers. VTrans is exploring other options for collecting the data that may be incorporated into future editions of the Profile (Aultman-Hall and Dowds, 2017).

.

2 Vermonters' Travel Behavior

Individuals' travel behaviors (where, how, and how often they travel) are a key determinant of the total energy and specific fuels consumed by the transportation sector. Travel behavior in Vermont is heavily influenced by the State's rural and village-based land-use patterns. Automobile usage is the dominant mode of travel, accounting for approximately 90% of all commute trips in the State. Per capita VMT in Vermont is above the national average and has increased by 5% since 2014, though it is below its 2007 peak.

2.1 Vehicle Miles Traveled

Total annual VMT is an estimate of the total mileage driven by all vehicles on a given road network. VMT is an important metric that is used in several capacities: in highway planning and management, to estimate fuel consumption and mobile-source emissions, to project potential gasoline tax revenues, and as a proxy for economic activity. Total VMT is influenced by how far and how frequently people drive and by vehicle occupancy rates.

After climbing steadily through the mid-2000s, VMT declined for several years at both the state and national levels beginning in 2008 (see Table 2-1 and Figure 2-1). At the national level, total VMT has risen since 2011 and per capita VMT has risen since 2013. In Vermont, total and per capita VMT hit their lowest levels in 2014 and both increased in the period from 2015 through 2017. These increases in VMT have been linked to increased economic activity and lower gasoline prices (McCahill, 2017) and are discussed more in Section 2.1.1. Demographic trends and changing travel preferences, particularly among teens and young adults, may mitigate future VMT growth. Drivers age 65 and older, a growing proportion of the Vermont population, drive considerably less than drivers between the ages of 20 and 64 (FHWA, 2015). In addition, teens and young adults are traveling less than their counterparts in previous generations did (Blumenberg et al., 2013). Rates of licensure and the use of car-sharing and ride-hailing service may also impact VMT and are discussed in Sections 2.1.2 and 2.1.3.

VEHICLE MILES TRAVELED (VMT)

Definition: Annual VMT is an estimate of the total miles driven by all vehicles on a road network. VMT can provide insight into transportation energy use, emissions, and economic activity.

Trends: Vermont's total and per capita VMT fell between 2007 and 2014 but increased since then. A similar pattern is apparent at the national level. Vermont's per capita VMT remains higher than the national and rural comparison state averages.

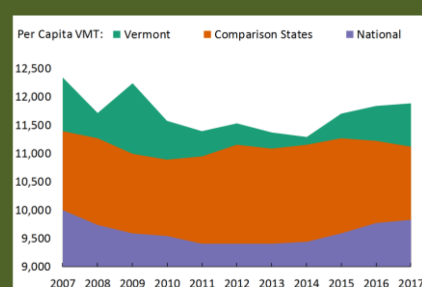


Figure 2-1. Trends in Per Capita VMT (FHWA, 2008–2018)

Driving Factors: The upward movement in VMT likely reflects improved economic conditions and lower gas prices.

Table 2-1. Total and Per Capita VMT, 2007–2017

Year	Total VMT (Millions)			VMT/Capita		
	Vermont	Comparison States	National	Vermont	Comparison States	National
2007	7.69	52.45	3,050	12,340	11,388	10,001
2008	7.31	52.14	2,996	11,715	11,267	9,731
2009	7.65	51.09	2,976	12,237	10,988	9,584
2010	7.25	50.88	2,985	11,580	10,889	9,536
2011	7.14	51.34	2,965	11,390	10,941	9,404
2012	7.22	52.62	2,987	11,525	11,150	9,409
2013	7.12	52.58	3,007	11,363	11,078	9,407
2014	7.06	53.16	3,040	11,291	11,151	9,444
2015	7.31	53.82	3,110	11,698	11,262	9,592
2016	7.38	53.62	3,189	11,837	11,219	9,768
2017	7.42	53.17	3,227	11,888	11,122	9,825

Source: FHWA, 2008 - 2018

Since 2014, total and per capita VMT in Vermont increased by 5.2% and 5.3%, respectively. Over this same time period, at the national level, total VMT increased by 6.2% and per capita VMT by 4%. In the four comparison states (ME, ND, SD, and WV), total VMT did not increase and per capita VMT decreased by 0.3%. Vermont's per capita VMT remained higher than the national average, and higher than the per capita VMT in every rural comparison state other than North Dakota, as shown in Figure 2-2. Overall, Vermont ranked 13th highest among all states in terms of per capita VMT in 2017, the most recent year for which national VMT data are available. As reported in the two previous editions of the Profile, Vermont ranked 10th in per capita VMT in 2011 and 2013 and 11th in 2015.

Vermont's comparatively high per capita VMT is influenced by the state's rural character. Sparse development patterns result in longer distances between residences, work, school, and shopping locations, requiring longer trips to meet residents' needs. Research suggests that compact development can reduce VMT, though the magnitude of the impact is a subject of on-going debate (Stevens, 2017; Nelson, 2017). The CEP identifies development of compact centers as a strategy for reducing VMT, supporting affordable housing and encouraging active lifestyles.

Since VMT estimates are made based on traffic counts, travel by out of state drivers contributes to total VMT. Vermont has a relatively high proportion of tourism and pass-through traffic originating out of state. An analysis by the Vermont Agency of Commerce and Community Development of credit card receipt data provided by VisaVue calculated that close to 25% of gasoline sales paid for with a Visa card were made by accounts tied to an out of state "home" location as determined by VisaVue (Jones, 2019). While these data do not include cash sales or sales with other cards, they may be indicative of the overall magnitude of traffic originating out of state.

Vermont's predominantly rural land use is reflected in the proportion of the State's total roadway miles in rural and urban areas, 89.5% and 10.5%, respectively (see Table 2-2). VMT on urban roads accounts for close to 30% of total VMT, more than 2.5 times the share of urban road miles.

Table 2-2. Vermont VMT by Road Class, 2017

	Urban/ Rural	Total Roadway Miles	% of Total	VMT (Millions)	% of Total
Interstate	Rural	255.97	1.8%	1,251	16.9%
	Urban	64.31	0.5%	571	7.7%
Arterial/Major Collector	Rural	3,038	21.3%	2,881	38.8%
	Urban	538	3.8%	1,229	16.6%
Minor Collector/Local	Rural	9,460	66.4%	1,148	15.5%
	Urban	899.46	6.3%	344	4.6%
Totals	Rural	12,753	89.5%	5,280	71.1%
	Urban	1,501	10.5%	2,144	28.9%
	Combined	14,255	100.0%	7,424	100.0%

Source: FHWA, 2018

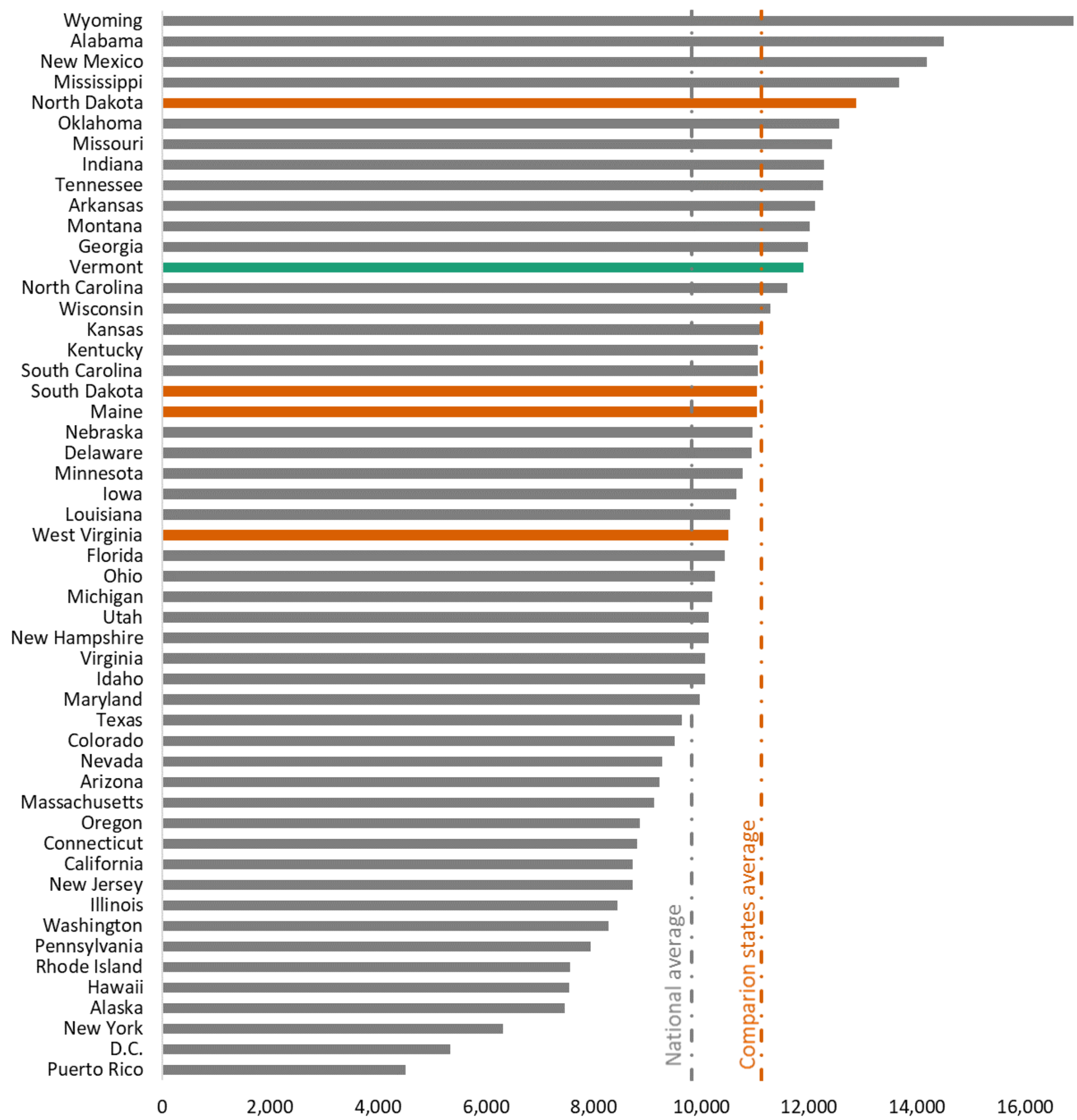


Figure 2-2. 2017 Per Capita VMT for U.S. States (FHWA, 2018; USCB, 2018)

2.1.1 Economic Context

VMT is influenced by both overall economic conditions and fuel prices. Historically, VMT has tracked closely with GPD. GDP is generally assumed to drive VMT since periods of high economic activity lead to greater work-related travel, and higher levels of discretionary income support more leisure travel, but it has been suggested that policies to reduce VMT could lead to a decrease in GDP. However, recent research suggests that reducing VMT is unlikely to cause a decline in economic activity (McMullen and Eckstein, 2012). At the national level, both GDP and VMT grew at the same 3.5% annual rate from 1960 through 1997 but GDP has increased more rapidly than VMT at the national level since that period (EERE, 2018). Figure 2-3 shows changes in Vermont GDP and VMT for 2000 through 2017 relative to a

2000 baseline. As at the national level, GDP has grown faster than VMT over the last decade.

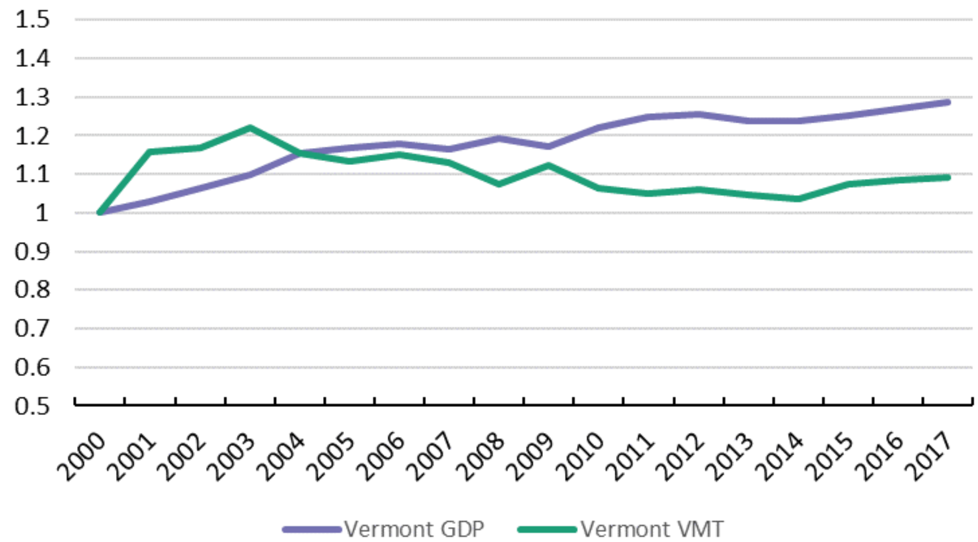


Figure 2-3. Vermont GDP and VMT relative to 2000 baseline, (U.S. BEA, 2019; FHWA, 2018).

VMT and fuel prices tend to be inversely correlated as lower fuel prices make travel less expensive. In the short term, however, travel demand is relatively inelastic, meaning that even relatively large changes in fuel prices result in relatively small changes in VMT (U.S. EIA, 2014). Figure 2-4 shows the national average annual gasoline price in constant dollars.

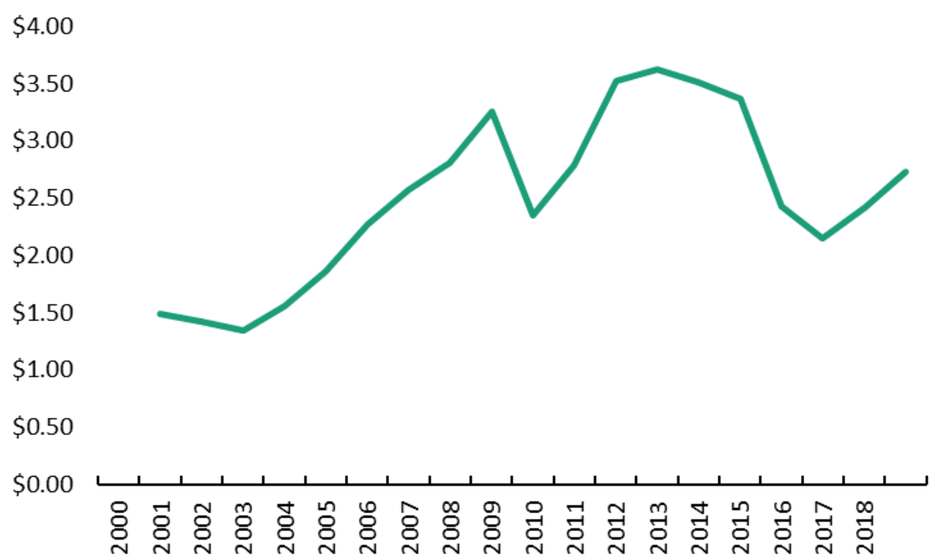


Figure 2-4. National Average Gas Price in 2019 dollars (U.S. EIA, 2019b)

2.1.2 Licensure

One factor that can influence VMT is the proportion of the population that is licensed to drive. The number of Vermonters with driver's licenses and learner's permits from 2010 through 2018 is shown in Table 2-3. The per capita licensure rate is at its highest level in since 2010.

Table 2-3. Driver's Licenses and Leaners Permits in Vermont, 2010–2018

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Driver's Licenses	513,481	521,666	541,462	546,573	533,742	551,622	557,287	585,667	591,344
Permits	17,768	18,661	19,943	20,731	19,457	20,764	21,230	21,764	22,724
Licenses /Capita	0.82	0.83	0.86	0.87	0.85	0.88	0.89	0.94	0.94

Sources: Fassett, 2019; USCB, 2018

Vermont's rate of licensure per capita is higher than the national average and higher than licensure rates in any of the four rural comparison states. In part, this reflects the state's demographics, as the percentage of the population that is over 16 is higher in Vermont than in any of the comparison states (FHWA, 2018).

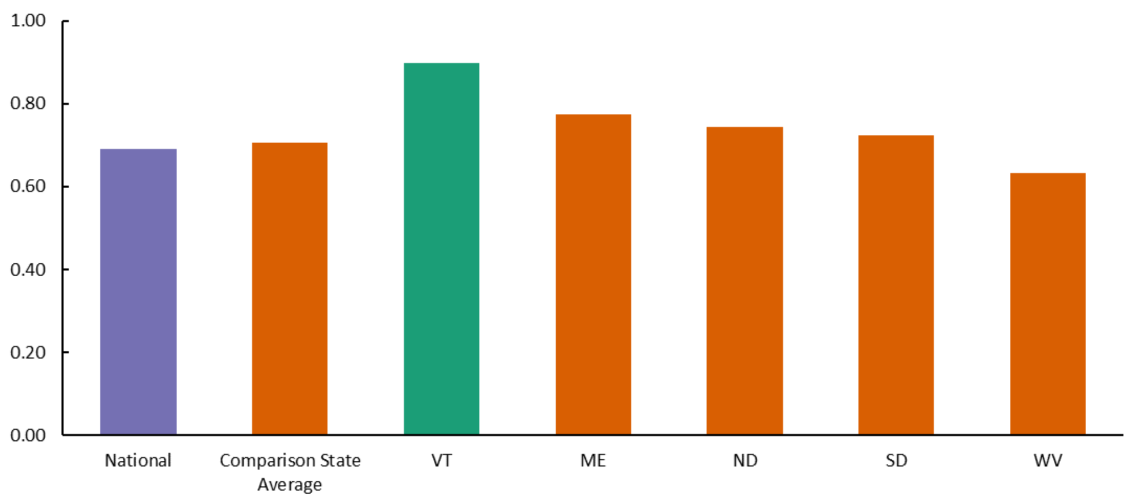


Figure 2-5. Per Capita Licensure, 2017 (FHWA, 2018; USCB, 2018)

2.1.3 Car-Sharing and Ride-Hailing Services

Vehicle-sharing organizations provide an alternative to personal vehicle ownership by allowing members to access and utilize vehicles on an as-needed (and usually short-term) basis. The net impact of car sharing on VMT is not yet known (Lovejoy et al., 2013). Researchers have alternatively suggested either that car sharing may increase VMT by giving non-car-owners access to a vehicle, or that it may decrease VMT by reducing overall car ownership rates. Several recent studies suggest that car sharing programs reduce overall car ownership rates, especially in urban areas (Martin, Shaheen, and Lidicker 2010; Clewlow 2016), and also produce a net decrease in VMT and GHG emissions (Shaheen and Cohen 2013), though the extent to which these impacts relate to self-selection among car share members has not yet been determined (Clewlow 2016). Two car-sharing services operate in Vermont. CarShare Vermont, a local non-profit which has vehicle locations throughout Burlington (CarShareVT.org), and ZipCar, a national for-profit car-sharing outfit, which has locations at Middlebury College and Norwich University (www.zipcar.com/cities). Person-to-person (P2P) car-sharing services, such as Turo, provide web-based options to search for privately owned vehicles available for hourly or daily rental. Early research on P2P car-sharing has shown a modest reduction in driving by a subset of P2P participants (Dill et. al, 2019).

Ride-hailing services allow users to arrange for rides in private vehicles through app and web-based interfaces. Ride-hailing services such as Uber and Lyft have grown rapidly in recent years and are now available in Vermont. As with car-sharing, ride-hailing can reduce the need for car ownership but may also reduce transit and walk/bike trips with vehicle trips. Preliminary research on the impact of ride-hailing on VMT suggest that these services are likely to contribute to an increase in VMT (Clewlow and Mishra, 2017).

2.2 Mode Share

VERMONT MODE SHARE

Definition: Mode share measures how people travel from location to location—that is, the proportion of trips that are made by private vehicle, public transit, active transport, or other means. Mode share is important for determining the overall energy efficiency of travel. Some modes, such as walking or taking a bus with high ridership, are considerably more energy efficient than others, notably SOV trips.

Status: The overwhelming majority of trips in Vermont, nearly 85%, are taken in passenger vehicles. However, Vermont's SOV commute rate is below that of the comparison states, reflecting higher rates of biking and walking by Vermont commuters than by commuters in ME, ND, SD, and WV. Since 2009, SOV commute mode share in Vermont has increased by 2.1% and carpooling has declined by 1.9%. Transit, walking, and biking commute mode shares have remained relatively stable in Vermont over this period.

Mode share refers to the proportion of all trips taken with a specific mode (e.g. private automobile, transit, or active transportation). It is commonly measured using travel surveys such as the NHTS. As shown in Figure 2-6, motorized modes, (cars, SUVs, trucks, and vans), were the dominant mode of travel reported in Vermont and New England in the 2009 NHTS. According to these data, cars, SUVs, trucks, and vans accounted for nearly 85% of all Vermonters' trips and nearly 82% of trips across New England. Notably, nearly half of these Vermont vehicle trips take place in larger, generally less energy-efficient vehicles—SUVs, light trucks, and vans. Active transportation—walking and biking—accounted for 12% of all Vermont trips in the 2009 NHTS data set. The share of trips taken using motorized modes dropped to 78% for New England in the 2017 NHTS but this change may in part reflect methodological changes in the NHTS rather than changes in travel behavior (McGucking and Fucci, 2018). State-specific data is not available in the 2017 NHTS.

