Vermont Energy Investment Corporation

Two Rivers-Ottauquechee Regional Energy Modeling

A Pathway to Reaching Vermont's Energy Goals

Appendix J: Outputs and Methodology

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Vermont Energy Investment Corporation

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Contents

A. Introduction

This document supplements the regional energy plans created by each Regional Planning Commission (RPC). It was developed by Vermont Energy Investment Corporation (VEIC) as documentation to modeling work performed for the RPCs. An award from the Department of Energy's SunShot Solar Market Pathways program funded the creation of a detailed statewide total energy supply and demand model. The VEIC team used the statewide energy model as a foundation for the region-specific modeling efforts. More detailed methodology is included at the end of this report.

B. Statewide Approach

Historic information was primarily drawn from the Public Service Department's Utility Facts 2013[1] and EIA data. Projections came from the Total Energy Study (TES)[2], the utilities' Committed Supply[3], and stakeholder input.

Demand Drivers

Each sector has a unit that is used to measure activity in the sector. That unit is the "demand driver" because in the model it is multiplied by the energy intensity of the activity to calculate energy demand.

RPC	Annual Growth
Addison	0.00%
Bennington	0.02%
Central VT	0.12%
Chittenden	0.48%
Lamoille	1.46%
Northwest	0.87%
NVDA	0.21%
Rutland	-0.27%
Southern Windsor	0.24%
Two Rivers	**0.29%**
Windham	0.34%

The population change for each region is calculated from town data in *Vermont Population Projections 2010-2030*.[4] Growth rates are assumed constant through 2050.

People per house are assumed to decrease from 2.4 in 2010 to 2.17 in 2050. This gives the number of households, the basic unit and demand driver in the model for residential energy consumption.

[1] Vermont Public Service Department, *Utility Facts 2013*, http://publicservice.vermont.gov/sites/dps/files/documents/Pubs_Plans_Reports/Utility_Facts/Utility%20Facts%202013.pdf

[2] Vermont Public Service Department, *Total Energy Study: Final Report on a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals.* December 8, 2014. http://publicservice.vermont.gov/sites/psd/files/Pubs_Plans_Reports/TES/TES%20FINAL%20Report%2020141208.pdf.

[3] Vermont Public Service Department provided the data behind the graph on the bottom half of page E.7 in *Utility Facts 2013.* It is compiled from utility Integrated Resource Plans

[4] Jones, Ken, and Lilly Schwarz, *Vermont Population Projections-2010-2030*, August, 2013. http://dail.vermont.gov/dail-publications/publications-general-reports/vt-population-projections-2010-2030.

Projected change in the **energy demand from the commercial sector** was based on commercial sector data in the TES. The demand driver for the commercial sector is commercial building square feet which grow almost 17% from 2010 to 2050.

The team entered total **industrial consumption** by fuel from the TES directly into the model. It grows from 1.1 TBtu in 2010 to 1.4 TBtu in 2050.

Transportation energy use is based on projections of vehicle miles traveled (VMT). VMT peaked in 2006 and has since declined slightly.[5] Given this, and Vermont's efforts to concentrate development and to support alternatives to single occupant vehicles, VMT per capita is assumed to remain flat at 12,000.

The regional models use two scenarios. The **reference scenario** assumes a continuation of today's energy use patterns, but does not reflect the Vermont's renewable portfolio standard or renewable energy or greenhouse gas emissions goals. The main changes over time in the reference scenario are more fuel efficient cars because of CAFE standards and the expansion of natural gas infrastructure. The **90% x 2050 $_{\text{VEIC}}$ scenario** is designed to achieve the goal of meeting 90% of Vermont's total energy demand with renewable sources. It is adapted from the TES TREES Local scenarios. It is a hybrid of the high and low biofuel cost scenarios, with biodiesel or renewable diesel replacing petroleum diesel in heavy duty vehicles and electricity replacing gasoline in light duty vehicles. Despite a growing population and economy, energy use declines because of efficiency and electrification. Electrification of heating and transportation has a large effect on the total demand because the electric end uses are three to four times more efficient than the combustion versions they replace.

C. Regionalization Approach

The demand in the statewide model was broken into the state's planning regions. Residential demand was distributed according to housing units using data from the American Community Survey. Commercial and industrial demand was allocated to the regions by service-providing and goods-producing NAICS codes respectively. Fuel use in these sectors was allocated based on existing natural gas infrastructure. In the commercial sector, it was assumed that commercial fuel use per employee has the same average energy intensity across the state. All commercial natural gas use was allocated to the regions currently served by natural gas infrastructure, and the rest of the fuel was allocated to create equal consumption by employee.