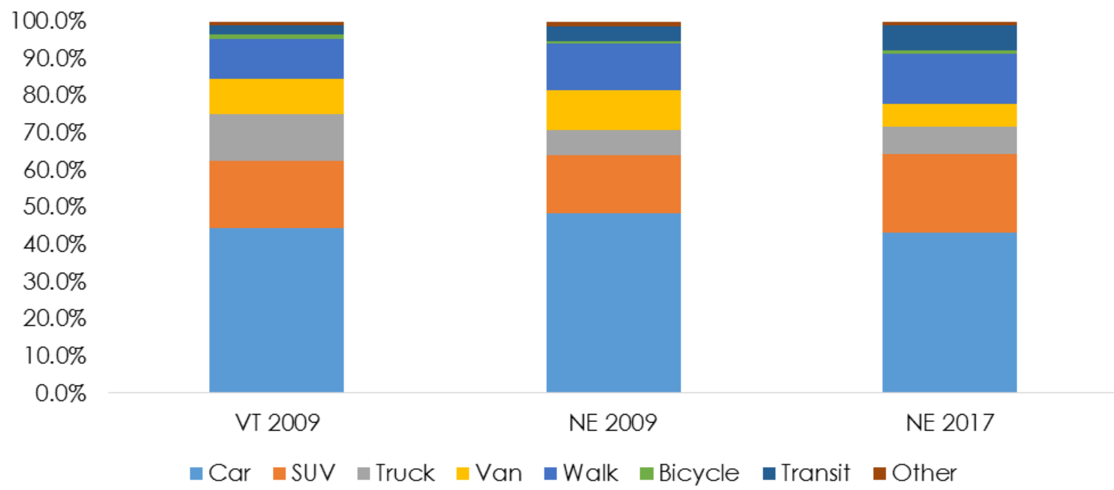


Figure 2-6 Mode Share in Vermont and New England (USDOT 2010; USDOT 2017)

In addition to the NHTS, mode share data for commute trips have been collected in the ACS and in the VTrans LRTPS (RSG, 2016). Mode share for commuting trips is discussed in Section 2.2.1.

2.2.1 Mode Shares for Commuter Travel

The ACS collects mode data for commute trips on an annual basis and reports these data in one-year and five-year estimates. Since single-year ACS estimates have a relatively small sample size, five-year estimates, which have a smaller margin of error, are used for comparing Vermonters' mode share with comparison states and national mode shares.[4] From 2009 through 2017, SOV commute mode share in Vermont increased from 79.3% to 81.4%. Over this same time period the carpooling mode share declined from 11.4% to 9.5% while shares for other non-SOV commute modes have remained relatively stable, as shown in Figure 2-7 and Table 2-4.

For comparison purposes, the 2016 LRTPS reported SOV as the primary mode for 83% of commuters with only 6% of commuters carpooling/traveling as a passenger in

[4] The 2015 Profile used three-year ACS estimates, but these estimates are no longer produced by the ACS.

a private vehicle. The primary commute mode shares for transit, walking, and biking were 3%, 4%, and 2%, respectively (RSG, 2016).

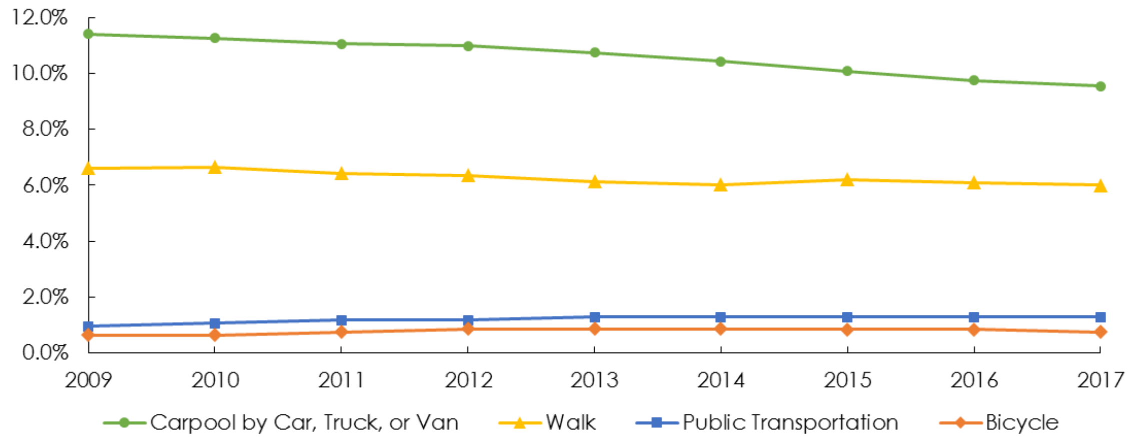


Figure 2-7. Mode Share for Non-SOV Vermont Commuters, 2009–2017 (ACS, 2011-2019)

Table 2-4. Comparison of Commuter Mode Share (%) for Vermonters, 2009 – 2017

	ACS (5-Year Estimates)								
Commuting Modes	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Drove Alone	79.3%	79.4%	79.5%	79.7%	80.1%	80.5%	80.7%	81.0%	81.4%
Carpool	11.4%	11.3%	11.1%	11.0%	10.8%	10.4%	10.1%	9.8%	9.5%
Walk	6.6%	6.6%	6.4%	6.4%	6.1%	6.0%	6.2%	6.1%	6.0%
Public Transportation	1.0%	1.1%	1.2%	1.2%	1.3%	1.3%	1.3%	1.3%	1.3%
Bicycle	0.6%	0.6%	0.8%	0.9%	0.9%	0.9%	0.9%	0.9%	0.8%
Other	1.1%	1.0%	1.1%	1.0%	0.9%	0.9%	0.9%	1.0%	1.0%

Source: ACS, 2011-2019

Using the five-year ACS estimates, the proportion of Vermonters who commuted by SOV, 81.4%, is slightly higher than the national average, 80.3%, but lower than all four of the comparison states, which had SOV commute rates ranging from 83.3% to 85%, as shown in Figure 2-8. As would be expected given the State's rural nature, Vermonters use public transit less frequently than the national average. Vermonters carpooled at a similar rate to residents of the comparison states but commuted by walking or biking at a considerably higher rate, 6.8%, than the national average or than in any of the comparison states.

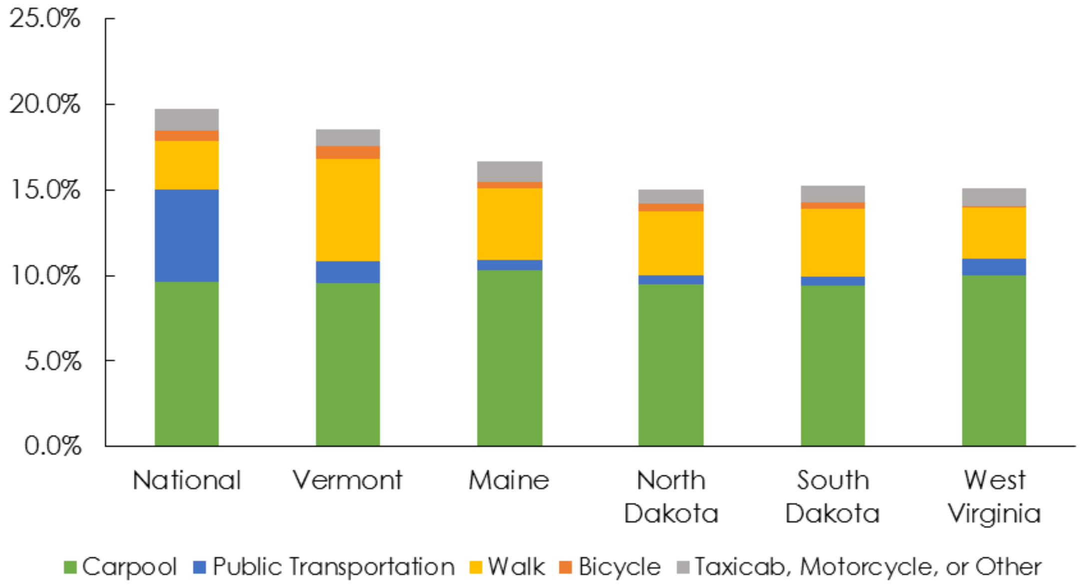


Figure 2-8. Commute Mode Share for Non-SOV Trips, 2017 (ACS, 2019)

Table 2-4, Figure 2-7, and Figure 2-8 only include primary modes to work for commuters. Workers who worked from home, and therefore did not make commute trips, are not included in these numbers. Vermonters worked from home at a higher rate (6.8%) than the national average (4.7%) or than in any of the comparison states (between 3.2% and 5.6%) (ACS, 2019).

2.2.2 Energy Intensity by Mode

Shifting travel to modes with lower energy intensities is one method for reducing energy use in transportation. Energy intensity can be considered at either the vehicle level or the passenger level. Vehicle energy intensity measures how much energy is required to move a vehicle one mile without adjusting for the number of passengers it carries. Passenger energy intensity measures the energy used to move each passenger one mile. An inverse relationship exists between occupancy and passenger energy intensity—the higher the occupancy, the lower the passenger energy intensity. For many applications, passenger energy intensity provides a more useful measure of energy efficiency than does vehicle efficiency.

Figure 2-9 shows U.S. Department of Energy (DOE) estimates of vehicle and passenger energy intensity for several commonly used motorized modes (Davis and Boundy, 2019). In Figure 2-9, passenger energy intensity is calculated using national average occupancy rates for rail, air, transit buses, and demand-response transit. Passenger energy-intensities for cars and light-duty trucks are calculated with both one and two occupants as well as for average occupancy to illustrate the impact of increased vehicle occupancy on passenger energy intensity. After demand-response transit, which frequently uses larger vehicles and has a low average occupancy rate, SOV trips in light-duty trucks and passenger cars have the highest energy intensity of the modes shown here. Policies aimed at reducing transportation energy use in Vermont may be able to achieve this objective by promoting mode shifting and increases in average vehicle occupancy rates. Shifting vehicle trips to vehicle types with lower energy intensity will also reduce energy use and is discussed in Section 3.2.1.

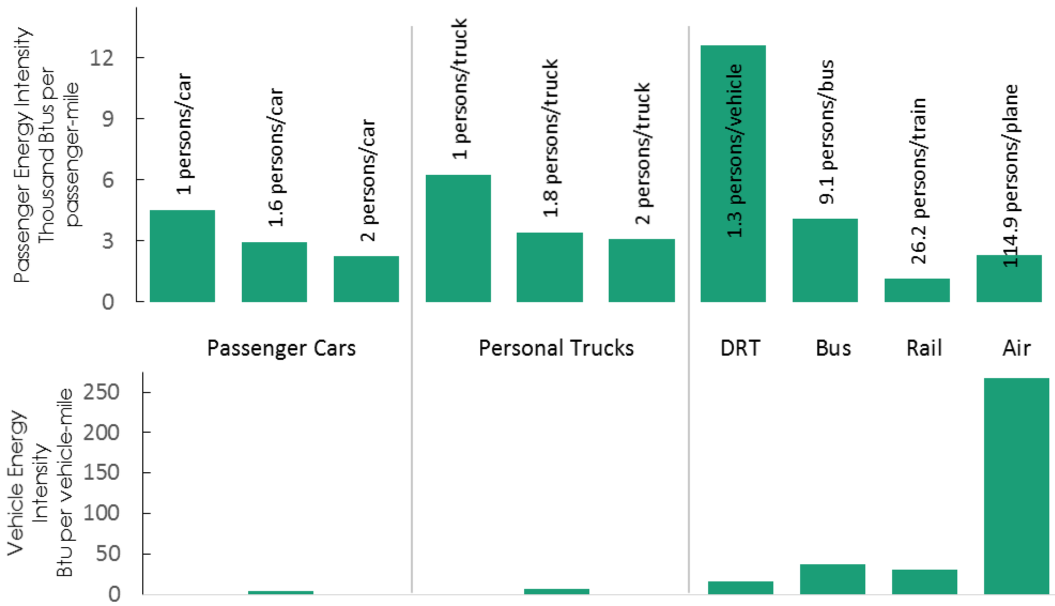


Figure 2-9. Energy Intensities of Common Transport Modes (Davis and Boundy, 2019)

Figure 2-10 shows the trend in average energy intensity per vehicle mile for cars and trucks from 2000 through 2016. Improving vehicle efficiency has led to a 20% drop in per mile energy intensity for cars and an 11% drop for light trucks.

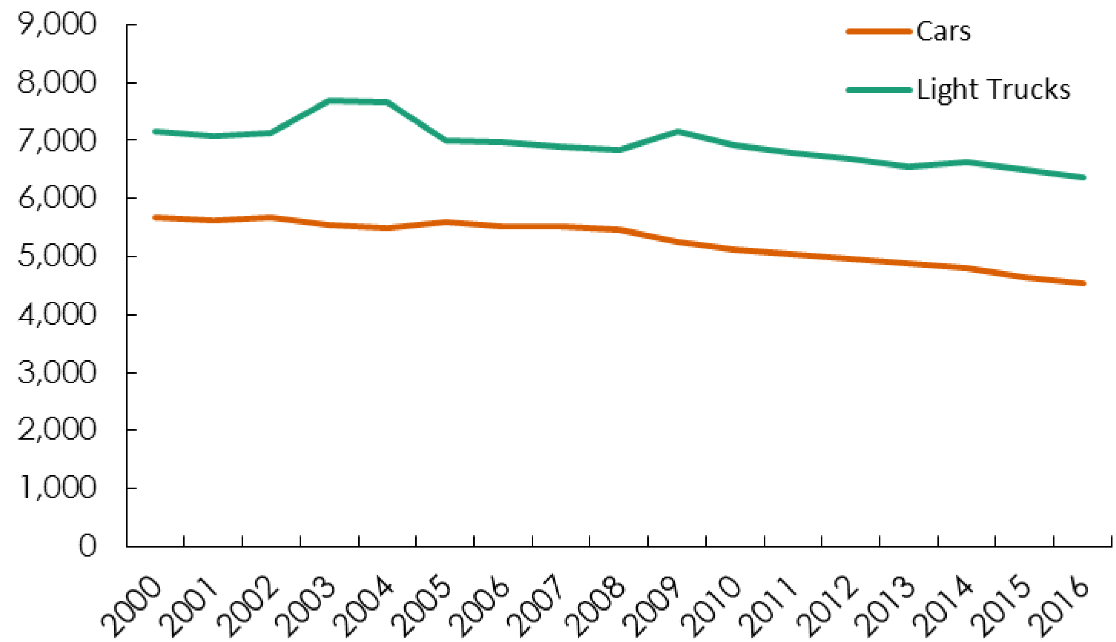


Figure 2-10. Per Vehicle Mile Energy Intensity Trends 2000 - 2016 (Davis and Boundy, 2019)

2.3 Vehicle Occupancy

VERMONT VEHICLE OCCUPANCY

Definition: Vehicle occupancy rates are a measure of the average number vehicle occupants per vehicle trip. Increasing vehicle occupancy can decrease VMT and the per passenger energy intensity of travel.

Status: Vehicle occupancy data are collected by travel surveys such as the NHTS. As of 2009, Vermonters' averaged a vehicle occupancy rate of 1.58 people per vehicle, below the national average of 1.68. Regional data from the 2017 indicate a small uptick in vehicle occupancy in New England, but the loss of carpooling commute mode share may indicate that Vermont's vehicle occupancy rate has declined since then.

Vehicle occupancy rates measure the average number of vehicle occupants per vehicle trip. Vehicle occupancy is an important component of transportation energy intensity, as described in Section 2.2.2. Increasing vehicle occupancy decreases the per passenger energy intensity per mile traveled. Generally, increasing vehicle occupancy also results in lower total VMT.

Occupancy data are generally collected via travel surveys. The most recent survey to collect vehicle occupancy data for Vermont was the 2009 NHTS. Vehicle occupancy rates from the 2009 and 2017 NHTS for New England and the nation are summarized in Table 2-5 and show relatively little change. Vehicle occupancy is generally lower for trips that take place entirely in-state than for trips that include travel in other states or Canada. Trips to work have the lowest occupancy rates of all trip types. Trips for meals and social or recreational purposes as well as trips to transport another individual, which by definition included multiple people per vehicle, have the highest vehicle occupancy rates (USDOT, 2010).

Table 2-5. Average Vehicle Occupancy, 2009 and 2017

	Average Vehicle Occupancy	
	2009	2017
Vermont	1.58	N/A
New England	1.58	1.61
National	1.68	1.65

Source: USDOT, 2010; USDOT, 2018

2.3.1 Carpooling Incentives

According to ACS data, carpooling rates in the Vermont have steadily declined from 2009 through 2017. This decline may be attributable to a number of factors such as rising rates of vehicle ownership, declining household size, sustained low fuel prices, and an increase in suburban settlement patterns. In 2008, the state of Vermont established Go! Vermont, a carpooling initiative designed to reduce single-occupancy trips by encouraging higher rates of carpooling, transit use, biking, and walking. This initiative includes a website to link potential carpool participants and provide information for those seeking to share rides to work, meetings, and conferences. Results of Go! Vermont activities are summarized in Table 2-6. Note that the method for tracking registered commuters with the Go! Vermont Program was revised in 2018 so figures from SFYs 2018 and 2019 are not directly comparable to the data from prior years. In addition, the program transitioned providers of its carpool matching service, resulting in a period where this service was unavailable and thus had lower activity in portions of SFY 2018 and 2019.

Table 2-6. Go! Vermont Program Benefits

Tracking Metric	SFY 2012-2015	SFY 2016	SFY 2017	SFY 2018	SFY 2019
Registered Commuters	3455	943	811	4389	5885
Rides Posted	4224	970	837	385	314
Vanpools	19	14	11	12	14
Total Estimated Reduction of VMT	16,466,000	3,085,636	2,453,499	1,003,367	987,105
Estimated Commute Cost Savings (dollars)	9,276,000	1,681,814	1,338,524	488,922	581,952

Source: McDonald, 2019

2.3.2 Park-and-Ride Facilities

Park-and-ride facilities provide safe, no-cost parking spaces for those who carpool or ride the bus. Currently, the state operates 31 park-and-ride sites with approximately 1,639 total spaces (see Table 2-7), while individual municipalities maintain an additional 69 sites with a total of approximately 1,362 spaces (see Table 2-8). Overall, the number of park-and-ride parking spaces has increased by 78% since 2012. In addition, park-and-ride facilities at both the state and municipal levels are considerably more likely to include connections to transit and bicycle parking. VTrans is currently installing Level 1 charging facilities at all new park-and-rides and at existing park-and-rides undergoing lighting retro-fits.

Table 2-7. State Park-and-Ride Facilities in Vermont, 2012 – 2019

Number of State:	2012	2015	2017	2019
Park-and-Rides	25	29	30	31
Parking Spaces (approximate)	1,140	1,380	1,525	1,639
Facilities with Bike Racks	11	20	22	23
Facilities with Transit Connection	3	19	21	21
Facilities with Paved Surface	17	24	26	27
Facilities Lighted	18	24	28	26
Facilities with PEV Charging	0	1	5	6
Source: VCGI, 2019				

Table 2-8. Municipal Park-and-Ride Facilities in Vermont, 2012 – 2019

Number of Municipal:	2012	2015	2017	2019
Park-and-Rides	26	53	65	69
Parking Spaces (approximate)	550	1,012	1,293	1,362
Facilities with Bike Racks	2	19	22	25
Facilities with Transit Connection	9	20	22	25
Facilities with Paved Surface	20	42	52	53
Facilities Lighted	18	37	49	51
Facilities with PEV Charging	0	0	3	3
Source: VCGI, 2019				

2.4 Active Transport

Active transportation – primarily walking and biking – has a very low energy intensity and, consequently, replacing vehicle trips with these modes can help reduce transportation energy use and GHG emissions. Of the nearly 10,800 unique trips recorded in the 2009 Vermont NHTS data set, 39% are less than two miles and 28% are less than one mile. Roughly 87% of the trips shorter than two miles were made by motor vehicle, suggesting an opportunity for increasing active transportation trips. The CEP includes an objective of increasing the share of commute trips completed by walking or biking to 15.6% of all commute trips.

To better understand the role of active transportation in the State, VTrans and the University of Vermont Transportation Research Center are collaborating to create a data portal to facilitate sharing bicycle and pedestrian counts among local, regional and state agencies. Because walking and biking count data are still not collected as widely as vehicle count data, travel surveys remain the best source of biking and walking data. The 2009 NHTS and the 2016 LRTPS both provide indications of the level of biking and walking in Vermont. Because the trip frequency estimates in these surveys are not collected as part of travel diaries that also capture the total number of trips taken, they cannot be used to calculate mode share. Nonetheless, they can provide some indication of biking and walking patterns in Vermont.

The active transportation tendencies of Vermonters, as reported in the 2009 NHTS, are shown in Table 2-9. Active transportation rates in Vermont are similar to those found nationally. Approximately 14% of Vermonters in the data set had taken at least one bike trip and 75% had taken at least one walking trip within the previous week.

Table 2-9. Vermonters' and Nationwide Biking and Walking Tendencies, 2009

Number of Trips in the Past Week	Vermonters		Nationwide	
	Bike	Walk	Bike	Walk
0	85.4%	24.6%	87.2%	32.1%
1–2	6.9%	16.9%	8.2%	16.2%
3–5	4.2%	26.3%	4.4%	24.1%
5+	3.6%	31.6%	2.2%	26.6%
	100%	100%	100%	100%
Source: USDOT, 2010.				

The 2016 LRTPS also asked about biking and walking tendencies, as shown in Table 2-10. Similarly to the NHTS results, the LRTPS indicates most Vermonters, 81%, walk at least occasionally.

Table 2-10. Walking and Biking Frequency among Vermonters, 2016

Mode	Mode Use Frequency		
	Frequently	Infrequently	Never
Walking	45%	36%	19%
Biking	14%	31%	55%
Source: RSG, 2016.			

2.5 Bus and Rail Service

Rail and bus service can each provide energy-efficient transportation options. At average occupancy rates, these modes are considerably more efficient than the state's most common commute mode, the SOV. The CEP includes goals to increase public transit and passenger rail ridership. This section describes current trends in passenger rail and transit ridership and highlights the role of private interregional bus companies and multimodal hubs in facilitating increased bus and passenger rail utilization.

2.5.1 Public Transit Ridership

As noted in the Public Transit Route Performance Reviews for 2017 and 2019 (KFH Group, 2017; KFH Group, 2019), the organization of Vermont's public transit system has changed substantially in recent years. The Chittenden County Transportation Authority (CCTA) and Green Mountain Transit Agency (GMTA) merged in 2011, and the merged entity began operating as Green Mountain Transit (GMT) in 2016. In 2015, the Deer Valley Regional Transit Association assumed the assets of Connecticut River Transit and now operates as Southeast Vermont Transit (SEVT). In 2017, ACTR and STSI merged operations under then name Tri-Valley Transit. Transit service territories are shown in Figure 2-11. The Profile reports on transit ridership for 8 transit divisions, see Table 2-11, as well as on volunteer driver services provided by the Vermont Association for the Blind and Visually Impaired (VABVI) and intercity bus routes operated by Greyhound and Vermont Translines. Greyhound and Vermont Transline data is included only for routes that receive financial assistance from VTrans.

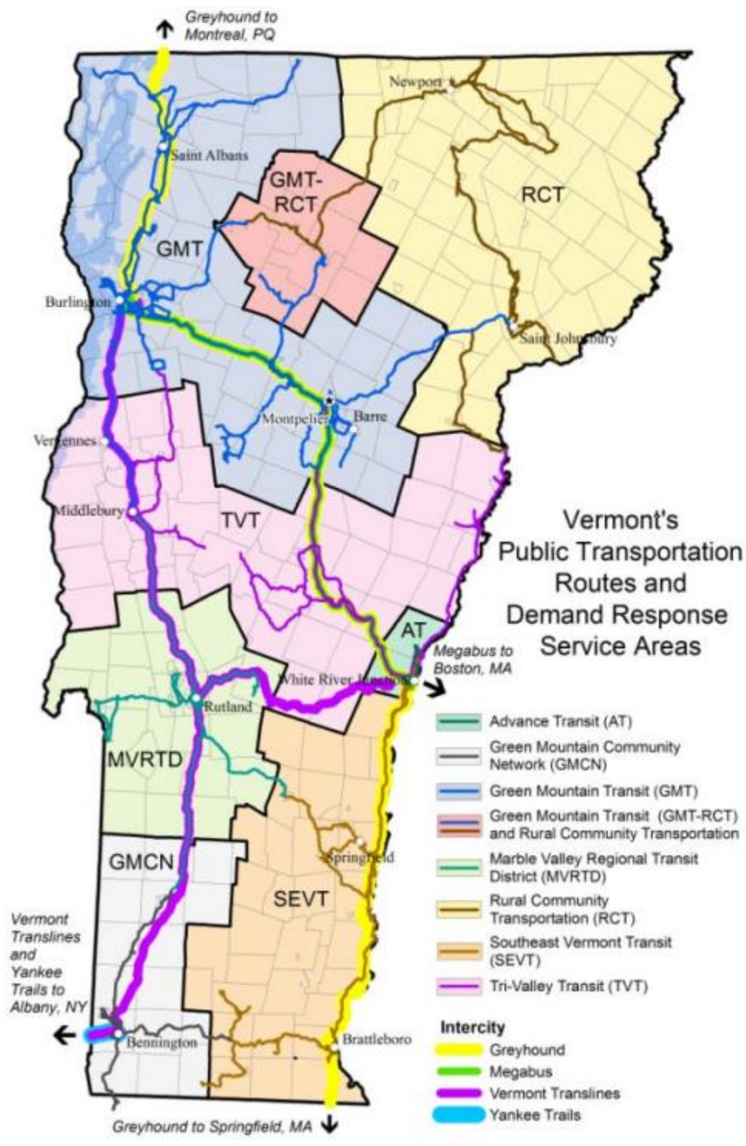


Figure 2-11. Transit Service Providers (KFH Group, 2019)

In SFY 2018, total public transit ridership was measured at 4.7 million passenger boardings, as shown in Table 2-11. Overall, transit ridership increased from SFY 2012 through SFY 2015 but declined in SFY 2016 and 2017 before increasing in SFY18.

Table 2-11. Bus Ridership for Vermont Transit Authority Providers, FY 2011–16

Transit Provider	Annual Ridership (thousands)							
	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18
AT	169.8	171.8	180.6	172.6	195.9	210.7	209.3	212.9
GMCN	75.4	96.5	109.9	117.1	19.7	4.2	8.4	104.4
GMT - Rural	419	424.2	427	418.4	417.5	381.0	68.7	387.8
GMT - Urban	2512.4	2703.2	2690.4	2545.4	2,703.5	2,510.7	2,281.5	2,271.8
Greyhound	N/A	N/A	N/A	N/A	14.4	14.3	16.5	14.3
MVRTD	557.8	545	585.8	633.4	631.7	607.3	647.5	687.0
RCT	163	150.3	175.1	191.8	186.4	205.2	262.7	210.1
SEVT	444.8	460.4	520.2	523.4	513.7	452.5	514.8	513.6
TVT (formerly ACTR and STSI)	230.9	265	266.4	247.3	233.9	201.2	271.7	319.1
VABVI	5.2	5.3	5.2	4.3	4.2	3.4	3.7	4.8
Vermont Translines	N/A	N/A	N/A	N/A	8.3	11.1	12.3	16.3
Statewide Totals	**4,578**	**4,822**	**4,961**	**4,854**	**5,029**	**4,712**	**4,687**	**4,742**

Source: Pelletier, 2019

2.5.2 Passenger Rail Ridership

Passenger rail service in Vermont is provided on two Amtrak lines: the Vermonter, running from St. Albans to its eventual terminus in Washington DC, and the Ethan Allen Express, running from Rutland to New York City via Albany. Passenger rail ridership is measured by tracking the number of passengers who board and disembark at rail stations in Vermont. Combined boardings and disembarkments (also called alightments) at Vermont rail stations from FY 2003 through FY 2018 are shown in Figure 2-12. Passenger rail ridership has increased steadily from FY 2005 through FY 2014 but has declined in FYs 2015 and 2016 and remained relatively stable in FYs 2017 and 2018.

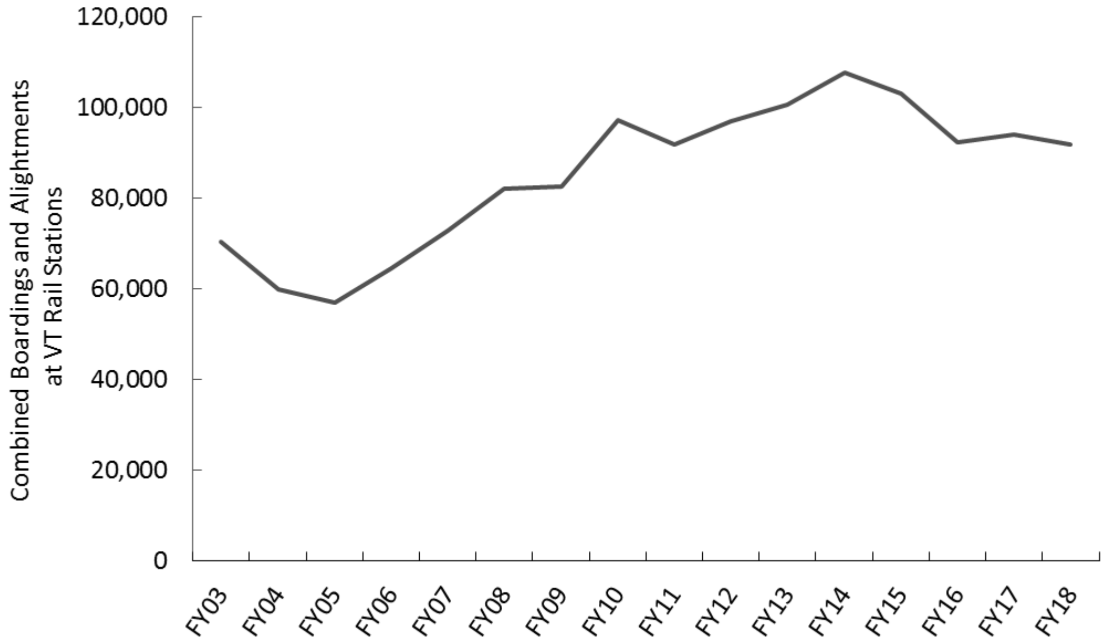


Figure 2-12. Amtrak Boardings and Alightments in Vermont, FY 2003–2018 (Pappis, 2019)

2.5.3 Private Interregional Bus Service

In addition to public transit services described previously, four major intercity bus carriers currently service locations in Vermont. These intercity bus carriers are Megabus, Greyhound, Yankee Trails, and Vermont Translines. With the exception of routes that receive support from VTrans, ridership data for these companies is proprietary and not included in the CEP transit metrics.

2.5.4 Multimodal Connections

Though often overlooked and difficult to measure, an additional indicator of reduced reliance upon personal vehicles is the expansion of mobility options provided through multimodal hubs. Typically, multimodality refers to the use of more than one mode in travel along a journey. From an energy-use perspective, the ability to access multiple modes along a journey increases the potential for reducing the use of the highest energy intensity modes of travel by shifting part of the trip to a less energy-intensive mode. Multimodal facilitation is an evolving priority within Vermont's transportation infrastructure.

Park-and-ride facilities are, by nature, multimodal because they facilitate shifts from automobiles to transit buses or from an SOV to a multi-passenger vehicle. As discussed previously, an increasing number of park-and-rides offer transit connections and bicycle parking, increasing their value as multimodal hubs. Co-locating bus lines at rail stops and airports is another example of the creation of multimodal hubs, providing options for the first leg of a passenger rail or airplane trip. Many GMT buses are equipped with bike racks for their riders, allowing for the combination of biking and bus transit on a trip.

3 Vermont Vehicle Fleet

The energy and specific fuel consumed per vehicle-mile traveled is a function of the vehicle used to drive that mile. The Vermont vehicle fleet encompasses a wide variety of vehicle types utilized for a wide range of travel purposes. Vehicle purchase decisions are influenced by a variety of factors, including household demographics, employment characteristics, regional geography, and perceptions about the local climate (Bhat et al. 2009; Busse et al., 2015). Local terrain may also influence the vehicle characteristics—such as clearance and four-wheel drive—that Vermonters look for in their vehicles. This section tracks private vehicle registrations to assess the overall efficiency of the Vermont vehicle fleet. Growth in sales of alternative fuel vehicles, such as PEVs, are also highlighted.

Vehicles can be classified based on several different characteristics, including weight, primary use, and fuel type. The precise classification of specific vehicles can vary by agency and jurisdiction. The FHWA's Federal Highway Statics series divides on-road vehicles into motorcycles, automobiles, buses and trucks. For the purpose of regulating mobile source emissions, the EPA divides on-road vehicles into motorcycles, light-duty vehicles with a gross vehicle weight rating (GVWR) under 8,500 pounds, and heavy-duty vehicles with a GVWR over 8,500 pounds (U.S. EPA, 2019) Light-duty vehicles can be further classified as either passenger cars (sedans, coupes, and station wagons) or light trucks (a category that includes most pickup trucks, minivans, and sport-utility vehicles), but a growing number of crossover utility vehicles (CUV) do not align well with these categories. CUVs such as the Toyota RAV4 and Ford Escape are categorized as light trucks by the Bureau of Economic Analysis but, depending on their specific features, may be counted as passenger cars by the EPA (U.S. EIA, 2017). The EPA's heavy-duty vehicle classification includes large pick-ups, commercial trucks, and buses.

Except where specifically noted otherwise, analysis in the Profile is focused on privately owned automobiles and trucks, as classified by the FHWA, registered in Vermont. Privately

VT PRIVATELY OWNED VEHICLE FLEET

Overview: The vehicles that Vermonters drive determine the efficiency of vehicle travel in the state as well as the fuels that are used for transportation. The Vermont vehicle fleet is composed almost entirely of gasoline- and diesel-fueled vehicles (94.2% and 5.2%, respectively), as shown in Figure 3-1. Less than 1% of all vehicles use other fuel types.

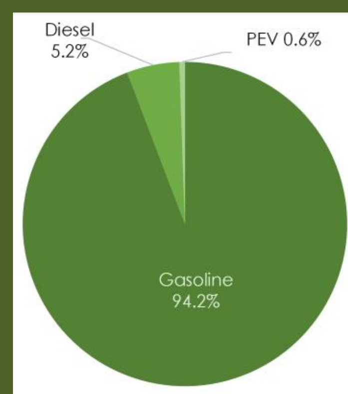


Figure 3-1. Vermont Private Vehicle Registrations by Fuel Type, 2019 (VDMV, 2019)

Trends in PEV Registrations: The number of all electric vehicles and plug-in hybrid electric vehicles increased by 81% and 25% respectively between December 2017 and July 2019. As shown in Figure 3-1, however, PEVs, are less than 1% of private vehicle registrations.

owned vehicles are defined as all vehicles with commercial or individual registrations. Publicly owned vehicles, as well as buses, motorcycles, and off-road vehicles, are excluded from most analyses. As of 2017, 12,194 publicly owned vehicles, 322 privately owned buses and 30,955 privately owned motorcycles were registered in Vermont (FHWA, 2018). These vehicles accounted for 7% of 2017 registrations.

3.1 Vehicle Registrations

Vehicle ownership is a strong predictor of vehicle use. Table 3-1 shows the trends in driver licensing and vehicle registration at the state and national level from 2007 through 2017, the most recent year for which national data are available. Nationally, per capita vehicle ownership and vehicle ownership per licensed driver fell slightly from 2007 to 2010 – likely impacted by the 2008 economic downturn – but have increased slightly since then. Perhaps because it is more difficult to forgo a vehicle in a rural state, Vermont did not experience a comparable dip in vehicles per licensed driver.

Table 3-1. Vehicle Registrations and Driver's Licenses in Vermont and the U.S., 2007–2017

	Vermont			National		
Year	Registered Vehicle (thousands)	Vehicles per Licensed Driver	Vehicles per Capita	Registered Vehicles (millions)	Vehicles per Licensed Driver	Vehicles per Capita
2007	555	1.04	0.89	243.1	1.18	0.81
2008	571	1.05	0.92	244	1.17	0.80
2009	546	1.08	0.88	242.1	1.16	0.79
2010	554	1.08	0.89	237.4	1.13	0.77
2011	564	1.08	0.9	240.8	1.14	0.77
2012	568	1.07	0.91	241.2	1.14	0.77
2013	574	1.06	0.92	243.1	1.15	0.77
2014	573	1.05	0.92	247.4	1.16	0.78
2015	614	1.12	0.98	250.5	1.15	0.78
2016	572	1.03	0.92	255.4	1.15	0.79
2017	578	1.03	0.93	259.1	1.15	0.80

Source: FHWA, 2008–2018

Vehicles per licensed driver and vehicles per capita in 2017 for Vermont and the four comparison states are shown in Figure 3-2. As discussed in Section 2.1.1, Vermont has a relatively high licensure rate and thus the difference in vehicles per licensed driver and vehicles per capita is relatively small. Only Maine has a lower ratio of vehicles to licensed drivers among the four comparison states.

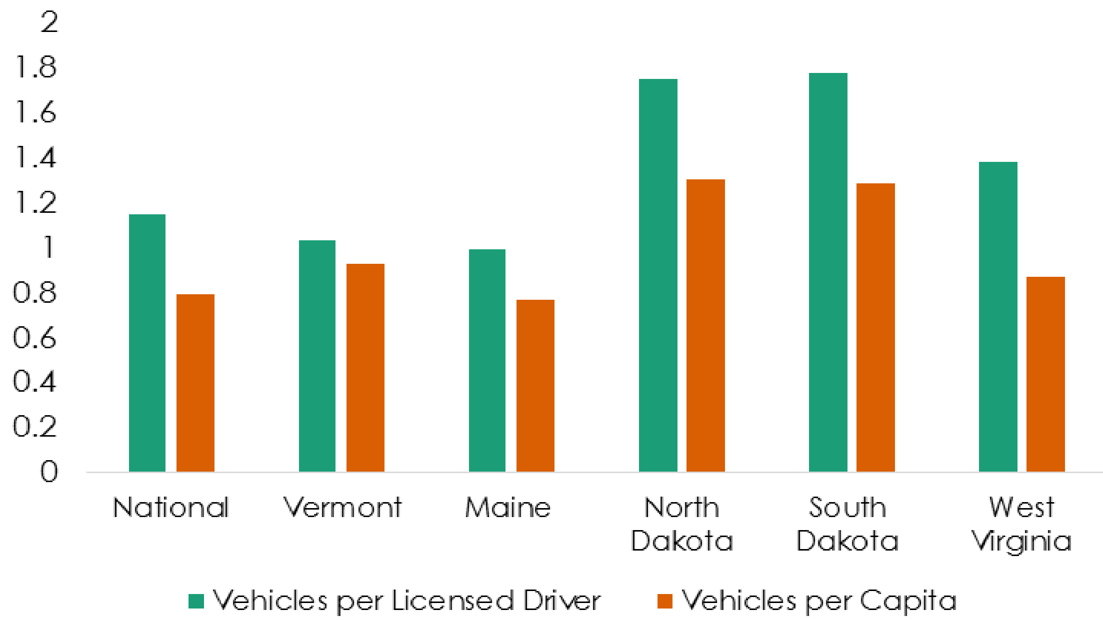


Figure 3-2. Vehicles per Capita and per Licensed Driver, 2017 (FHWA, 2018)

Note that for consistency of comparison between Vermont, national, and rural comparison state figures, all vehicle data here are taken from the FHWA's Highway Statistics, 2017 (FHWA, 2018). The Vermont vehicle numbers in Section 3.2 and 3.3 are directly from the Vermont DMV data and vary with respect to the FHWA data by as much as 6%.

3.2 Vehicle Types

The vehicle fleet can be characterized by the type of fuel or propulsion system that powers it as well as by vehicle body type. As shown in Table 3-2, the Vermont fleet is dominated by conventionally powered vehicles, running on either gasoline or diesel. While gasoline internal combustion engine vehicles (ICEVs) are by far the most common vehicles registered in Vermont, gasoline-powered hybrid electric vehicles (HEVs) such as the Toyota Prius, plug-in hybrid electric vehicles (PHEVs) such as the Chevy Volt, and all-electric vehicles (AEVs) such as the Nissan Leaf have all grown in popularity. PHEVs and AEVs, collectively known as PEVs, derive some or all of their energy from electricity, helping to reduce the amount of petroleum-based fuels used for transportation. The number of PEVs registered in Vermont, as well as their share of the total vehicle registrations, has increased every year from 2011 through 2019. HEVs are powered entirely by gasoline but tend to have significantly better fuel efficiency than comparable ICEVs and thus also help reduce transportation energy use.

Table 3-2. Private Vehicles Registered in Vermont by Fuel Type, 2008–2019

Fuel Type	PEV[1]		Propane/ CNG	Diesel	Gasoline	
	AEV	PHEV			ICEV	Gas: HEV
2008	NA	NA	75	32,140	578,881	4,656
2009	NA	NA	69	30,724	528,930	5,473
2010	NA	NA	59	25,932	524,810	5,877
2011	NA	NA	51	28,513	550,711	7,056
2012	48	140	48	38,684	541,872	7,693
2013	130	466	43	28,209	516,339	7,945
2014	197	670	43	29,879	525,199	9,242
2015	248	865	44	31,239	533,118	9,895
2016	330	1,192	43	31,213	533,021	10,676
2017	695	1,632	40	30,597	548,417	11,556
2018	1,010	1,975	37	30,699	546,340	12,027
2019	1,256	2,032	34	31,107	547,199	12,077

[1] PEV data includes public as well as private vehicle registrations
2019 Data through June 30th, data for all other years through December 31st
Sources: VDMV, 2019; Drive Electric Vermont, 2019.