The industrial sector was assumed to be more diverse in its energy consumption. In the industrial sector, natural gas was allocated among the regions currently served by natural gas based on the number of industrial employees in each region. Other non-electric fuels were

[5] Jonathan Dowds et al., "Vermont Transportation Energy Profile," October 2015, http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Vermont%20Transportation%20Energy%20Profile%202015.pdf.

distributed among regions without access to natural gas, as it was assumed that other non-electric fuels were primarily used for combustion purposes, and that purpose could likely be served more cheaply with gas.   Transportation demand was primarily regionalized through population. The passenger rail sector of transportation demand was regionalized using Amtrak boarding and alighting data to create percentages of rail miles activity by region.[6] The freight rail sector of transportation was regionalized using the following approach: in regions with freight rail infrastructure, activity level was regionalized by share of employees in goods-producing NAICS code sectors. Regions without freight rail infrastructure were determined using a Vermont Rail System map and then assigned an activity level of zero.[7] A weighting factor was applied to regions with freight rail infrastructure to bring the total activity level back up to the calculated statewide total of freight rail short-ton miles in Vermont. Each region's share of state activity and energy use is held constant throughout the analysis period as a simplifying assumption.

D. Results

The numbers below show the results of the scenarios in "final units," sometimes referred to as "site" energy. This is the energy households and businesses see on their bills and pay for. Energy analysis is sometimes done at the "source" level, which accounts for inefficiency in power plants and losses from transmission and distribution power lines. The model accounts for those losses when calculating supply, but all results provided here are on the demand side, so do not show them.

The graphs below show the more efficient 90% x 2050 $_{\text{VEIC}}$ scenario, which is one path to reduce demand enough to make 90% renewable supply possible. This scenario makes use of wood energy, but there is more growth in electric heating and transportation to lower total energy demand. Where the graphs show "Avoided vs. Reference," that is the portion of energy that we do not need to provide because of the efficiency in this scenario compared to the less efficient Reference scenario.

[6] National Association of Railroad Passengers, "Fact Sheet: Amtrak in Vermont," 2016, https://www.narprail.org/site/assets/files/1038/states_2015.pdf.
[7] Streamlined Design, "Green Mountain Railroad Map" (Vermont Rail System, 2014), http://www.vermontrailway.com/maps/regional_map.html.

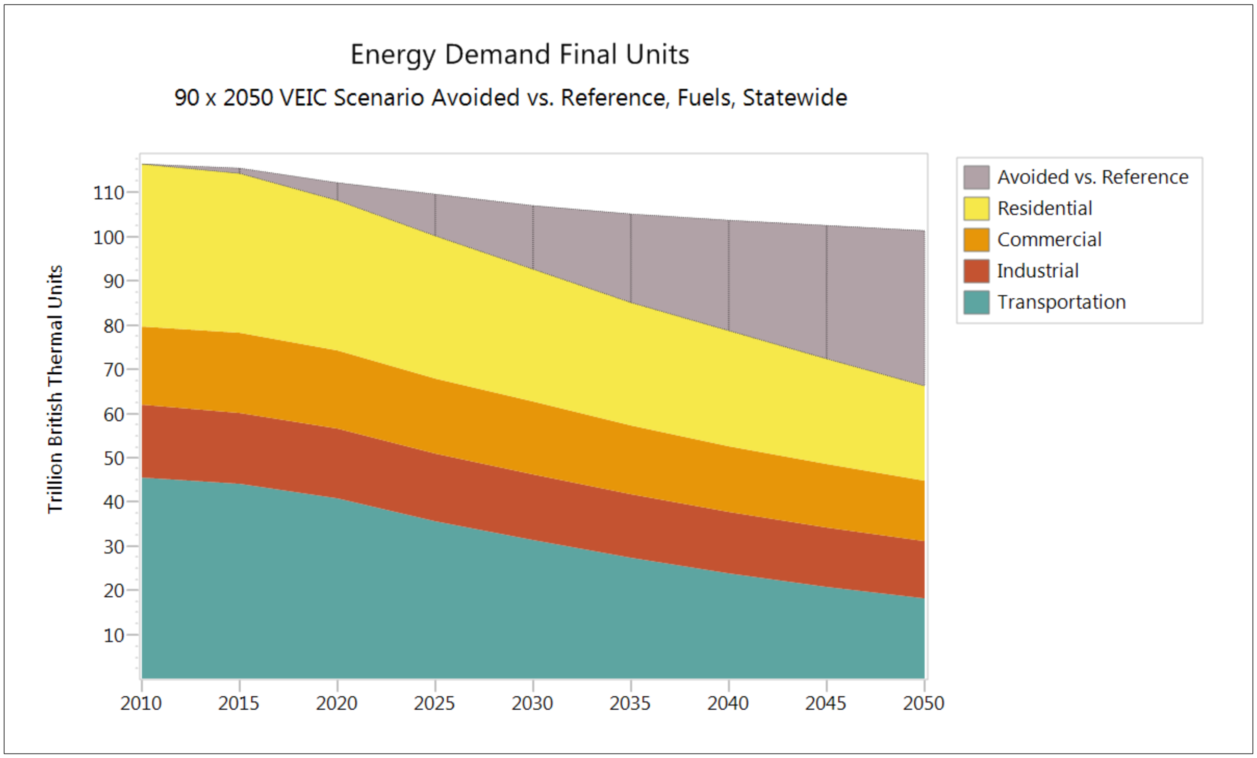

Figure 1 - Statewide energy consumption by sector, 90% x 2050 $_{VEIC}$ scenario compared to the reference scenario