A breakdown of the most popular PEV models currently registered in Vermont and the efficiency of the vehicles measured in mile per gallon equivalent (MPGe) is provided in Table 3-3. Note that the MPGe, which is used to compare the energy use of PEVs to conventional gasoline vehicles, varies with model features such as battery capacity; thus, the values should be seen as illustrative not definitive. The efficiency of the most popular PHEVs in Vermont ranges from 88 – 133 MPGe for model years 2015 – 2019. As of the 2019 model year, the lowest MPGe of the AEVs in Table 3-3 is 93.

Table 3-3. Vermont PEV Registration and MPGe by Vehicle Model

Plug-In Type	Make and Model	Vermont Registration as of July 2019	MPGe for Model Year: 2015	2017	2019
AEV	Nissan Leaf	391	114	112	108
AEV	Chevrolet Bolt	209	N/A	119	119
AEV	Tesla Model S	125	95	99	109
AEV	Tesla Model 3	112	N/A	126	161
AEV	Tesla Model X	54	N/A	93	93
PHEV	Toyota Prius Plug-In Hybrid	579	88	97	103
PHEV	Ford C-Max Energi Plug-in Hybrid	486	95	133	133
PHEV	Chevrolet Volt	391	98	106	106
PHEV	Ford Fusion Energi Plug-in Hybrid	227	88	97	103
PHEV	Honda Clarity	68	N/A	N/A	110

Source: Drive Electric Vermont, 2019; US DOE & EPA, 2019

The Vermont Department of Environmental Conservation is launching an electric school bus and transit bus pilot program funded from Vermont's Volkswagen Mitigation Trust. Selected pilot projects are scheduled to be announced in late 2019 (VT DEC, 2019). VTrans also received a $3 million grant from the Federal Transit Agency for the purchase of electric transit buses and associated charging infrastructure (FTA, 2019).

Vehicle size and body type are also important determinants of fuel efficiency. Figure 3-3 shows the 20 most common vehicle makes and models registered in Vermont. Several truck makes are among the most popular vehicles.

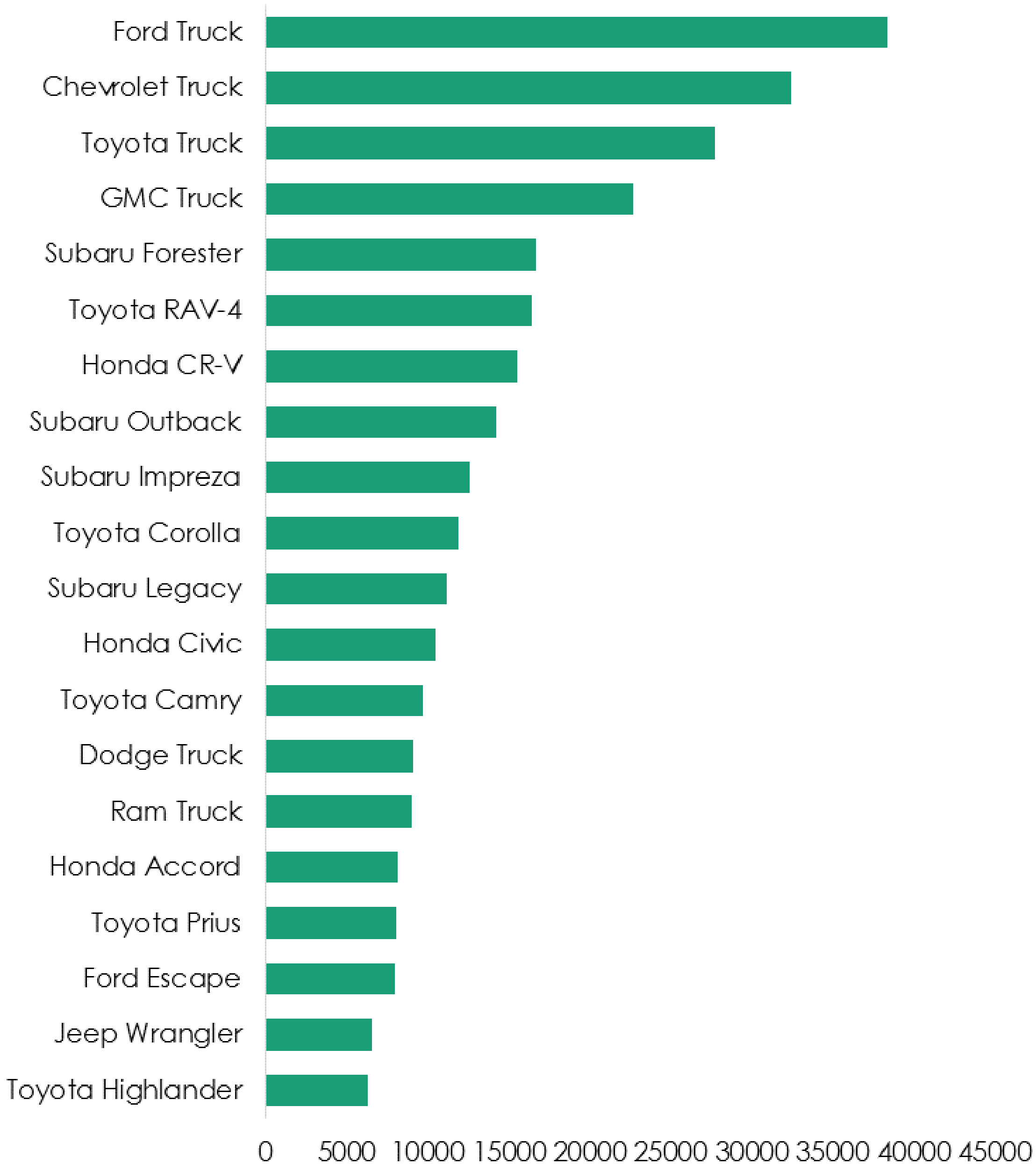


Figure 3-3. Top 20 Vehicle Models Registered in Vermont, 2019 (VDMV, 2019)

3.2.1 Life Cycle Energy and GHG Intensity by Vehicle Type

Life cycle assessments (LCAs) are used to evaluate the environmental impacts of a product comprehensively, including the impacts related to producing, operating, and decommissioning the product. Vehicle LCA for energy use and GHG emissions include the liquid fuel production (for ICEVS, HEVs, and PHEVs) and electricity generation processes (for PEVs). Figure 3-4 shows national and Vermont specific estimates of the energy and GHG intensities of ICEVs, HEVs, PHEVs with 18 and 62 mile electric-ranges, and AEVs (Onat, Kucukvar, and Tatari 2015). For PEVs, LCA energy and GHG intensity are both influenced by the source of the electricity used to charge the vehicle. Burning fossil fuels for electricity generation results in substantial energy loss and GHG emissions when compared to most renewable electricity sources. Given the composition of electricity sources in Vermont, Onat et al. show AEVs outperform other vehicle types on both energy use and GHG emissions (Onat, Kucukvar, and Tatari 2015).

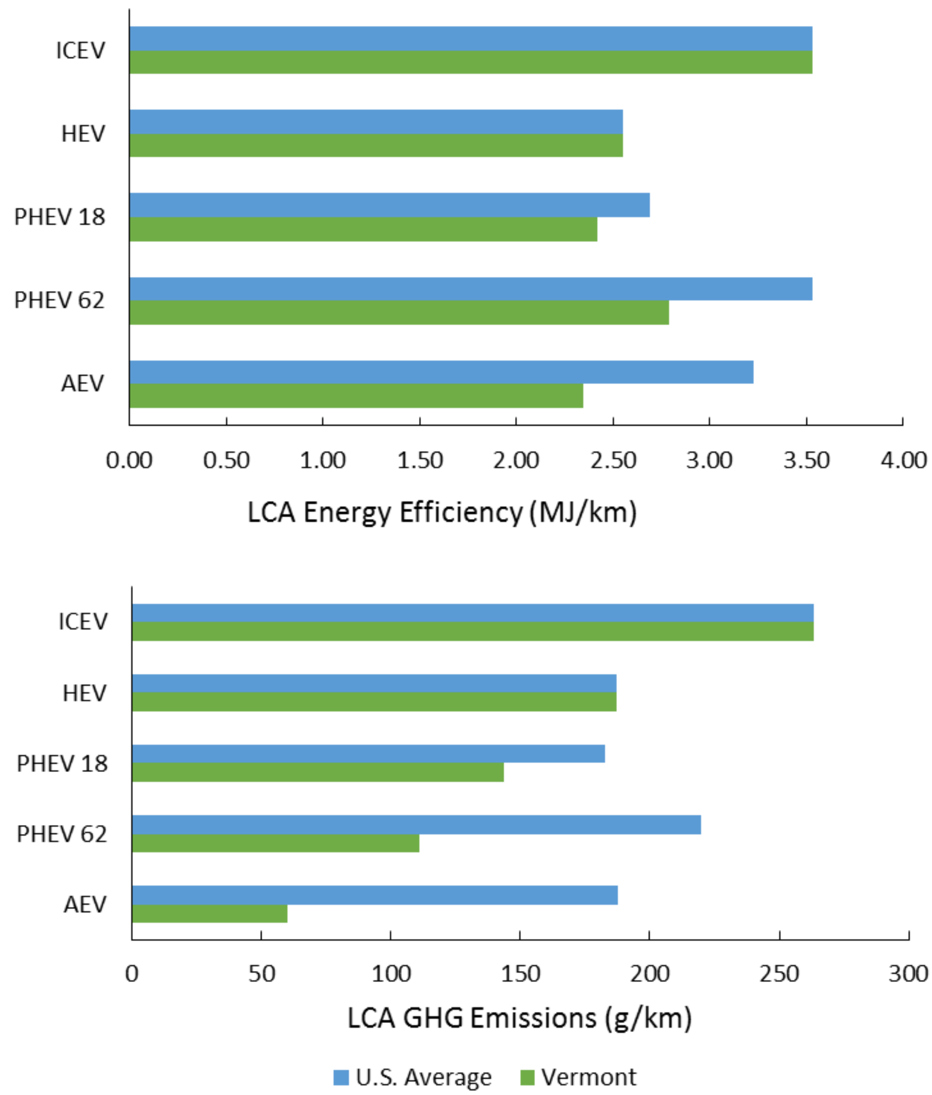


Figure 3-4. WTW Energy and GHG Intensity (Onat et al., 2015)

3.3 Fleet Age

Though new vehicles with increased fuel efficiency are being introduced rapidly into the American market, the fuel-saving effect of these models is highly dependent upon the turnover rate of vehicles in the current fleet. Figure 3-5 shows the distribution of automobile and truck model years for the vehicles registered in Vermont as of July 2019. Approximately 60% of Vermont's registered vehicles are model year 2010 or newer. According to the Alliance of Automobile Manufacturers, an auto industry advocacy group, Vermont has the lowest average vehicle age (9.7 years) of any state in the country (Auto Alliance, 2019). A decrease in the average age of the fleet is likely to result in an improvement in the fuel economy of Vermont's privately-owned vehicle fleet.

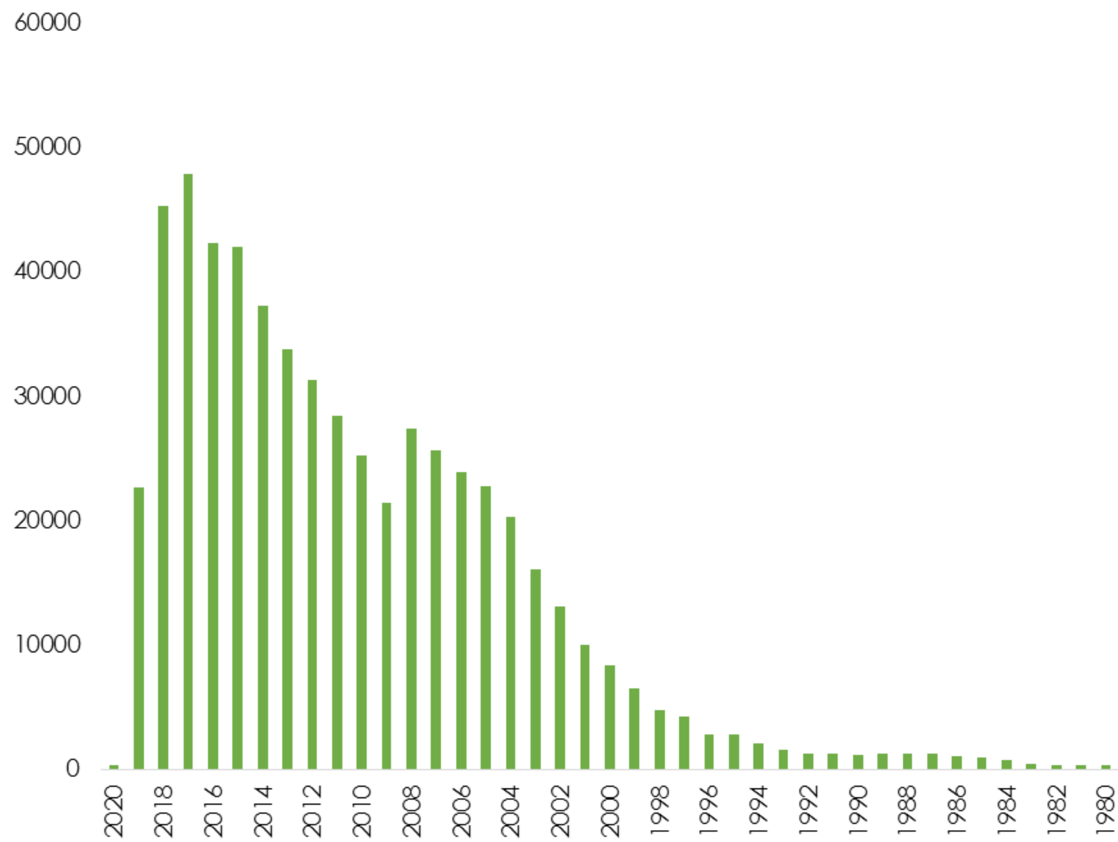


Figure 3-5. Distribution of Model Years for Vehicles in Vermont, 2019 (VDMV, 2019)

3.4 Fleet-Wide Fuel Economy

Vehicle fuel efficiency is a critical determinant of transportation energy use. Higher fuel economy vehicles can provide comparable mobility benefits with lower energy consumption than equivalent vehicles with lower fuel economy. The combined MPG of vehicles registered in Vermont has increased by an average 0.3 combined MPG per year from 2011 through the middle of 2019, as shown in Table 3-4. The values in Table 3-4 were calculated by matching DMV vehicle registration data to EPA fuel economy data available from FuelEconomy.gov. Because the DMV vehicle-make-and-model data are manually recorded in abbreviated form, matching these records to the EPA MPG data required identifying irregularities in the abbreviations used and translating these abbreviations into the complete make-and-model names in the FuelEconomy.gov data set. For instance, the Nissan Versa could be entered into the DMV database with the make defined as NISS, and model defined as VSA or VRS.

Approximately 85% of the registered vehicles in the reported time period (2011-2017) could be matched to MPG data. The remaining 15% of the privately-owned vehicle fleet could not be matched either because the vehicles were not in the FuelEconomy.gov data set, which is only available for vehicle model years after 1984 and does not include medium- and heavy-duty trucks, or because of anomalous make-and-model abbreviations. Since older and heavier vehicles are less well represented in the matched data set, the actual fuel economy of the Vermont fleet is likely lower than the values shown here.

Table 3-4. EPA Fuel Economy for Vehicles Registered in Vermont, 2011–2019

Year	Registered Vehicles	Vehicles with MPG Estimates	Average City MPG	Average Highway MPG	Combined MPG	
					Average	Std Dev
2011	586,422	85.00%	18.1	24.2	20.3	5.7
2012	578,415	85.60%	18.4	24.5	20.7	6.1
2013	552,665	85.80%	18.7	24.8	20.9	6.5
2014	564,591	86.40%	19.1	25.3	21.4	7.1
2015	589,608	85.44%	19.5	25.6	21.8	7.3
2016	591,864	85.64%	19.8	25.9	22.1	7.5
2017	593,076	86.93%	20.1	26.2	22.4	7.7
2018	592,237	86.68%	20.4	26.4	22.6	7.8
2019[1]	593,877	86.46%	20.5	26.5	22.7	7.9

Source: VDMV, 2019.

[1] As of July 2019, all other values as of yearend.

In addition, the realized fuel economy for Vermont drivers depends on the distance that each vehicle is driven. If lower-MPG vehicles are driven over longer distances than more fuel-efficient vehicles, fuel consumption is higher than if more fuel-efficient vehicles are driven preferentially.

One method for estimating the realized fuel economy in Vermont is dividing the annual VMT by the annual fuel sales in the state. Table 3-5 shows the MPG values that result from this approach. This approach provides a lower estimate of MPG but also shows a trend toward greater fuel efficiency.

Table 3-5. Realized MPG (VMT/Fuel Sales)

Year	Average MPG[1]
2011	18.3
2012	18.8
2013	18.7
2014	18.7
2015	18.9
2016	19.4
2017	19.5

[1] Annual VMT divided by combined annual gas and diesel sales.
Source: FHWA, 2018; VT JFO, 2019

4 Transportation Energy Consumption

The transportation sector continues to be the largest consumer of energy among all sectors in Vermont as shown in Figure 4-1. In 2017, 48 trillion Btus of energy were consumed for transportation purposes in Vermont (U.S. EIA, 2019). Vermont is one of 23 U.S. states that consumes more energy in the transportation sector than in any other sector (U.S. EIA, 2019).

Nonetheless, Vermont's per capita transportation sector energy use, 77.2 million Btus annually, was below the national average, 86.2 million Btus, in 2017. In contrast, per capita transportation-sector energy consumption in all four of the rural comparison states is above the national average, as shown in Figure 4-2.

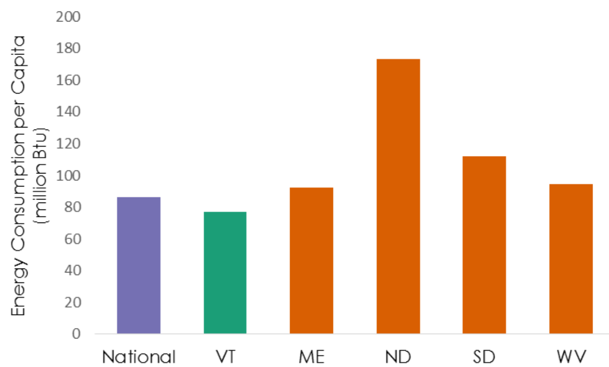


Figure 4-2. 2017 Per Capita Transportation Sector Energy Consumption (U.S. EIA, 2019)

Petroleum-based fuels accounted for close to 95% of the total energy used by the Vermont transportation sector in 2017. Gasoline (excluding blended ethanol) accounted for 70.1% percent of Vermont's total transportation energy usage, while diesel, (excluding blended biodiesel) accounted for 20.5%. Jet fuel accounted for an additional 2.7%. Ethanol and biodiesel, sold primarily blended in gasoline and diesel, accounted for 5.0% and 0.9% of energy usage respectively (U.S. EIA, 2019).

As shown in Figure 4-3, total transportation energy consumption peaked in Vermont in 2006 and then declined through 2012. Energy consumption has been relatively stable since 2012, ranging between 48.2 and 49.5 trillion BTUs.

VT TRANSPORTION ENGERY CONSUMPTION

Overview: The transportation sector is responsible for 36% of total energy consumption in Vermont, as shown in Figure 4-1. Close to 95% of all the energy used for transportation in Vermont is derived from petroleum fuels.

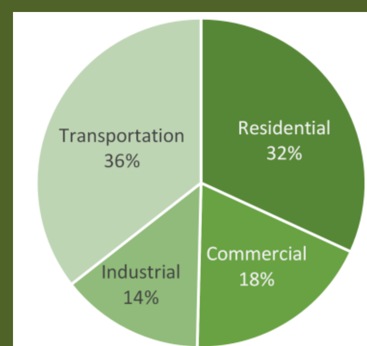


Figure 4-1. Vermont Sectoral Energy Consumption, 2017 (U.S. EIA, 2019)

Status of Alternative Fuel Sales: Apart from ethanol, sales of alternative fuels are not well documented at the state level.

Growth in the number of PEV registrations and public PEV charging stations (up by more than 44% since the 2017 Profile) indicate a growing role for electricity as a transportation fuel.

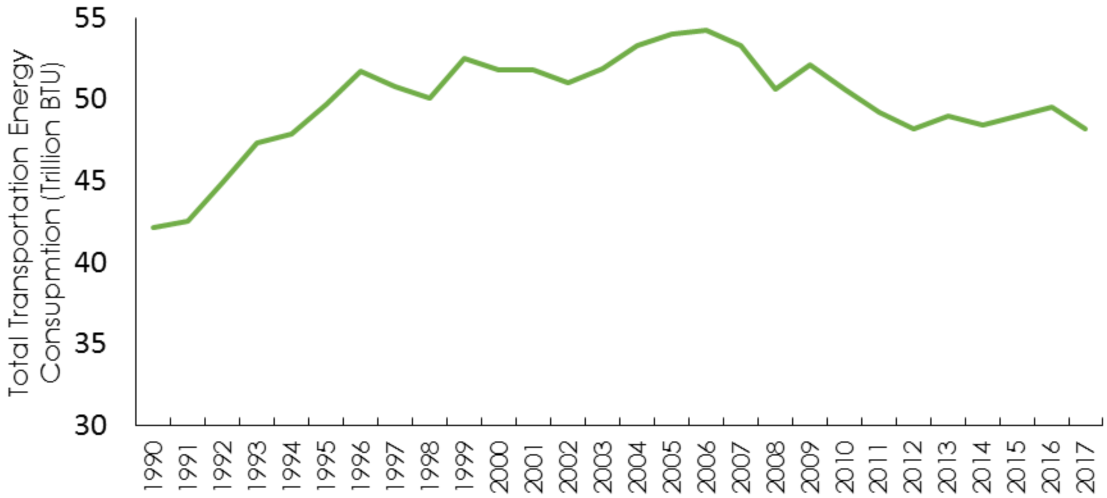


Figure 4-3. Total Vermont Transportation Energy Consumption, 1990 - 2017 (U.S. EIA, 2019)

Sections 4.1 through 4.4 present information on the use of gasoline and diesel, biofuels, electricity, and natural gas for ground transportation. Sales of aviation fuels and natural gas for pipeline operations are not considered in this Profile. Tracking and reporting requirements differ for each of these fuel types and, with the exception of ethanol, are not well documented at the state level. Registrations of alternative fuel vehicles and national production data for biodiesel can be used to understand the magnitude of current energy consumption for other fuel types.

The fuels that are used for transportation purposes vary considerably in GHG intensity and thus fuel shifting can be an important strategy for GHG emissions reductions. For additional context about these potential GHG reductions, life-cycle GHG intensity estimates certified by the California Air Resource Board (CARB) are provided for each fuel type. The GHG intensity of each fuel provides a way to assess the technical potential for GHG reductions by switching from gasoline or diesel to that fuel. Since the degree of fuel switching that can occur is limited by the number of alternative fuel vehicles on the road, projected changes in the composition of the light-duty vehicle fleet, as estimated by the U.S. Energy Information Agency (EIA) are also reported. The EIA's projections depend on assumptions about relative fuel and vehicle costs as well as about consumer acceptance and thus should not be considered definitive.

The California Air Resourced Board (CARB) certifies life-cycle GHG intensity values for different fuels and fuel production methods as part of that State's low-carbon fuel standard (LCFS) regulation (CARB, 2019). These GHG intensity values, reported in grams of CO_{2e} per megajoule (MJ), measure the total GHG emissions related to energy production, distribution, and use for different fuel types, feedstocks, and production methods and account for the impacts of land use change from biofuel production. Because they are specific to feedstocks and production methods (referred to as "fuel pathways") there can be a wide range of of GHG intensities for a specific fuel type. Ethanol produced using corn kernels as a feedstock, for example, has a much higher GHG intensity than cellulosic ethanol produced from wheat straw or corn stover.

4.1 Gasoline and Diesel

As shown in Table 4-1, gasoline is the predominant fuel used for ground transportation in Vermont. Diesel constitutes 16–18% of ground transportation fuel sales. Mirroring VMT, gasoline sales fell steadily from 2011 through late 2014, as illustrated in Table 4-1 and Figure 4-4, before increasing in 2015 and has been relatively steady since that time. Gasoline and diesel sales in Table 4-1 and Figure 4-4 include ethanol and biodiesel sold in blended form.

Table 4-1. Gasoline and Diesel Sales in Vermont, 2011–2018

	2011	2012	2013	2014	2015	2016	2017	2018
Gasoline	328.3	320.1	318.1	309.4	319.8	315.7	314.01	316.29
Diesel	62.0	63.6	62.6	68.6	67.9	64.1	64.13	66.29

Note: Gasoline and diesel sales, in millions of gallons, include blended ethanol and biodiesel.
Sources: VT JFO, 2019

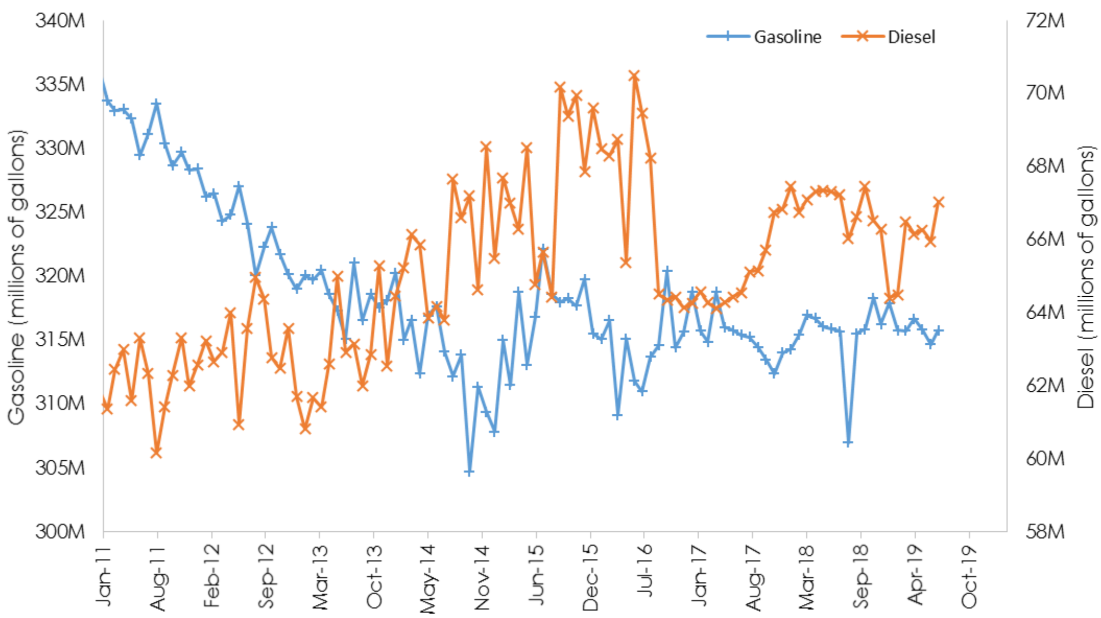


Figure 4-4. VT Gasoline and Diesel Sales, Rolling 12-Mo. Total, 2011 – 2019 (VT JFO, 2019)

The CARB GHG intensity values for gasoline and diesel are 100.8 and 100.5 g CO_{2e}/MJ respectively (CARB, 2019). At the national level, the EIA projects a decline of less than 1% in the number of ICEV gasoline vehicles by 2030 and significant growth, nearly 190%, in the number of diesel vehicles. Across gasoline and diesel ICEVs, they project a 5% net decline in market share, from 90% to 85%, for conventional light-duty vehicles (U.S. EIA, 2019c).

4.2 Biofuels

The two primary transportation biofuels are ethanol and biodiesel. Commercially, ethanol is produced from sugars in organic materials such as corn and sugar cane. Research on the use of cellulosic feedstocks is on-going, but they are not yet widely commercialized. Biodiesel is chemically processed from either raw feedstock (e.g. soybeans or rapeseed) or waste vegetable oil.

Ethanol sales are tracked at the federal level in order to ensure compliance with the National Renewable Fuel Standard (RFS) that was passed in 2007. It is sold primarily in blended gasolines. In 2017, approximately 29.8 million gallons of ethanol were consumed in Vermont which is equal to approximately 9.5% of "at the pump" gasoline sales.

Biodiesel production, though not state level biodiesel sales, is also tracked at the national level. Nationally, biodiesel accounted for approximately 4% of the volume of diesel fuel consumed by the transportation sector (U.S. EIA, 2019). As with ethanol, biodiesel is consumed predominantly in blended form. If the ratio of biodiesel to total diesel sold in Vermont matches that reported at the national level, this would equate to 2.5 million gallons of biodiesel sales in the state.

On an energy basis, 29.8 million gallons of ethanol and 2.5 million gallons of biodiesel provide 2.9 trillion Btus. This represents 6% of the total energy consumed by the transportation sector. As noted in the CEP, the environmental benefits of biofuels vary with fuel type, feedstock, and production methods (VDPS, 2016). There are several social and environmental uncertainties associated with corn ethanol that are noted in the CEP. Nonetheless, as a result of federal policies promoting ethanol, ethanol currently accounts for nearly 90% of the biofuel energy consumed in the State.

The current default carbon intensities for ethanol and biodiesel are 70 and 34 grams CO_2e/MJ respectively (CARB 2019). This represents a GHG saving of approximately 30% for ethanol and 66% for biodiesel relative to gasoline or diesel. Some biodiesel and ethanol production pathways, produced from plant residues and waste products, have GHG intensities that are 85% to 90% lower than gasoline but these fuels are not currently produced and sold in large volumes (CARB, 2019).

Ethanol is predominantly sold in blended form, most commonly as E10, which is compatible with all gasoline vehicles. Only flex fuel vehicles are capable of burning E85 and other high concentration blends. By 2030, the EIA projects the market share for flex fuel ethanol vehicles to decline from 7.7% of the light duty vehicle stock to 6.6% of the stock (U.S. EIA, 2019c).

4.3 Electricity

As discussed in Section 3, PEV registration has increased rapidly in recent years, though the absolute number of PEVs in the Vermont fleet remains small. PEVs can be charged at home outlets or at public charging stations. As of August 2019, there are a total of 225 publicly accessible electric charging stations in Vermont, an increase of 69 charging stations since July 2017. Table 4-2 shows the total number of charging stations and plugs by charger and connection type. In addition, close to $3 million from Vermont's Volkswagen Mitigation Trust Funds have been allocated to support the installation of Level 2 and DC fast charging stations in Vermont.

Over $1million in funding has been distributed to support charging infrastructure at 30 sites to date. The Vermont Agency of Commerce and Community Development is currently developing an RFP for the installation of fast charging stations at 11 additional sites in Vermont (VT DEC, 2019).

Table 4-2. Publicly Accessible Charging Stations in Vermont, 2019

	Charger Type			Connectors			
	Level 1	Level 2	DC Fast	J1772	CHAdeMO	SAE CCS	Tesla
Stations	16	192	26	155	20	14	41
Outlets	66	451	58	315	20	14	160

Source: AFDC, 2019

There are currently no reporting requirements for either home-based or public charging, so directly tracking the total electricity used for vehicle charging is not possible. Electricity consumption can be estimated based on the number of registered PEVs, however, as shown in Table 4-3. Several assumptions must be made to make these calculations, including the distance that PEVs drive and their electric drive efficiency. For Table 4-3, PEVs are assumed to be driven at the average VMT per vehicle for the state of Vermont. Average electric drive efficiency is calculated based on estimates from the Alternative Fuels Data Center (AFDC, 2017). PHEVs are assumed to travel 55% of the time on electric power (AFDC, 2017). Based on these assumptions, total electricity demand can be estimated at 9 million kWhs for 2016. This equates to almost 30 billion Btus or approximately 0.06% of the direct transportation energy use in the state. Some fraction of this energy comes from renewable sources but it does not yet contribute significantly toward the CEP goal of increased renewable energy use.

Table 4-3. Estimated PEV Electricity Consumption in Vermont for 2018

EV Type	Number of Registered Vehicles (December 2018)	Annual Miles Driven	Miles Driven On Electricity	Average Electric Drive Efficiency (kWh/mi.)	Total Electricity Use (kWhs)
AEV	1010	12,497	100%	0.320	4,039,030
PHEV	1975	12,497	55%	0.367	4,981,976
				Total	9,021,006

The availability of public charging infrastructure is an important component of PEV adoption as access to charging away from the home increases the effective range of PEVs and reduces range anxiety. To illustrate the current levels of charging at publicly accessible charging stations, Green Mountain Power has voluntarily provided charging data through the Vermont Clean Cities Coalition. Aggregate data for all GMP stations on the EVgo network, for 2018 are provided in Table 4-4.

Table 4-4. Aggregate electricity demand at GMP EVgo PEV charging stations in VT

Charging Station Type	Charging Episodes	Total Energy Usage (kWh)	Mean Charge (kWh)	Mean Charge Time (Min)
Level 2	6,860	62,604	9.13	148.8
DC Fast	3601	47,727	13.25	29.3
Source: GMP, 2019.				

Adjusted for the efficiency of PEVs, CARB certified GHG intensity values for electricity range from 0 grams CO2e/MJ for carbon free electricity sources such as solar photovoltaic to 24 grams CO2e/MJ for the average grid electricity in California (CARB, 2019). By 2030, the EIA projects the market share for PEVs to increase from 0.3% of the light duty vehicle stock to 5.1% of the stock (U.S. EIA, 2019c).

4.4 Compressed and Liquefied Natural Gas

Natural gas can be utilized as a transportation fuel in either compressed or liquefied form. Compressed natural gas (CNG) is pressurized to increase its energy density and is used in light-, medium-, and heavy-duty vehicles. Liquefied Natural Gas (LNG) is super-cooled to increase its energy density. LNG has a higher energy density than CNG and therefore provides greater range than CNG for an equivalent volume of fuel. However, LNG has higher production costs than CNG and requires dedicated distribution infrastructure and is generally used only in medium- and heavy-duty vehicles.

In Vermont there are four fleet operators who employ CNG vehicles, made up primarily of heavy-duty vehicles and Honda Civics, the only factory-built passenger vehicle to run on CNG in the United States. The production of CNG powered Honda Civics ended in 2015. These fleets are served by three CNG filling stations, only one of which is public. Omya is the only Vermont fleet utilizing LNG. Omya exclusively uses this fuel in their heavy-duty fleet operations.

Table 4-5. Vermont CNG Fleet

Fleet Operator	CNG Vehicles
University of Vermont	9 40-Ft. Buses
City of Burlington	3 Recycling Trucks 1 Honda Civic
Casella Waste Systems	10 Waste Trucks
Vermont Gas Systems	3 Honda Civics 6 Service Vans

Although lower tailpipe emissions and lower fuel costs make CNG an attractive alternative to petroleum, limited geographic availability of natural gas supplies and fueling infrastructure inhibit statewide adoption of CNG. Additional obstacles include the initial cost of the vehicle technology, shorter vehicle range relative to gasoline vehicles, and additional space requirements for on-board fuel storage systems.

CARB certified GHG intensity values for conventional CNG range from 78 to 94 grams CO_2e/MJ. Conventional LNG ranges from 86 to 91 grams CO_2e/MJ. CNG and LNG derived from the anaerobic decomposition of organic matter (such as animal manure, food scraps, and landfill materials) is frequently referred to as renewable natural gas (RNG). RNG has a significantly lower GHG intensity than conventional CNG or LNG. Four RNG pathways that use manure and food waste for feedstocks have negative GHG intensity scores in the CARB rating system. Other CARB certified GHG intensity values for RNG (in both compressed and liquified form) range from 0 to 81 grams CO_2e/MJ (CARB, 2019). By 2030, the EIA projects the market share for light-duty natural gas vehicles to decline from 0.06% of the light duty vehicle stock to 0.03% of the stock (U.S. EIA, 2019c) reflecting the very limited availability of light duty natural gas vehicles. Changes in the heavy-duty vehicle stock are not projected by the EIA.

5 Greenhouse Gas Emissions

Greenhouse Gas Emissions

Emissions Goals: The 2016 CEP calls for a 30% reduction in transportation sector GHGs relative to 1990 levels by 2025.

Drivers of Transportations Emissions: Three primary factors influence transportation sector GHG emissions: VMT, vehicle energy efficiency, and vehicle fuel type. Reducing VMT, increasing vehicle energy efficiency, and switching to low-carbon fuels (e.g. electricity generated by renewable sources) will all help to reduce GHG emissions.

Historical Trend: As of 2015, transportation GHG emissions were between 12% (U.S. EPA, 2018) and 34% (VT ANR, 2019) above 1990 levels.

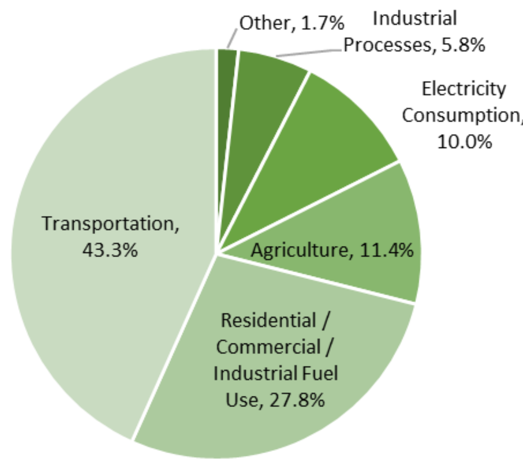


Figure 5-1. Vermont GHG Emissions by Sector, 2015 (VT ANR, 2019)

The transportation sector is the largest single source of GHG emissions in the state of Vermont as shown in Figure 5-1. These emissions are largely the result of burning fossil fuels, though a smaller portion are from biofuel combustion and PEV charging, as discussed in Sections 4.2 and 4.3. Three different transportation sector GHG emissions estimates are reported here.

The first emissions estimate is from the Vermont Greenhouse Gas Emissions Inventory produced by the Agency of Natural Resources (VT ANR, 2019). For the Inventory, transportation emissions are calculated using outputs from the EPA's Motor Vehicle Emissions Simulator, also known as MOVES. This "bottom up" approach simulates the GHG emissions, including methane and nitrous oxide, for vehicles registered in Vermont. MOVES accounts for a wide variety of factors that influence emissions including vehicle fuel and body type, vehicle age, vehicle speeds, and road types and is calibrated with both fuel sales and VMT data. MOVES is considered state-of-the-art for mobile source emissions (U.S. EPA, 2016). The transportation sector GHG emissions reported in the most recent edition of the state's GHG inventory are shown in Table 5-1 in millions of metric tons.

The GHG estimate from ANR is supplemented by two "top down" emissions estimates that calculate GHG emissions based on fuel sales data. The U.S. EPA (U.S. EPA, 2018) calculates CO_2 emissions by sector at the state level based on EIA fuel sales data. These emissions estimates are shown in Figure 5-2. Finally, GHG emissions estimates were calculated based on gasoline and diesel fuel sales data collected by the VT JFO and on the electricity demand estimates made in Section 4.3. This estimate breaks down emissions from ethanol and biodiesel separately using the sales volumes reported in Section 4.2 since these emissions come from biogenic sources. As noted previously and in the CEP, the net impact of biofuels atmospheric CO_2 is uncertain. Using the average GHG intensity of the New England grid, electricity related emissions were less than 1,500 metric tons for 2018 and thus are not visible on the figure. Both of these methods only calculate CO_2 emissions and do not include the impact of methane and nitrous oxide, which vary depending on vehicle technology and are approximately 1% of transportation emissions (U.S. EPA, 2016b).

It is notable that while all three GHG calculations showed a similar trend through approximately 2013, (increasing emissions from 1990, a peak in emissions in the mid-2000s, followed by a period of slowly declining emissions) the ANR method has shown substantially high growth in emissions in 2013-2015 than top down methods. It is worth monitoring this divergence going forward.