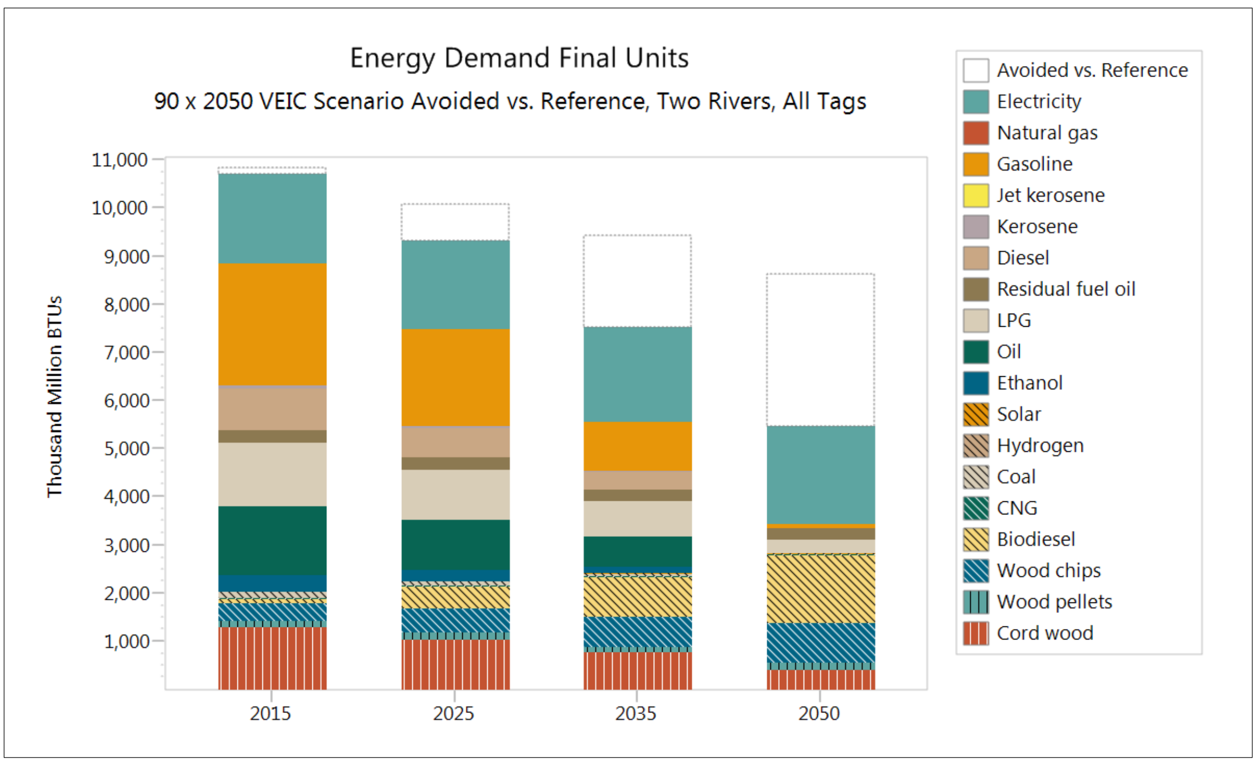

Figure 2: Regional energy consumption by fuel. 90% x 2050 $_{VEIC}$ scenario compared to the reference scenario