Table 5-1 Transportation Sector GHG Emissions (MMTCO$_2$e)

Emissions Source	Year							
	1990	2000	2005	2011	2012	2013	2014	2015
On-road Gasoline	2.64	3.20	3.29	2.75	2.70	2.73	3.03	3.16
On-road Diesel	0.41	0.66	0.69	0.65	0.63	0.62	0.54	0.57
Jet Fuel & Aviation Gasoline	0.08	0.07	0.17	0.10	0.10	0.10	0.09	0.11
Rail/Ship/Boats/Other Non-road	0.09	0.06	0.05	0.18	0.22	0.22	0.44	0.50
Total	3.22	3.99	4.20	3.68	3.65	3.67	4.10	4.34

Source: ANR, 2019

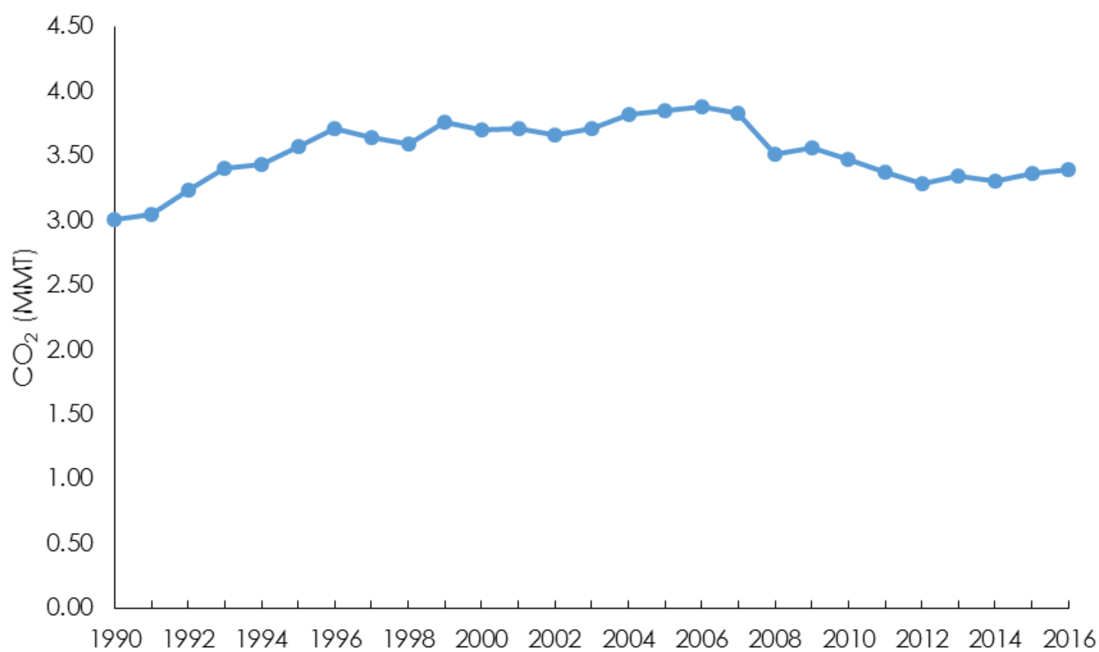


Figure 5-2. CO_2 Emissions: Transportation Sector Fossil Fuel Consumption (U.S. EPA, 2018)

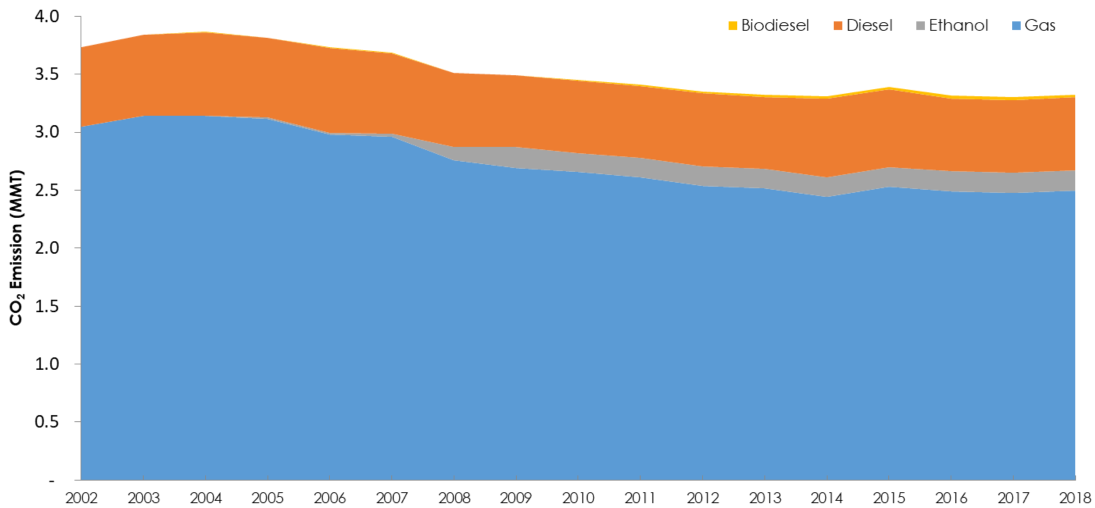


Figure 5-3. Vermont CO_2 Emissions from Gasoline and Diesel Sales

6 Freight Transport

Transporting goods and commodities to, from, within, and through Vermont is an essential component of the state economy and relies on the State's freight network. This network consists of the highway system, rail lines, airports, and pipelines. On average, the energy intensity of rail, 320 Btu per ton-mile, is less than a quarter of the energy intensity of truck transport, 1,390 Btu per ton-mile, (Grenzeback et al., 2013), though the specific energy intensity of each mode depends on a number of factors including utilization levels and the commodity being transported. For this reason, the CEP calls for doubling rail freight tonnage (Objective 7 in Table 1-1). As of 2014, rail was estimated to carry 7.3 million tons of freight in Vermont (ORNL, 2017; STB, 2017), an increase of 700,000 tons since 2011. The Vermont State Rail Plan will be updated in 2020 and updated freight estimates from the plan will be reported in the 2021 Profile.

Collecting freight data is challenging given the proprietary nature of the movement of goods, and the quality of freight flow estimates varies considerably depending upon mode choice and type of commodity. The Freight Analysis Framework (FAF), produced by the Oak Ridge National Laboratory (ORNL), is a primary source of freight information for Vermont and many other states. At the state level, FAF estimates freight movements that originate within, end within, or travel entirely within each state but does not provide estimates of pass-through freight traffic at this level (ORNL, 2017). The Surface Transportation Board's (STB) Carload Waybill Sample (STB, 2017) is the primary data source for pass-through tonnage for rail. The Carload Waybill Sample includes both public use data and a more detailed confidential sample that is considered the best source of rail data.

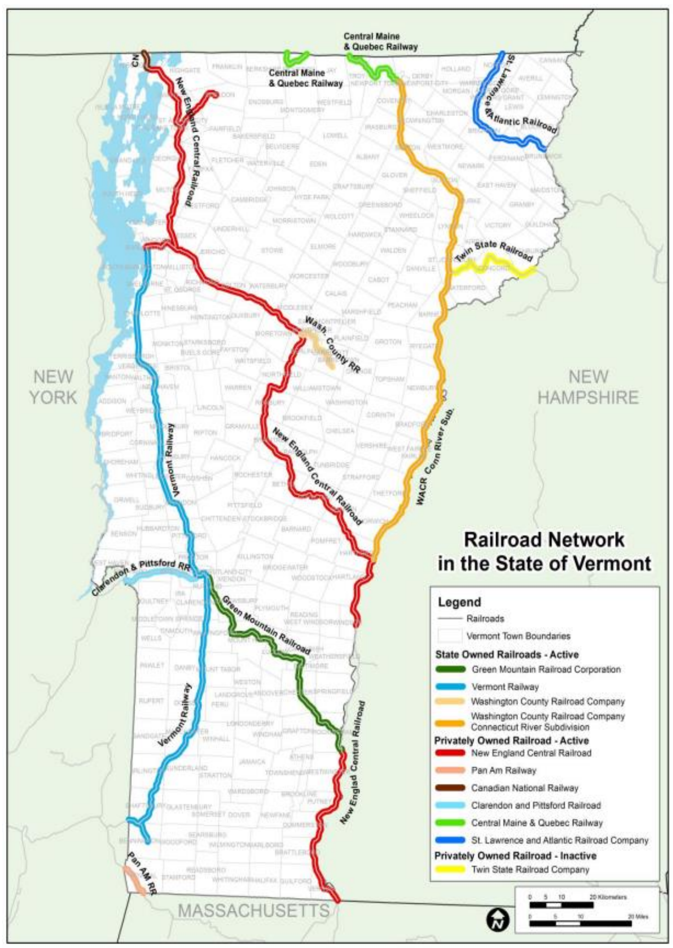


Figure 6-1. Vermont's Rail Network (VTrans, 2015)

The freight data presented here are the same as those presented in the 2017 Profile since the FAF has not been updated since that time. Data are drawn from Version 4 of the FAF for 2014 and the 2014 public use waybill (ORNL, 2017; STB, 2017). The confidential waybill was used to estimate 2011 rail-freight tonnage in the Vermont State Rail Plan (VTrans, 2015) and reported in the 2015 Profile. Rail tonnage for 2014 is estimated based on the growth in rail transport in the FAF and the public waybill sample. Pipeline freight conveyance is not considered in the Profile.

6.1 Vermont Rail Freight Infrastructure

The state rail network consists of 578 total miles of rail bed, all of which is available for freight service and which is serviced by short line and regional railroads (VTrans, 2015). A map of the current rail system is shown in Figure 6-1.

6.2 Modal Flows

As of 2014, transport of 43 million tons of freight originated and/or terminated in Vermont. This volume includes inbound and outbound freight movements as well as all freight movements internal to the State. Freight that passed through Vermont and neither originated nor terminated in the State is not included in this number.

Trucking was the dominant mode of transport for freight originating or terminating in Vermont, accounting for 90% of the total freight tonnage transported. Rail accounted for 8% of all freight tonnage. Rails' share of outbound freight transport (23%) was considerably higher than its share of transport within the State or inbound (both under 4%). A complete modal breakdown of all freight movements in 2014 in thousands of tons is shown in Table 6-1.

Table 6-1. Freight Movement in Vermont by Mode, 2014

Mode	Intrastate	Inbound	Outbound	Total
Truck	19,577	11,625	7,640	38,842
Rail	674	547	2,379	3,600
Multiple Modes/Mail	186	255	246	688
Air	0	9	8	17
Other	5	9	72	86
Total	20,442	12,446	10,345	43,233

Note: All values in thousands of tons.
Source: ORNL, 2017

Total 2014 rail tonnage is estimated in Table 6-2. This estimate is derived by applying annual growth rates from the FAF and public waybill sample to 2011 baseline values developed from the confidential waybill sample for the 2015 Vermont State Rail Plan. Overall pass-through rail tonnage was assumed to increase at a rate equal to that shown in public waybill sample from 2011 to 2014, approximately 3.3% on an annual basis. Rail traffic originating and/or terminating in Vermont was assumed to increase by 2.2% per year based on the 2012 to 2014 increase in the FAF. Based on these calculations overall 2014 rail tonnage is estimated at 7.3 million tons (ORNL, 2017; STB, 2017). This total represents an increase of 10% from the 2011 total. Note that the tonnage for intrastate, inbound, and outbound rail freight differs between Table 6-1 and Table 6-2 due to alternative estimates in FAF4 and the confidential waybill sample reported in the Vermont State Rail Plan, which are considered a more reliable estimate at the state level.

Table 6-2. Vermont Rail-Tonnage 2011 and 2014

	2011 Rail Tonnage	Annual Growth Rate	Estimated 2014 Rail Tonnage
Pass-through Tonnage	4.6 million	3.3%	5.1 million
Intrastate, Inbound & Outbound Tonnage	2.1 million	2.2%	2.2 million
Total	6.6 million		7.3 million

Note: 2011 components do not sum to total due to independent rounding
Source: VTrans, 2015; ORNL, 2017; STB, 2017

6.3 Future Freight Enhancements

Vermont's reliance upon trucking reflects an overall national trend as well as a lack of intermodal terminals to facilitate shipments of containers and trailers on flat car rolling stock. Standardized containers that can be exchanged between rail cars and flatbed trucks allow for a greater proportion of freight travel to be captured by non-highway modes. Currently, there are no intermodal facilities for making these types of container transfers along Vermont's relatively underutilized rail network, despite a significant proportion of Vermont's employment centers being located proximate to rail facilities. There are at least five transfer load facilities, but these only facilitate the transfer of bulk material or smaller shipment transfers from rail to truck, not container transfers (VTrans, 2015). Enhancement of Vermont's rail system—including "286" track upgrades to allow for heavier car loads and faster running speeds, removal of obstructions that limit access to double-stacked container cars, and development of intermodal facilities—will make rail more competitive with trucking and facilitate a shift to lower energy-intensity freight modes.

7 Progress toward 2016 CEP Transportation Targets

The 2016 CEP sets out three short-term transportation goals and nine supporting objectives with target dates in 2025 and 2030. The State's progress toward reaching each of these targets is assessed here. In order to conduct this assessment, the recent trend in each metric was extrapolated out to the target date and compared to the CEP goal for that date.[5] When the extrapolated value did not meet the CEP target, the State's progress was assessed as lagging behind the CEP target. For example, the CEP calls for the State to reduce transportation energy use from 49 trillion Btus to 39.2 trillion Btus by 2025. Extrapolating from the last five years of data, however, demonstrates that if current trends continue, transportation energy consumption will total 48.3 trillion Btus in 2025 and thus that energy reductions are currently lagging the CEP target.

Two figures are provided to illustrate the evaluation of each metric. The first shows the historical data for that metric and the linear path needed to achieve the associated CEP target over the full implementation period – from the date the target was first established through the target date. The second figure includes the extrapolated linear trend based on the last five years of data and an updated path needed to achieve the CEP target from the date of the most recently available data through the target date. Because the State is lagging in achieving these targets, the updated paths are steeper, that is, they require a larger annual change in order to hit the CEP targets than the initial pathways.

For many of these metrics, progress toward achieving the CEP objective is likely to lag in the early years due to the need for upfront investments and the slow pace of behavioral change. Metrics related to the vehicle fleet may be particularly slow to make progress given the long active life of cars and trucks. Thus, cases where the State is currently lagging in achieving a particular objective should not be taken to mean that the objective cannot be achieved but may indicate that additional policy measures are warranted. Nonetheless, a substantial gap between the extrapolated path and the linear trend required to meet the CEP targets may be evidence that additional policies may need to be implemented to achieve these targets.

[5] Current trends are calculated based on the last five years of data using a least-squares, linear-fitting process. This method finds the straight line which minimizes the sum of the squared residuals between the line and the empirical data points.

7.1 Goal 1: Reduce Total Transportation Energy Use

Goal: Reduce total transportation energy use by 20% from 2015 levels by 2025.

- Goal Set: 2016 CEP
- Period of Implementation: 2016 - 2025

Current Status: Progress lagging target.

- 2015 Baseline: 49 trillion Btus
- 2025 Target: 39.2 trillion Btus
- Extrapolated 2025 Value: 48.2 trillion Btus
- Average Reduction (2018-2025) Needed to Achieve Target: 1.1 trillion Btus per year

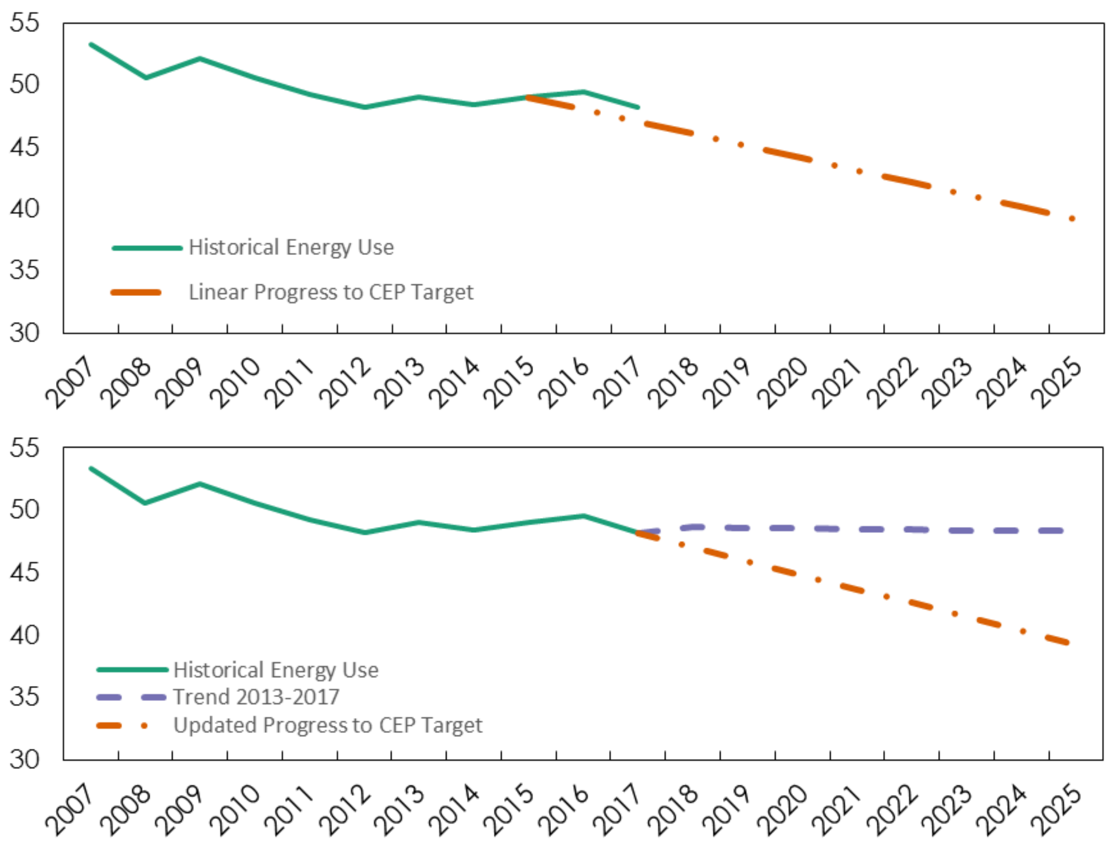


Figure 7-1. Trends in total transportation energy use

Outlook: Realizing sustained reductions in energy use of close to one trillion Btus per year will require a combination of reducing VMT and reducing the energy used per mile traveled by switching to more efficient vehicles such as PEVs. Even if VMT is held constant (and the most recent data show it increasing), fuel efficiency per mile traveled would have to increase by 25% to achieve this goal.

Data Sources: Sectoral energy consumption is tracked at the state level by the U.S. EIA as part of the State Energy Data System (SEDS).

7.2 Goal 2: Increase Renewable Energy Use in Transportation

Goal: Increase the share of renewable energy in all transportation to 10% by 2025.

- Goal Set: 2016 CEP
- Period of Implementation: 2016 - 2025

Current Status: Progress lagging target.

- 2015 Baseline: 5.5%
- 2025 Target: 10%
- Extrapolated 2025 Value: 6.3%
- Average Growth (2018-2025) Needed to Achieve Target: 0.51%

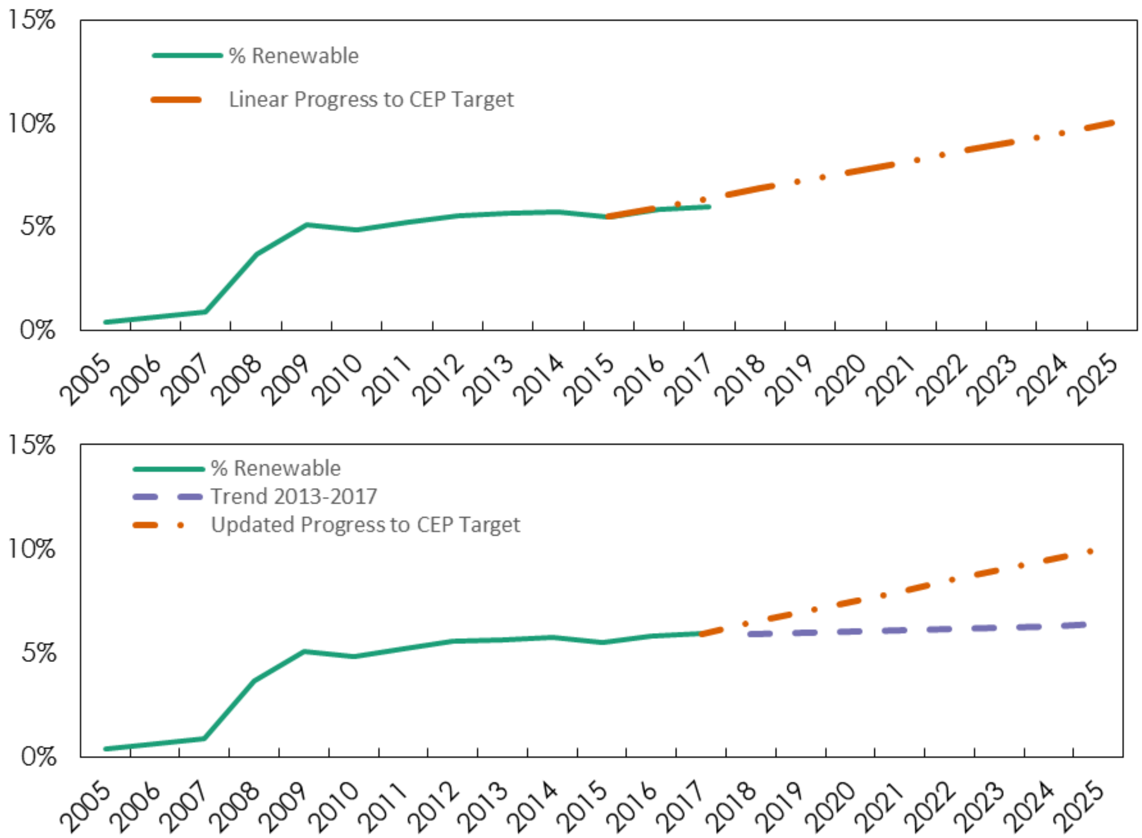


Figure 7-2. Trends in renewable energy use

Outlook: There is relatively little potential for growth in blended ethanol sales in the near future. Ethanol currently constitutes close to 10% of the at-the-pump gasoline sales in Vermont and the CEP does not support the promotion of E-85 infrastructure because of environmental concerns about ethanol production. Therefore, significant growth in biodiesel and especially renewable electricity use will be needed to achieve this goal.

Data Sources: Ethanol use is tracked at the state level by the U.S. EIA as part of the State Energy Data System (SEDS). Biodiesel use is tracked at the national level by the U.S. EIA. Electricity for vehicle charging can be estimated based on PEV registration data from VDMV.

7.3 Goal 3: Reduce Transportation GHG Emissions

Goal: Reduce transportation-emitted GHGs by 30% from 1990 levels by 2025.

- Goal Set: 2016 CEP
- Period of Implementation: 2016 - 2025

Current Status: Progress lagging target.

- 1990 Baseline: 3.22 million metric tons CO_2e
- 2025 Target: 2.25 million metric tons CO_2e
- Extrapolated 2025 Value: 6.01 million metric tons CO_2e
- Average Reduction (2018-2025) Needed to Achieve Target: 0.21 million metric tons CO_2e per year

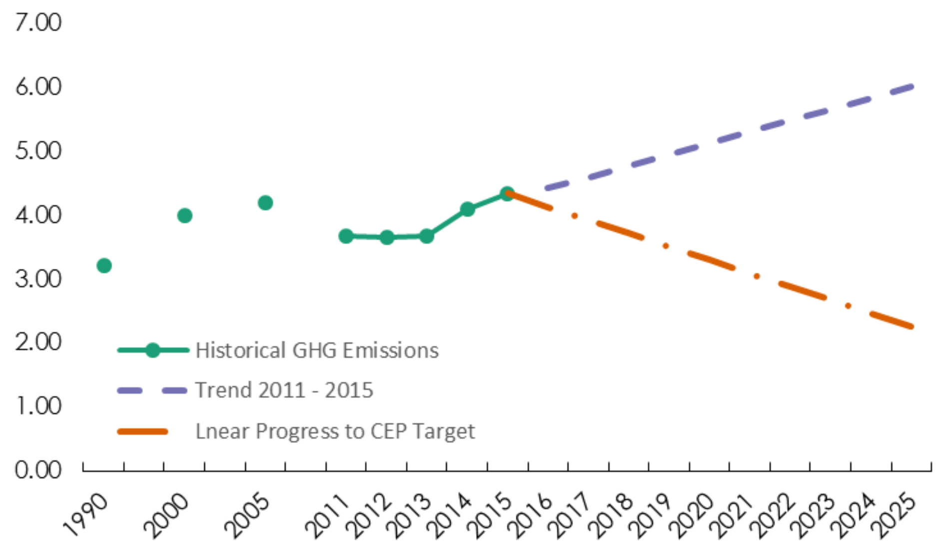


Figure 7-3. Trends in GHG emissions

Recent Trends: From 2011 through 2015 (the most recent years for which VT ANR data are available) GHG emissions have increase by 18%. Fuel sales based estimates do not show a comparable increase but all methods show current emissions above 1990 levels.

Outlook: Reducing GHG emission will require a combination of reducing VMT and reducing the GHG intensity per mile traveled by switching to vehicles with lower LCA GHG profiles such as PEVs.

Data Sources: The Vermont Greenhouse Gas Inventory produced by the Agency of Natural Resources.

7.4 Objective 1: Per Capita VMT

Objective: Hold VMT per capita to 2011 base year value of 11,390.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 11,390 miles
- 2030 Target: 11,390 miles
- Extrapolated 2030 Value: 14,008 miles
- Average Reduction (2018-2030) Needed to Achieve Target: 34.3 miles

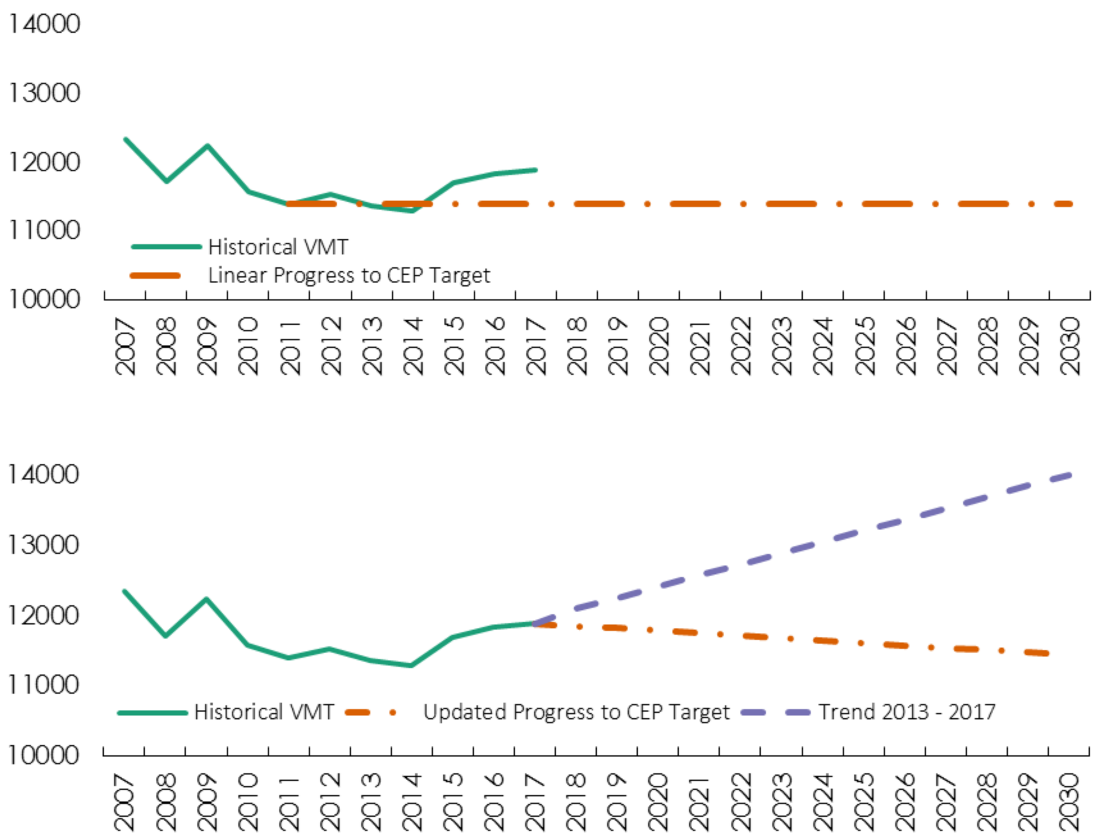


Figure 7-4. Trends in per capita VMT

Outlook: Achieving the CEP target will require stable per capita VMT from 2011 through 2030. Per capita VMT increased from 2011 to 2017 with increases of between 50 and 400 miles per year in 2015 – 2017.

Data Sources: VMT collected by VTrans as part of the Highway Performance Monitoring System; USCB population estimates.

7.5 Objective 2: Reduce SOV Commute Trips

Objective: Reduce share of SOV commute trips by 20% by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 79.5%
- 2030 Target: 64%
- Extrapolated 2030 Value: 85%
- Average Reduction (2018-2030) Needed to Achieve Target: 1.4% per year

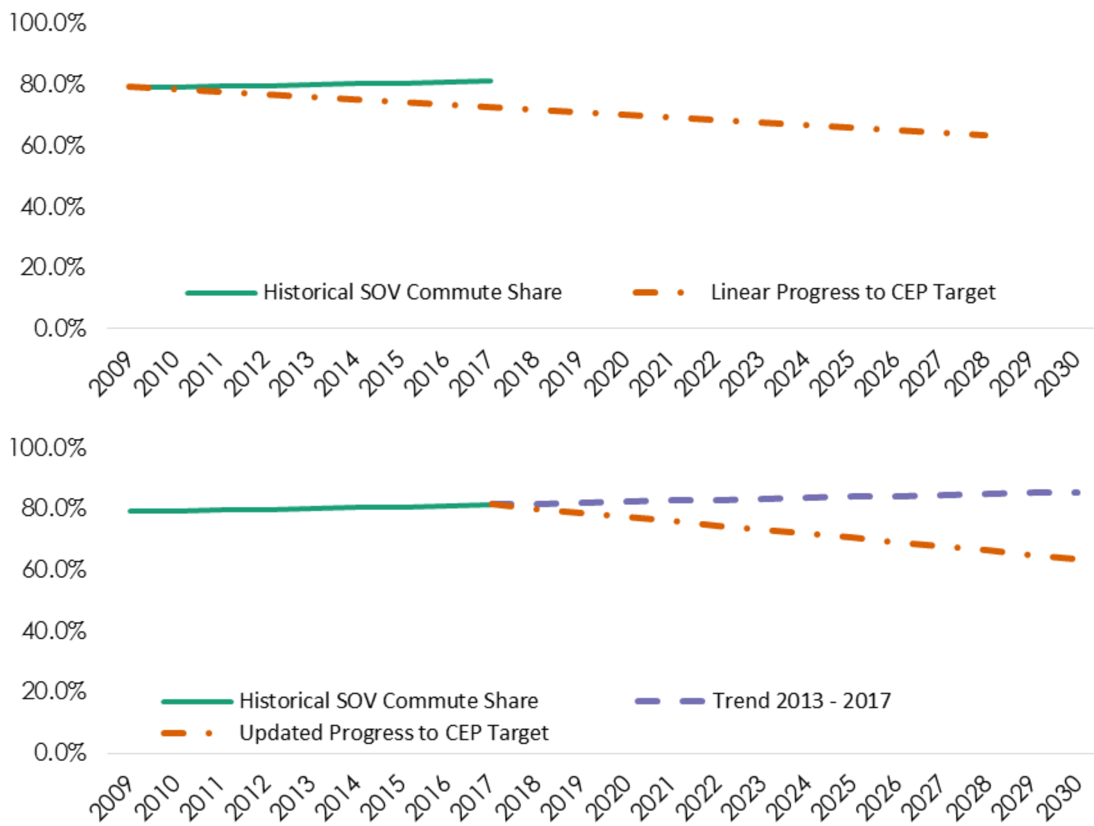


Figure 7-5. Trends in SOV commute mode share

Outlook: Achieving the CEP target will require an average decrease in SOV commute share of 1.4% per year from 2011 through 2030. SOV commute share increased from 2011 through 2017.

Data Sources: American Community Survey.

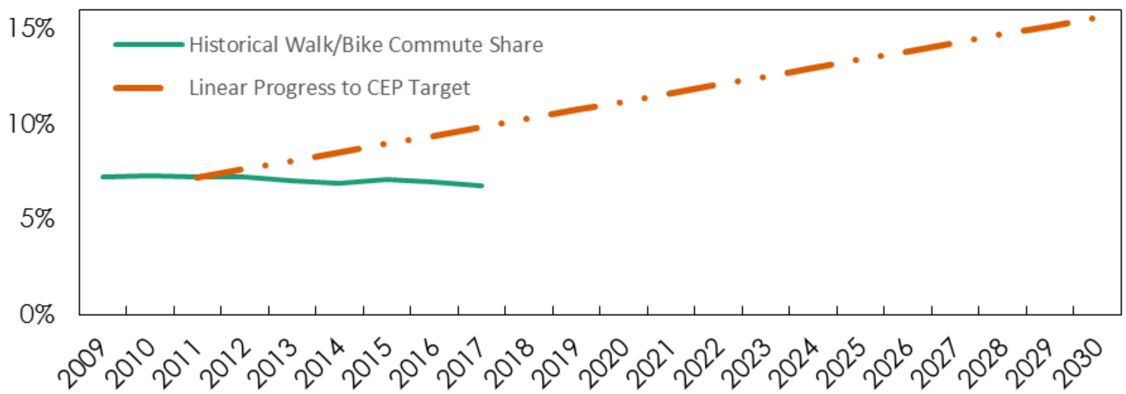
7.6 Objective 3: Increase Bike/Ped Commute Trips

Objective: Double the share of bicycle/pedestrian commute trips to 15.6% by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 7.2%%
- 2030 Target: 15.6%
- Extrapolated 2030 Value: 6.4%
- Average Growth (2018-2030) Needed to Achieve Target: 0.7% per year



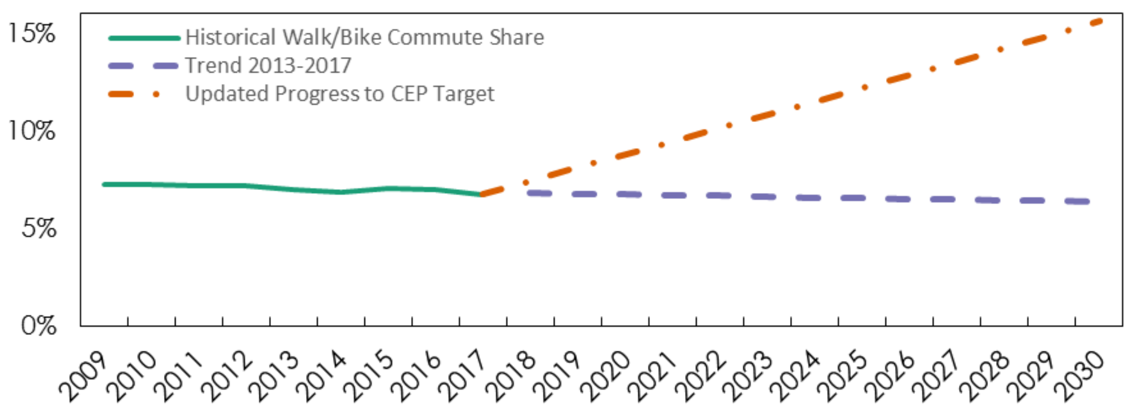


Figure 7-6. Trends in walk/bike commute mode share

Outlook: Achieving the CEP target will require an average increase in bicycle/pedestrian commute share of 0.68% per year from 2011 through 2030.

Data Sources: American Community Survey.

7.7 Objective 4: Increase State Park-and-Ride Spaces

Objective: Triple the number of state park-and-ride spaces to 3,426 by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 1,140
- 2030 Target: 3,426
- Extrapolated 2030 Value: 2,357
- Average Growth (2020-2030) Needed to Achieve Target: 162.5 parking spaces per year

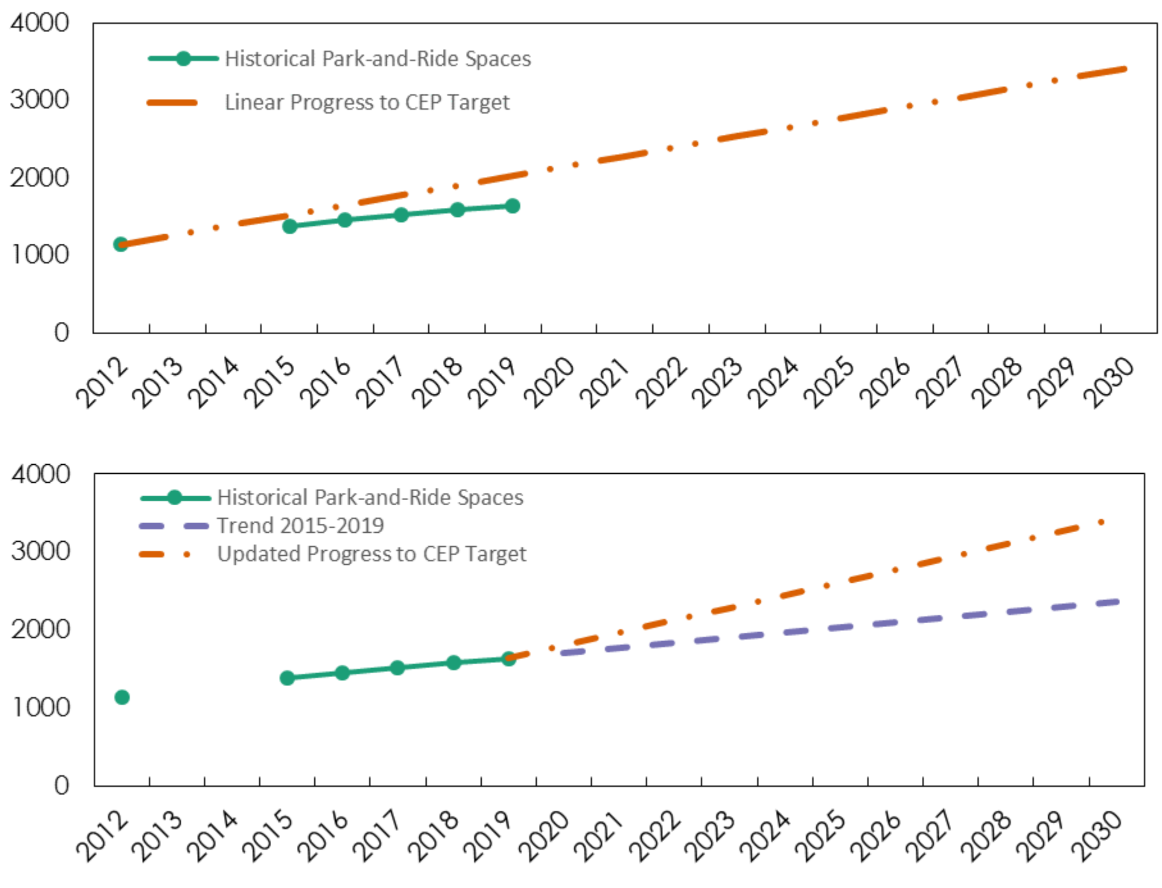


Figure 7-7. Trends in state park-and-ride spaces

Outlook: Achieving this target will require an average annual increase of 163 spaces per year.

Data Source: VTrans Municipal Assistance Bureau

7.8 Objective 5: Increase Transit Trips

Objective: Increase public transit ridership by 110%, to 8.7 million annual trips by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 4.57 million trips
- 2030 Target: 8.7 million trips
- Extrapolated 2030 Value: 4.01 million trips
- Average Growth (2020-2030) Needed to Achieve Target: 0.33 million trips per year

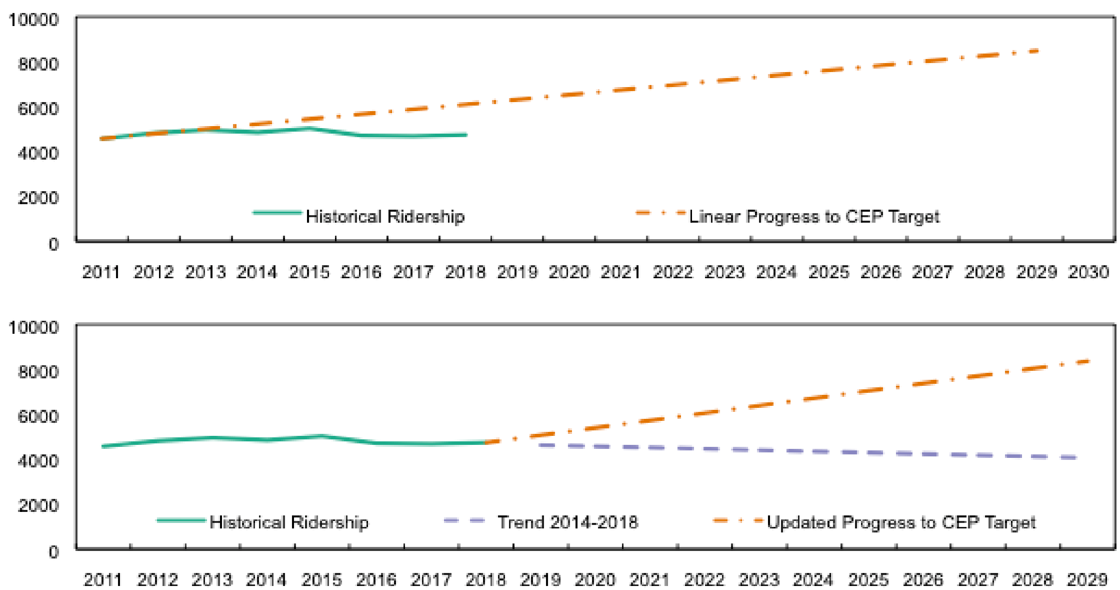


Figure 7-8. Trends in public transit ridership

Outlook: Achieving the CEP target will require an average annual increase of close to 330,000 trips per year. The number of transit rides peaked in FY 2015.

Data Source: VTrans Public Transit Route Performance Reviews.

7.9 Objective 6: Increase Passenger Rail Trips

Objective: Quadruple passenger rail trips to 400,000 Vermont-based trips by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 91,942 boardings and alightments
- 2030 Target: 400,000 boardings and alightments
- Extrapolated 2030 Value: 41,198 boardings and alightments
- Average Growth (2020-2030) Needed to Achieve Target: 25,672 boardings and alightments

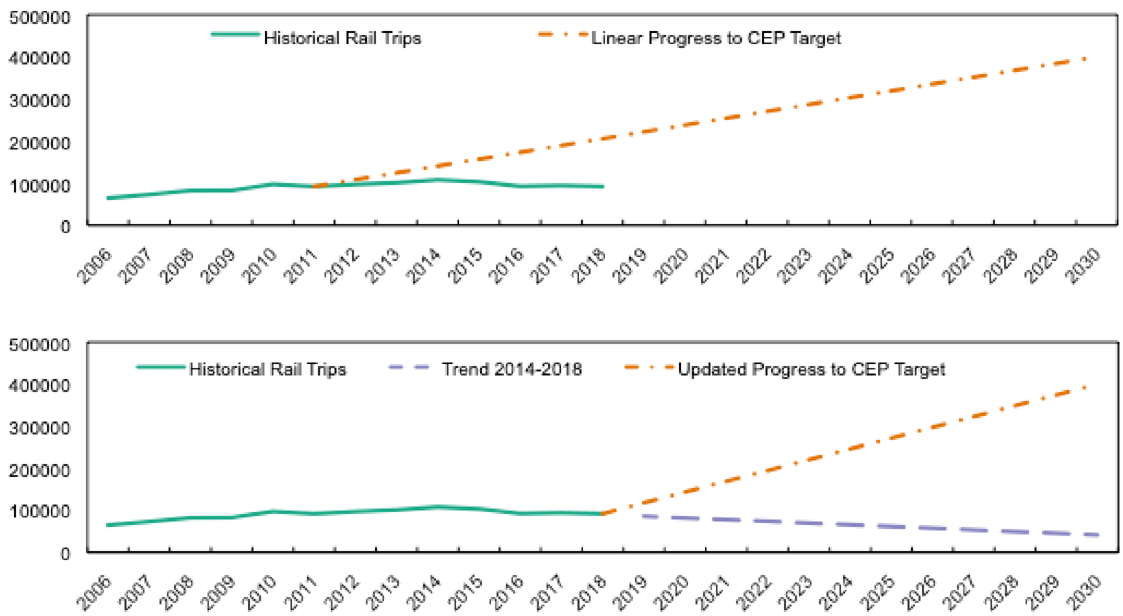


Figure 7-9. Trends in passenger rail trips

Outlook: Achieving the CEP target will require an average annual increase of close to 26,000 boardings and alightments per year. Combined boardings and alightments peaked in FY 2014 and were approximately 15% below that peak in FY 2018.