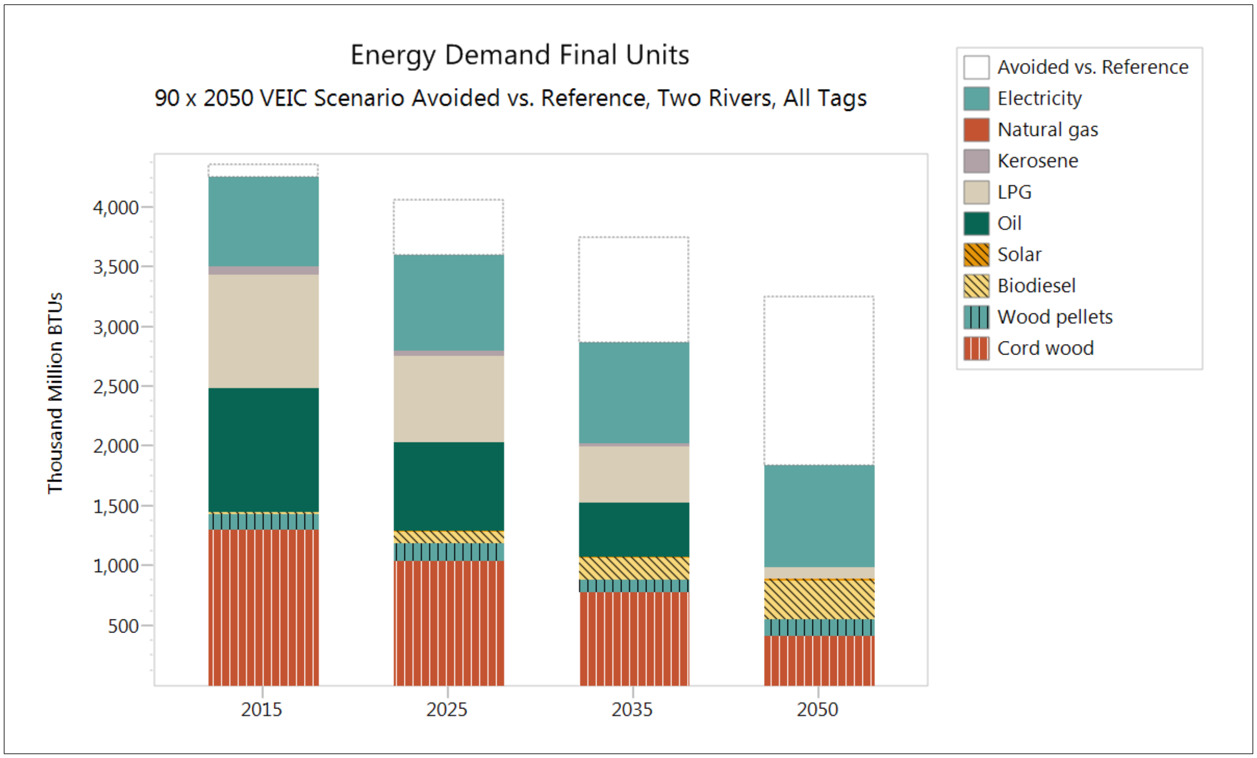

Figure 3: Regional residential energy consumption by fuel, 90% x 2050 VEIC scenario compared to the reference scenario

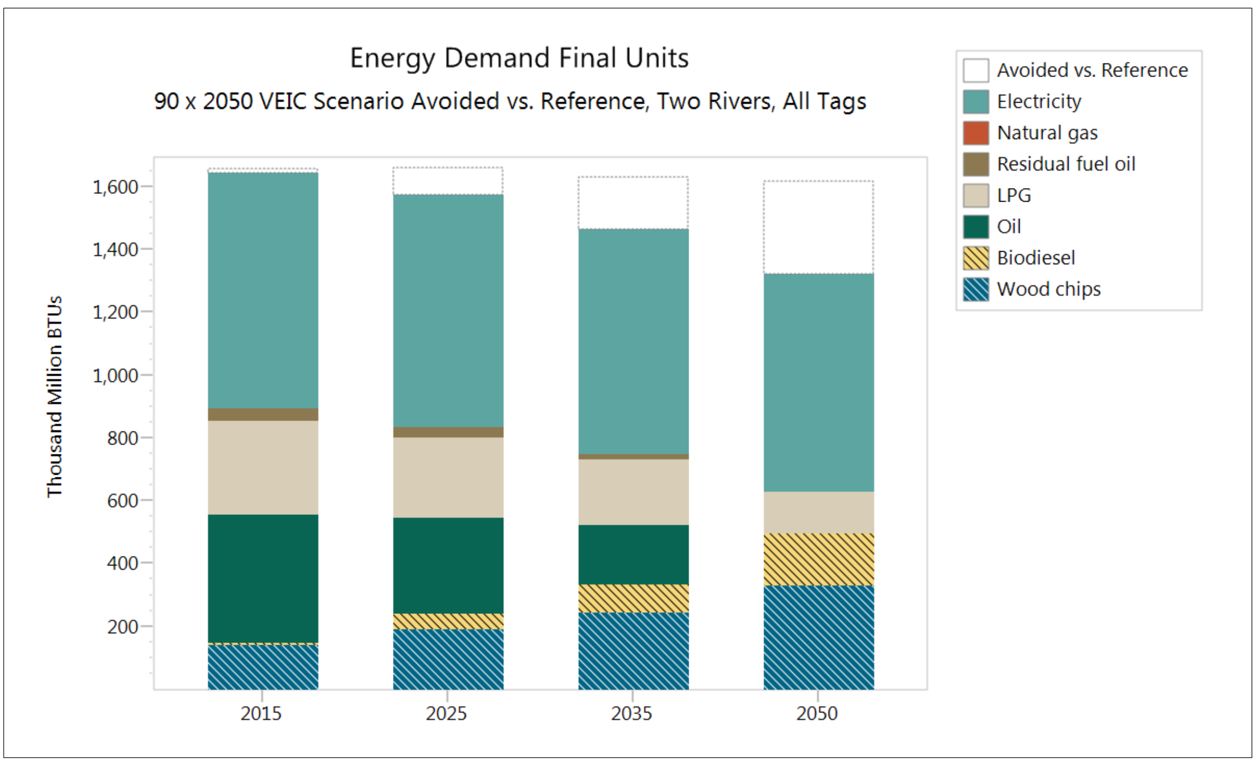

Figure 4: Regional commercial energy consumption by fuel, 90% x 2050 VEIC scenario compared to the reference scenario