Note: Passenger rail ridership is measured as the *combined* boardings and alightments at Vermont Amtrak stations. This is consistent with the CEP objective but counts trips that begin and end at Vermont stations twice, so should not be equated with the *number* of rail trips in Vermont.

Data Source: VTrans.

7.10 Objective 7: Increase Rail-Based Freight

Objective: Double the amount of rail freight tonnage in the state from 2011 levels by 2030.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Current Status: Progress lagging target.

- 2011 Baseline: 6.6 million tons.
- 2014 Value: 7.3 million tons.

There is not yet enough data to establish a trend in rail freight tonnage. Additional freight rail data will be provided in the 2020 Vermont State Rail Plan. As of the 2011 baseline, achieving the CEP target would have required an average annual increase of 0.35 million tons per year from 2011 through 2030. Between 2011 and 2014 rail freight tonnage is estimated to have increased by 0.23 million tons per year.

Data Source: ORNL, 2017; STB, 2017.

7.11 Objective 8: Increase Registration of Electric Vehicles

Objective: Increase the number of electric vehicles registered in Vermont to 10% of the fleet by 2025.[6]

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2025

Status: Progress lagging target

- 2011 Baseline: 0.0%
- 2025 Target: 10% PEVs
- Extrapolated 2025 Value: 1.1% PEVs
- Average Growth (2019-2025) Needed to Achieve Target: 1.36% PEVs per year

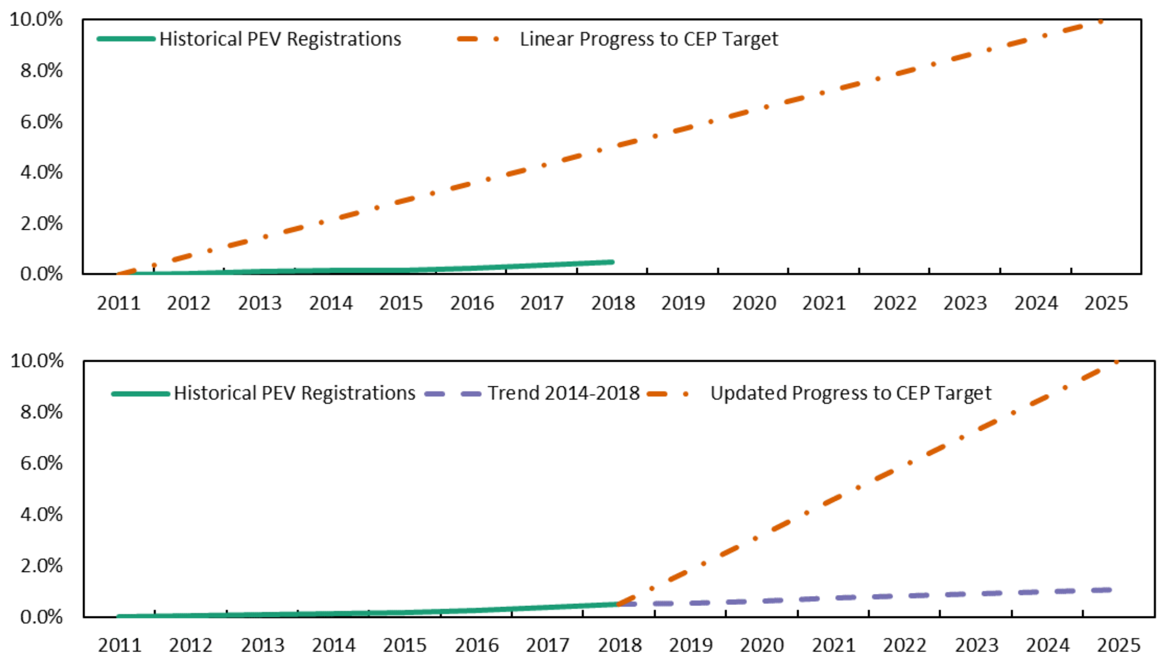


Figure 7-10. Trends in PEV registrations

Outlook: Achieving the CEP target will require an average annual increase in PEV registrations of 1.36% of the vehicle fleet from 2019 through 2025. This equates to approximately 8,400 new PEV registrations each year. To date the largest annual increase in PEV registrations occurred in 2017 which saw an increase of 805 PEV registrations. In 2018, the number of PEVs registered increase by 658.

Data Sources: VDMV/Drive Electric Vermont, FHWA

[6] Throughout the Profile, "the fleet" is assumed to refer to all on-road vehicles registered in Vermont unless specifically indicated otherwise. Thus achieving this objective would require that the number of electric vehicles registered in Vermont equal 10% of all on-road vehicle registrations by 2025.

7.12 Objective 9: Increase Renewable Fuel Use in Heavy-Duty Fleets

Objective: Increase the number of heavy duty vehicles that are renewably powered to 10% by 2025.

- Objective Set: 2011 CEP
- Period of Implementation: 2011 - 2030

Status: Additional data required to evaluate this objective.

This objective is challenging to measure since a diesel vehicle can drive on 100% biodiesel, 100% conventional diesel, or a mixture of the two. Therefore, it is infeasible to track this metric without tracking biodiesel sales. Electrification of the bus and truck fleet may also help achieve this goal and could be tracked in future Profiles.

8 Conclusions

The 2016 CEP sets forth an energy vision that requires rapid changes in transportation energy use patterns relative to trends in the recent past. This includes reducing total transportation energy use by 20% from 2015 levels and reducing GHG emissions by 30% from 1990 levels by 2025. Achieving this ambitious vision will require a combination of reducing VMT and reducing the energy used – and GHGs emitted – per mile traveled. Reducing VMT can be achieved by increasing vehicle occupancy and by shifting passenger vehicle trips to rail, transit, walking, and biking trips. VMT reductions may therefore be linked to Vermont's principal planning goal of compact settlements surrounded by working rural landscapes. Reducing energy use per mile traveled can be achieved by increasing the fuel economy of the vehicle fleet. Increasing vehicle electrification is one important avenue for improving fuel economy and reducing GHG intensity per mile traveled. PEVs offer significant energy and GHG savings relative to ICEV vehicles and are available in an increasing range of vehicle body types, electric ranges, and price points. The CEP provides targets related to many of these strategies.

To date, however, the State is lagging behind the rate of change required to achieve each of the targets evaluated in this Profile. Notably, most of the metrics related to travel behavior are currently trending in the opposite direction of the CEP targets. Per capita VMT and SOV commute mode share are both increasing. Simultaneously, biking and walking commute mode shares, public transit ridership, and passenger rail ridership are all showing slight declines over the last five years. PEV registrations are increasing but remain substantially below the levels need to reach the CEP target of 10% of the vehicle fleet by 2025. Renewable energy use in the transportation sector has remained relatively flat and the potential for growth in renewable energy usage may depend on a substantial increase in renewable biodiesel or accelerated vehicle electrification.

The current limited progress toward several CEP targets may suggest that additional policy initiatives should be considered. As laid out in the CEP, a variety of policy tools are available to accelerate progress toward these targets. These tools include strategic investments in needed infrastructure (e.g. supporting the deployment of PEV charging facilities and road infrastructure that supports safe walking and biking), public outreach/information sharing (e.g. the *Go! Vermont* program, partnerships with *Drive Electric Vermont*, the *Vermont Clean Cities Coalition,* and other groups), regulatory mechanisms (e.g. development standards that support smart growth), and market mechanisms (e.g. PEV purchase rebates).

Two areas of additional research may be helpful in this process. The first area of research is to evaluate the efficacy of each of the nine supporting objectives toward achieving the three overarching transportation goals (e.g. what are the relative impacts of increasing transit ridership and increasing PEV registration on total energy use?). The second area of research is to determine what policy levers can be used to achieve these objectives most effectively (e.g. are vehicle pricing incentives or improved charging infrastructure more effective at increasing PEV sales?). Greater understanding of these issues can support more effective strategies for achieving CEP targets.

9 References

ACS. 2010–2019. 2009–2017 Data Release of the American Community Survey. U.S. Census Bureau.

AFDC 2017. Hybrid and Plug-in Electric Vehicle Emissions Data Sources and Assumptions. U.S. Department of Energy. Accessed at https://www.afdc.energy.gov/vehicles/electric_emissions_sources.html August 2017.

AFDC 2019. Alternative Charging Station Locations. U.S. Department of Energy. Accessed at https://afdc.energy.gov/stations/#/find/nearest

Aultman-Hall, Lisa, and Jonathan Dowds. 2017. "Designing the All-in-One Vermont Transportation Survey." TRC Report #17-004. UVM Transportation Research Center. http://www.uvm.edu/trc/research-reports/.

Auto Alliance. 2019. "What Consumers Drive | Alliance of Automobile Manufacturers." https://autoalliance.org/whats-new/.

Bhat, C. R., S. Sen, and N. Eluru. The impact of demographics, built environment attributes, vehicle characteristics, and gasoline prices on household vehicle holdings and use. *Transportation Research Part B: Methodological*, Vol. 43, No. 1, Jan. 2009, pp. 1–18.

Blumenberg, Evelyn, Brian D. Taylor, Michael Smart, Kelcie Ralph, Madeline Wander, and Stephen Brumbaugh. 2013. The Next Generation of Travel: Statistical Analysis. Office of Transportation Policy Studies, FHWA. Accessed at https://www.fhwa.dot.gov/policy/otps/nextgen_stats/nextgen.pdf on 9/17/2015.

Busse, M. R., D. G. Pope, J. C. Pope, and J. Silva-Risso. The Psychological Effect of Weather on Car Purchases. *The Quarterly Journal of Economics*, Vol. 130, No. 1, Feb. 2015, pp. 371–414.

CARB, 2019. LCFS Pathway Certified Carbon Intensities. California Air Resources Board. https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm October 2019.

Clewlow, Regina R. 2016. "Carsharing and Sustainable Travel Behavior: Results from the San Francisco Bay Area." *Transportation Policy* 51 (October):158–64. https://doi.org/10.1016/j.tranpol.2016.01.013.

Clewlow, Regina R., and Gouri Shankar Mishra. 2017. "Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States." Institute of Transportation Studies, University of California, Davis.

Davis, Stacy C., and Robert G. Boundy. 2019. Transportation Energy Data Book: Edition 37 Prepared for the Vehicle Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy by the Oak Ridge National Laboratory. August 2019.

Dill, Jennifer, Nathan McNeil, and Steven Howland. 2019. "Effects of Peer-to-Peer Carsharing on Vehicle Owners' Travel Behavior." *Transportation Research Part C: Emerging Technologies* 101 (April): 70–78. https://doi.org/10.1016/j.trc.2019.02.007.

Drive Electric Vermont, 2019. Electric Vehicles Registered in Vermont.

EERE, 2018. Gross Domestic Product Continues to Outpace Vehicle Miles Traveled. U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy. https://www.energy.gov/eere/vehicles/articles/fotw-1023-april-2-2018-gross-domestic-product-continues-outpace-vehicle-miles

Fassett, Shannon, 2019. Vermont licensure data. Provided by Shannon Fassett, Vermont Department of Motor Vehicles. August 2019.

FHWA, 2008–2018. Highway Statistics 2007–2017. Published by the Office of Highway Policy Information, Highway Statistics Series of the Federal Highway Administration.

FHWA, 2015. Average Annual Miles per Driver by Age Group. Published by the Office of Highway Policy Information of the Federal Highway Administration. Accessed at https://www.fhwa.dot.gov/ohim/onh00/bar8.htm on September 17, 2015.

FTA, 2019. Fiscal Year 2019 Low or No-Emission (Low-No) Bus Program Projects. Federal Transit Administration. https://www.transit.dot.gov/funding/grants/fiscal-year-2019-low-or-no-emission-low-no-bus-program-projects

GMP, 2019. Sample electricity demand at GMP stations. Provided by Green Mountain Power, August 2019.

Grenzeback, L.R., A. Brown, M.J. Fischer, N. Hutson, C.R. Lamm, Y.L. Pei, L. Vimmerstedt, A.D. Vyas, and J.J. Winebrake. 2013. Freight Transportation Demand: Energy-Efficient Scenarios for a Low-Carbon Future. Transportation Energy Futures Series. Prepared by Cambridge Systematics, Inc., and the National Renewable Energy Laboratory (Golden, CO) for the U.S. Department of Energy, Washington, DC. DOE/GO-102013-3711. 82 pp.

Jones, Kenneth, 2019. VisaVue credit card receipt information. Provided by Kenneth Jones, Vermont Agency of Commerce and Community Development, October 2019.

KFH Group, 2017. Public Transit Route Performance Reviews: Annual Report for State Fiscal Year 2016. Vermont Agency of Transportation.

KFH Group, 2019. Public Transit Route Performance Reviews: Annual Report for State Fiscal Year 2018. Vermont Agency of Transportation.

Lovejoy, Kristin, Susan Handy, and Marlon G. Boarnet. 2013. Impacts of Carsharing on Passenger Vehicle Use and Greenhouse Gas Emissions. California Air Resource Board.

Martin, Elliot, Susan Shaheen, and Jeffrey Lidicker. 2010. "Impact of Carsharing on Household Vehicle Holdings." *Transportation Research Record: Journal of the Transportation Research Board* 2143 (October):150–58. https://doi.org/10.3141/2143-19.

McCahill, Chris. "VMT Growth Continued, Slowed in 2016." State Smart Transportation Initiative. Accessed at http://www.ssti.us/2017/05/vmt-growth-continued-slowed-in-2016/ Aug. 2017.

McDonald, Ross, 2019. Personal Communication with Ross McDonald, Go! Vermont Program Manager, Vermont Agency of Transportation, August 2019.

McGuckin, N, and A Fucci. 2018. "Summary of Travel Trends 2017 National Household Travel Survey." FHWA-PL-18-019. Federal Highway Administration. https://doi.org/10.2172/885762.

McMullen, B. Starr and Nathan Eckstein, 2012. "Relationship between Vehicle Miles Traveled and Economic Activity." *Transportation Research Record: Journal of the Transportation Research Board.* https://doi.org/10.3141%2F2297-03

Nelson, Arthur C. 2017. "Compact Development Reduces VMT: Evidence and Application for Planners—Comment on 'Does Compact Development Make People Drive Less?'" *Journal of the American Planning Association* 83 (1): 36–41. https://doi.org/10.1080/01944363.2016.1246378.

Onat, Nuri Cihat, Murat Kucukvar, and Omer Tatari. 2015. "Conventional, Hybrid, Plug-in Hybrid or Electric Vehicles? State-Based Comparative Carbon and Energy Footprint Analysis in the United States." *Applied Energy* 150 (Supplement C):36–49. https://doi.org/10.1016/j.apenergy.2015.04.001.

ORNL, 2017. Freight Analysis Framework Version 4. Developed by the Center for Transportation Analysis in the Oak Ridge National Laboratory. Accessed at http://faf.ornl.gov/fafweb/Extraction0.aspx in August 2017.

Pappis, Costa, 2019. Amtrak Vermont Station Ridership FY 2003–2018. Provided by Costa Pappis, Modal Planner, Vermont Agency of Transportation, August 2019.

Pelletier, David, 2019. Public Transit Route Performance Report source data. Provided by David Pelletier, Vermont Agency of Transportation, August 2019.

RSG, 2016. "LRTP Public Opinion Survey." Vermont Agency of Transportation. Accessed at http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/VTrans%20LRTP%20Survey%20Report%20Final%202016.pdf in August 2017.

Shaheen, Susan A., and Adam P. Cohen. 2013. "Carsharing and Personal Vehicle Services: Worldwide Market Developments and Emerging Trends." *International Journal of Sustainable Transportation* 7 (1):5–34. https://doi.org/10.1080/15568318.2012.660103.

STB, 2017. Revised 2014 Public Use Waybill Sample. Industry Data of the Surface Transportation Board. Accessed at https://www.stb.gov/stb/industry/econ_waybill.html in August 2017.

Stevens, Mark R. 2017. "Does Compact Development Make People Drive Less?" *Journal of the American Planning Association* 83 (1): 7–18. https://doi.org/10.1080/01944363.2016.1240044.

USCB, 2012. Intercensal Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2010. Created by the U.S. Census Bureau, Population Division. Accessed at https://www.census.gov/data/tables/time-series/demo/popest/intercensal-2000-2010-state.html in August 2019.

USCB, 2016. Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018. Created by the U.S. Census Bureau, Population Division. Accessed at https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2016_PEPAGESEX&prodType=table in August 2019.

U.S. DOE & U.S. EPA. 2019. "Fuel Economy Guide: Datasets for All Model Years (1984–2020." http://www.fueleconomy.gov/feg/download.shtml.

USDOT, 2010. The 2009 National Household Travel Survey. Accessed at http://nhts.ornl.gov/.

USDOT, 2018. The 2017 National Household Travel Survey. Accessed at http://nhts.ornl.gov/.

U.S. EIA, 2014. Today in Energy: Gasoline prices tend to have little effect on demand for car travel. U.S. Energy Information Agency. https://www.eia.gov/todayinenergy/detail.php?id=19191

U.S. EIA, 2017. Today in Energy: Crossover utility vehicles blur distinction between passenger cars and light trucks. U.S. Energy Information Agency. https://www.eia.gov/todayinenergy/detail.php?id=31352.

U.S. EIA, 2019. State Energy Data System (SEDS): 1960–2017 (Complete). Profile data from the U.S. Energy Information Administration. Accessed at http://www.eia.gov/state/seds/seds-data-complete.cfm in August 2019.

U.S. EIA, 2019b. Short-Term Energy Outlook: Regular Gasoline Retail Prices. U.S. Energy Information Agency. https://www.eia.gov/outlooks/steo/realprices/real_prices.xlsx

U.S. EPA 2016. Using MOVES for Estimating State and Local Inventories of Onroad Greenhouse Gas Emissions and Energy Consumption. U.S. Environmental Protection Agency.

U.S. EPA 2016b. Greenhouse Gas Inventory Guidance Direct Emissions from Mobile Combustion Sources. U.S. Environmental Protection Agency.

U.S. EPA, 2018. State Level CO_2 Emissions from Fossil Fuel Combustion. U.S. Environmental Protection Agency. Accessed at https://www.epa.gov/statelocalenergy/state-co2-emissions-fossil-fuel-combustion.

U.S. EPA, 2019. Basic Information about the Emission Standards Reference Guide for On-road and Nonroad Vehicles and Engines. U.S. Environmental Protection Agency. https://www.epa.gov/emission-standards-reference-guide/basic-information-about-emission-standards-reference-guide-road

VCGI, 2019. VT Park and Rides. Vermont Center for Geographic Information. http://geodata.vermont.gov/datasets/VTrans::vt-park-and-rides/data?geometry=-80.827%2C42.208%2C-64.139%2C44.992

VDMV, 2015. Vermont Motor Vehicle Registration Database 2011 through 2015. Provided by the Vermont Department of Motor Vehicles of the Agency of Transportation.

VDMV, 2017. Vermont Motor Vehicle Registration Database 2015 through 2017. Provided by the Vermont Department of Motor Vehicles of the Agency of Transportation.

VDMV, 2019. Vermont Motor Vehicle Registration Database 2017 through 2019. Provided by the Vermont Department of Motor Vehicles of the Agency of Transportation.

VDPS, 2016. Comprehensive Energy Plan 2016. Prepared by the Vermont Department of Public Service, January 2016.

VT ANR, 2018. Greenhouse Gas Emissions Inventory Update: Brief (1990 - 2015). Vermont Agency of Natural Resources.

VT DEC, 2019. VW Environmental Mitigation Funds. Vermont Department of Environmental Conservation. https://dec.vermont.gov/air-quality/vw. Accessed October, 2019.

VT JFO, 2019. Gas and Diesel Tax Revenue and Gallons Sold -Monthly Update, Vermont Legislative Joint Fiscal Office. Accessed at https://ljfo.vermont.gov/search/filter/keywords/gas/subject/transportation, on September, 2019.

VTrans, 2015. Vermont State Rail Plan—2015: DRAFT: June 19, 2015. Vermont Agency of Transportation.

VTrans, 2017a. Vermont Park and Rides. Created by VTrans Park-and-Ride Program. Accessed at http://parkandrides.vermont.gov/ on August 31, 2017.