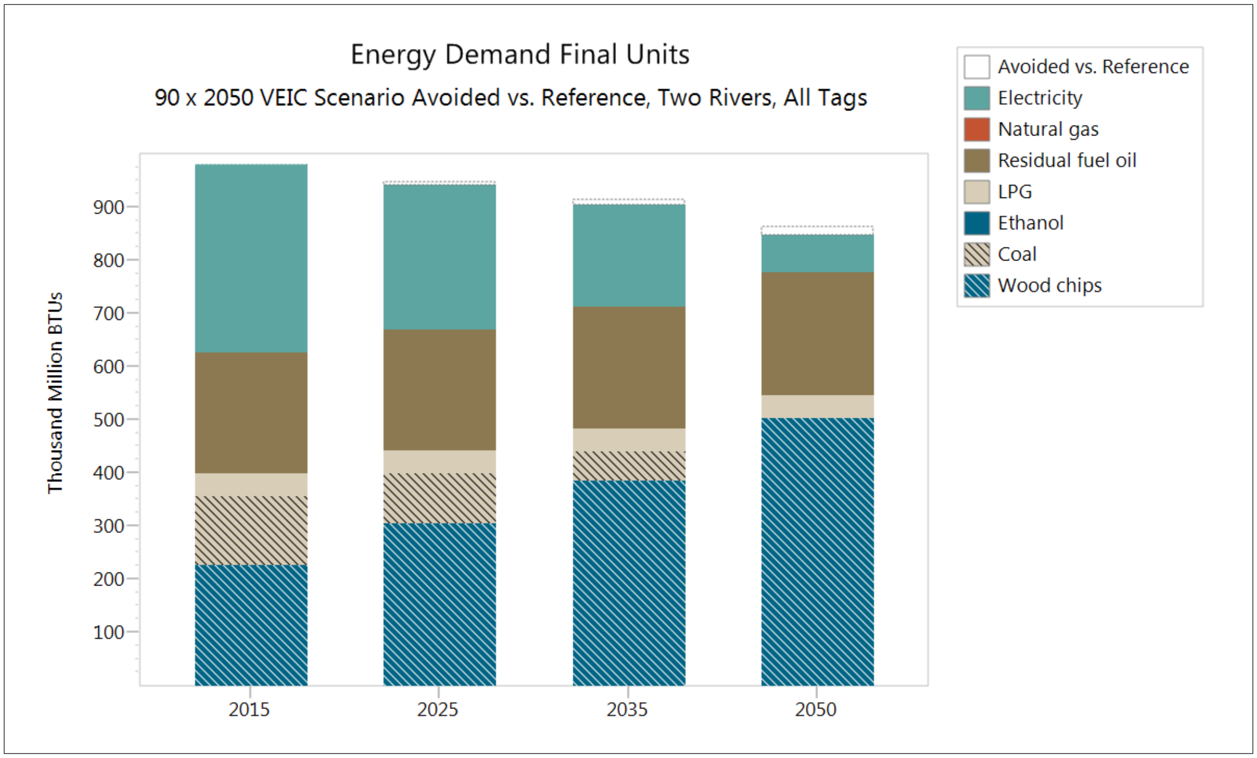

Figure 5: Regional industrial energy consumption by fuel

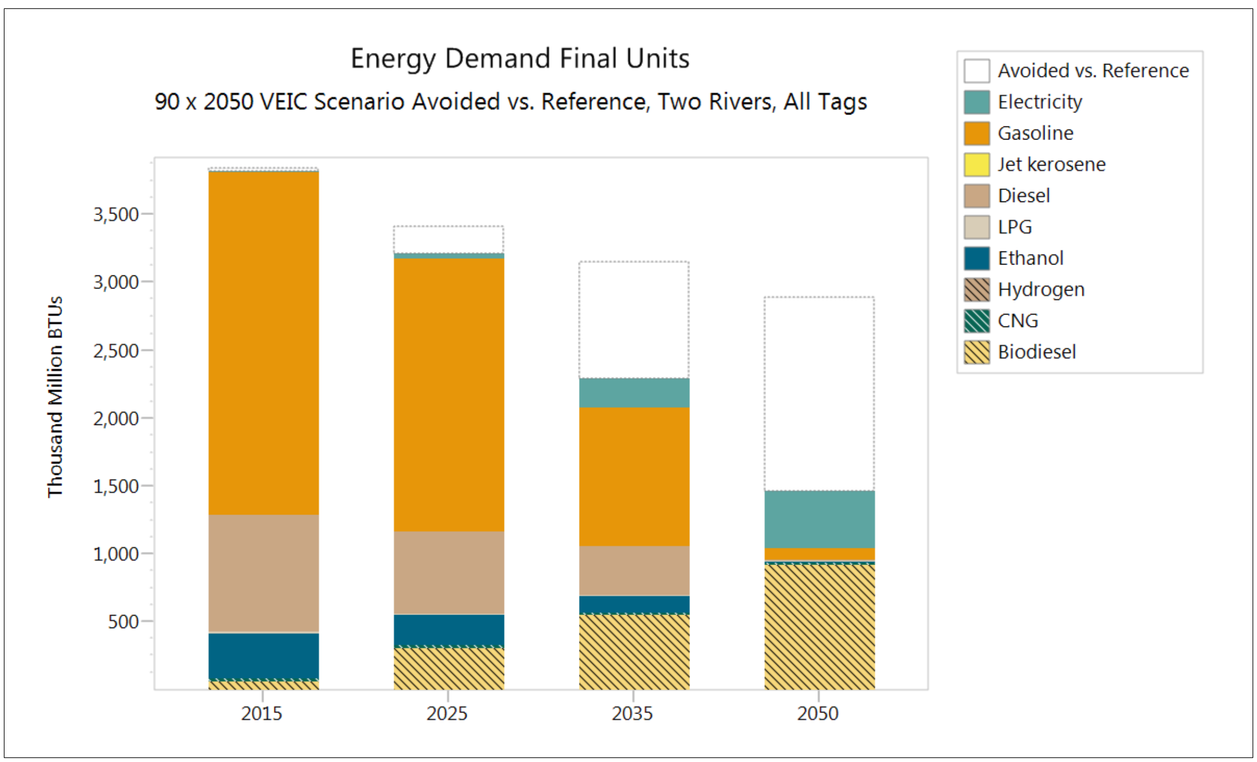

Figure 6: Regional transportation energy consumption by fuel

E. Detailed Sources and Assumptions

Residential

The TES provides total fuels used by sector. We used a combination of industry data and professional judgement to determine demand inputs at a sufficiently fine level of detail to allow for analysis at many levels, including end use (heating, water heating, appliances, etc.), device (boiler, furnace, heat pump) or home-type (single family, multi-family, seasonal, mobile). Assumptions for each are detailed below. All assumptions for residential demand are at a per-home level.

Space Heating

The team determined per home consumption by fuel type and home type. EIA data on Vermont home heating provides the percent share of homes using each type of fuel. 2009 Residential energy consumption survey (RECS) data provided information on heating fuels used by mobile homes. Current heat pumps consumption estimates were found in a 2013 report prepared for Green Mountain Power by Steve LeTendre entitled *Hyper Efficient Devices: Assessing the Fuel Displacement Potential in Vermont of Plug-In Vehicles and Heat Pump Technology*. Future projections of heat pump efficiency were provided by Efficiency Vermont Efficient Products and Heat Pump program experts.

Additional information came from the following data sources:

- 2010 Housing Needs Assessment[8]
- EIA Vermont State Energy Profile[9]
- 2007-2008 VT Residential Fuel Assessment[10]
- EIA Adjusted Distillate Fuel Oil and Kerosene Sales by End Use[11]

The analyst team made the following assumptions for each home type:

- Multi-family units use 60% of the heating fuel used by single family homes, on average, due to assumed reduced size of multi-family units compared to single-family units. Additionally, where natural gas is available, the team assumed a slightly higher percentage of multi-family homes use natural gas as compared to single family homes, given the high number of multi-family units located in the Burlington area, which is

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[8] Vermont Housing and Finance Agency, “2010 Vermont Housing Needs Assessment,” December 2009 http://www.vtaffordablehousing.org/documents/resources/623_1.8_Appendix_6_2010_Vermont_Housing_Needs_Assessment.pdf.

[9] U.S. Energy Information Administration, “Vermont Energy Consumption Estimates, 2004,” https://www.eia.gov/state/print.cfm?sid=VT

[10] Frederick P. Vermont Residential Fuel Assessment: for the 2007-2008 heating season. Vermont Department of Forest, Parks and Recreation. 2011.

[11] U.S. Energy Information Administration, “Adjusted Distillate Fuel Oil and Kerosene Sales by End Use,” December 2015, https://www.eia.gov/dnav/pet/pet_cons_821usea_dcu_nus_a.htm.

served by the natural gas pipeline. The team also assumed that few multi-family homes rely on cordwood as a primary heating source.

- Unoccupied/Seasonal Units: On average, seasonal or unoccupied homes were expected to use 10% of the heating fuel used by single family homes. For cord wood, we expected unoccupied or seasonal homes to use 5% of heating fuel, assuming any seasonal or unoccupied home dependent on cord wood are small in number and may typically be homes unoccupied for most of the winter months (deer camps, summer camps, etc.)
- Mobile homes—we had great mobile home data from 2009 RECS. As heat pumps were not widely deployed in mobile homes in 2009 and did not appear in the RECs data, we applied the ratio of oil consumed between single family homes and mobile homes to estimated single family heat pump use to estimate mobile home heat pump use.
- The reference scenario heating demand projections were developed in line with the TES reference scenario. This included the following: assumed an increase in the number of homes using natural gas, increase in the number of homes using heat pumps as a primary heating source (up to 37% in some home types), an increase in home heated with wood pellets, and drastic decline in homes heating with heating oil. Heating system efficiency and shell efficiency were modeled together and, together, were estimated to increase 5-10% depending on the fuel type. However, heat pumps are expected to continue to rapidly increase in efficiency (becoming 45% more efficient, when combined with shell upgrades, by 2050). We also reflect some trends increasing home sizes.
- In the 90% x 2050 $_{\text{VEIC}}$ scenario, scenario heating demand projections were developed in line with the TES TREES Local scenarios, a hybrid of the high and low biofuel cost scenarios. This included the following: assumed increase in the number of homes using heat pumps as a primary heating source (up to 70% in some home types), an increase in home heated with wood pellets, a drastic decline in homes heating with heating oil and propane, and moderate decline in home heating with natural gas. Heating system efficiency and shell efficiency were modeled together and were estimated to increase 10%-20% depending on the fuel type. However, heat pumps are expected to continue to rapidly increase in efficiency (becoming 50% more efficient, when combined with shell upgrades by 2050). We also reflect some trends increasing home sizes.

Lighting

Lighting efficiency predictions were estimated by Efficiency Vermont products experts.

Water Heating

Water heating estimates were derived from the Efficiency Vermont Technical Reference Manual.[12]

[12] Efficiency Vermont, "Technical Reference User Manual (TRM): Measure Savings Algorithms and Cost Assumptions, No. 2014-87," March 2015, http://psb.vermont.gov/sites/psb/files/docketsandprojects/electric/majorpendingproceedings/TRM%20User%20Manual%20No.%202015-87C.pdf.

Appliances and Other Household Energy Use:

EnergyStar appliance estimates and the Efficiency Vermont Electric Usage Chart[13] provided estimates for appliance and other extraneous household energy uses.

Using the sources and assumptions listed above, the team created a model that aligned with the residential fuel consumption values in the TES.

Commercial

Commercial energy use estimates are entered in to the model as energy consumed per square foot of commercial space, on average. This was calculated using data from the TES.

Industrial

Industrial use was entered directly from the results of the TES data.

Transportation

The transportation branch focused on aligning with values from the Total Energy Study (TES) Framework for Analysis of Climate-Energy-Technology Systems (FACETS) data in the transportation sector in the Business as Usual (BAU) scenario. The VEIC 90% x 2050 scenario was predominantly aligned with a blend of the Total Renewable Energy and Efficiency Standard (TREES) Local High and Low Bio scenarios in the transportation sector of FACETS data. There were slight deviations from the FACETS data, which are discussed in further detail below.

Light Duty Vehicles

Light Duty Vehicle (LDV) efficiency is based on a number of assumptions: gasoline and ethanol efficiency were derived from the Vermont Transportation Energy Profile.[14] Diesel LDV efficiency was obtained from underlying transportation data used in the Business as Usual scenario for the Total Energy Study, which is referred to as TES Transportation Data below. Biodiesel LDV efficiency was assumed to be 10% less efficient than LDV diesel efficiency.[15] Electric vehicle (EV) efficiency was derived from an Excel worksheet from Drive Electric Vermont. The worksheet calculated EV efficiency using the number of registered EVs in Vermont, EV efficiency associated with each model type, percentage driven in electric mode by model type (if a plugin hybrid vehicle), and the Vermont average annual vehicle miles traveled. LDV electric vehicle efficiency was assumed to increase at a rate of .6%. This was a calculated weighted average of 100-mile electric vehicles, 200-mile electric vehicles, plug-in 10 gasoline hybrid and

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[13] Efficiency Vermont, "Electric Usage Chart Tool," https://www.efficiencyvermont.com/tips-tools/tools/electric-usage-chart-tool.

[14] Jonathan Dowds et al., "Vermont Transportation Energy Profile," October 2015, http://vtrans.vermont.gov/sites/aot/files/planning/documents/planning/Vermont%20Transportation%20Energy%20Profile%202015.pdf.

[15] U.S. Environmental Protection Agency: Office of Transportation & Air Quality, "Biodiesel," *Www.fueleconomy.gov*, accessed August 19, 2016, https://www.fueleconomy.gov/feg/biodiesel.shtml.

plug-in 40 gasoline hybrid vehicles from the Energy Information Administration Annual Energy Outlook.[16]

Miles per LDV was calculated using the following assumptions: data from the Vermont Agency of Transportation provided values for statewide vehicles per capita and annual miles traveled.[17] The total number of LDVs in Vermont was sourced TES Transportation Data. The calculated LDV miles per capita was multiplied by the population of Vermont and divided by the number of LDVs to calculate miles per LDV.

The number of EVs were sourced directly from Drive Electric Vermont, which provided a worksheet of actual EV registrations by make and model. This worksheet was used to calculate an estimate of the number of electric vehicles using the percentage driven in electric mode by vehicle type to devalue the count of plug-in hybrid vehicles. Drive Electric Vermont also provided the number of EVs in the 90% x 2050_{VEIC} scenario.

Heavy Duty Vehicles

Similar to the LDV vehicle efficiency methods above, HDV efficiency values contained a variety of assumptions from different sources. A weighted average of HDV diesel efficiency was calculated using registration and fuel economy values from the Transportation Energy Data Book.[18] The vehicle efficiency values for diesel and compressed natural gas (CNG) were all assumed to be equal.[19] Diesel efficiency was reduced by 10% to represent biodiesel efficiency.[20] Propane efficiency was calculated using a weighted average from the Energy Information Administration Annual Energy Outlook table for Freight Transportation Energy Use.[21]

In the 90% x 2050_{VEIC} scenario, it was assumed HDVs will switch entirely from diesel to biodiesel or renewable diesel by 2050. This assumption is backed by recent advances with biofuel. Cities such as Oakland and San Francisco are integrating a relatively new product called renewable diesel into their municipal fleets that does not gel in colder temperatures and has a much lower overall emissions factor.[22] Historically, gelling in cold temperatures has prevented higher percentages of plant-based diesel replacement products.

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[16] U.S. Energy Information Administration, "Light-Duty Vehicle Miles per Gallon by Technology Type," *Annual Energy Outlook 2015*, 2015, https://www.eia.gov/forecasts/aeo/data/browser/#/?id=50-AEO2016&cases=ref2016~ref_no_cpp&sourcekey=0.

[17] Jonathan Dowds et al., "Vermont Transportation Energy Profile."

[18] Ibid.

[19] "Natural Gas Fuel Basics," *Alternative Fuels Data Center*, accessed August 19, 2016, http://www.afdc.energy.gov/fuels/natural_gas_basics.html.

[20] U.S. Environmental Protection Agency: Office of Transportation & Air Quality, "Biodiesel."

[21] US Energy Information Administration (EIA), "Freight Transportation Energy Use, Reference Case," *Annual Energy Outlook 2015*, 2015, http://www.eia.gov/forecasts/aeo/data/browser/#/?id=58-AEO2015&region=0-0&cases=ref2015&start=2012&end=2040&f=A&linechart=ref2015-d021915a.6-58-AEO2015&sourcekey=0.

[22] Oregon Department of Transportation and U.S. Department of Transportation Federal Highway Administration, "Primer on Renewable Diesel," accessed August 29, 2016, http://altfueltoolkit.org/wp-content/uploads/2004/05/Renewable-Diesel-Fact-Sheet.pdf.

Although there has been some progress toward electrifying HDVs, the VEIC 90% x 2050 scenario does not include electric HDVs. An electric transit bus toured the area and gave employees of BED, GMTA, and VEIC a nearly silent ride around Burlington. The bus is able to fast charge using an immense amount of power that few places on the grid can currently support. The California Air Resources Board indicated a very limited number of electric HDVs are in use within the state.[23] Anecdotally, Tesla communicated it is working on developing an electric semi-tractor that will reduce the costs of freight transport.[24]

The total number of HDVs was calculated using the difference between the total number of HDVs and LDVs in 2010 in the Vermont Transportation Energy Profile and the total number of LDVs from TES Transportation Data.[25] HDV miles per capita was calculated using the ratio of total HDV miles traveled from the 2012 Transportation Energy Data Book and the 2012 American Community Survey U.S. population estimate.[26,27] The total number of HDVs and HDV miles per capita were combined with the population assumptions outlined above to calculate miles per HDV.

Rail

The rail sector of the transportation branch consists of two types: freight and passenger. Currently in Vermont, freight and passenger rail use diesel fuel.[28,29] The energy intensity (Btu/short ton-mile) of freight rail was obtained from the U.S Department of Transportation Bureau of Transportation Statistics.[30] A 10-year average energy intensity of passenger rail (Btu/passenger mile) was also obtained from the U.S Department of Transportation Bureau of Transportation Statistics.[31] Passenger miles were calculated using two sets of information. First, distance between Vermont Amtrak stations and the appropriate Vermont border location were estimated using Google Maps data. Second, 2013 passenger data was obtained from the

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[23] California Environmental Protection Agency Air Resources Board, "Draft Technology Assessment: Medium- and Heavy-Duty Battery Electric Trucks and Buses," October 2015, https://www.arb.ca.gov/msprog/tech/techreport/bev_tech_report.pdf.

[24] Elon Musk, "Master Plan, Part Deux," *Tesla*, July 20, 2016, https://www.tesla.com/blog/master-plan-part-deux.

[25] Jonathan Dowds et al., "Vermont Transportation Energy Profile."

[26] "Transportation Energy Data Book: Edition 33" (Oak Ridge National Laboratory, n.d.), accessed August 18, 2016.

[27] U. S. Census Bureau, "Total Population, Universe: Total Population, 2012 American Community Survey 1-Year Estimates," *American Fact Finder*, 2012, http://factfinder.census.gov/bkmk/table/1.0/en/ACS/12_1YR/B01003/0100000US.

[28] US Energy Information Administration (EIA), "Freight Transportation Energy Use, Reference Case."

[29] Vermont Agency of Transportation Operations Division - Rail Section, "Passenger Rail Equipment Options for the Amtrak Vermonter and Ethan Allen Express: A Report to the Vermont Legislature," January 2010, http://www.leg.state.vt.us/reports/2010ExternalReports/253921.pdf.

[30] U.S. Department of Transportation: Office of the Assistant Secretary for Research and Technology Bureau of Transportation Statistics, "Table 4-25: Energy Intensity of Class I Railroad Freight Service," accessed August 26, 2016, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_25.html.

[31] U.S. Department of Transportation: Office of the Assistant Secretary for Research and Technology Bureau of Transportation Statistics, "Table 4-26: Energy Intensity of Amtrak Services," accessed August 26, 2016, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_26.html.

National Association of Railroad Passengers.[32] Combined, these two components created total Vermont passenger miles. We used a compound growth rate of 3% for forecast future passenger rail demand in the 90% x 2050 $_{VEIC}$ scenario, consistent with the historical growth rates of rail passenger miles in Vermont.[33] Passenger rail is assumed to completely transform to electric locomotion. Freight rail is assumed to transform to biodiesel or renewable diesel.

Air

The total energy of air sector used appropriate FACETS data values directly. The air sector is expected to continue using Jet Fuel in both scenarios.

[32] National Association of Railroad Passengers, "Fact Sheet: Amtrak in Vermont," 2016, https://www.narprail.org/site/assets/files/1038/states_2015.pdf.
[33] Joseph Barr, AICP et al., "Vermont State Rail Plan: Regional Passenger Rail Forecasts."