Contents

Vermont Energy Investment Corporation

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Statewide and RPC energy modeling

Outputs and Methodology through August, 2015

Statewide Model Methodology

Vermont Energy Investment Corporation created and revised a model of the demand and supply of total energy in Vermont. Historic information was primarily drawn from the Public Service Department's Utility Facts 2013 and Energy Information Administration (EIA) data. Projections came from the Total Energy Study (TES), the utilities' Committed Supply, and stakeholder input.

The population is assumed to grow at 0.35% per year.[1] 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 in the model for residential energy consumption.

The commercial demand driver was area of commercial buildings. This data and projections were extracted from inputs for the TES.

Industrial energy use was entered as the actual totals for each energy type, without a driver specified in the model.

Transportation energy use is based on projections of vehicle miles traveled (VMT). This metric has risen through most of American history and people had assumed it would continue to do so. However, VMT peaked in 2006 and has since declined slightly. Given this, and Vermont's efforts to concentrate development and to support alternatives to single occupant vehicles, VMT is assumed in the model to remain flat while population and economic activity grow slightly. VMT county totals are from VTrans.

Scenarios

The regional models use two scenarios. The reference scenario is similar to today. The main differences are expansion of natural gas infrastructure and more fuel efficient cars because of CAFE standards. The other scenario is designed to achieve the goal of meeting 90% of Vermont's total energy demand with renewable sources. The $90x50_{VEIC}$ scenario is adapted from the TES TREES Local scenarios. It is a hybrid of the high and low biofuel cost scenarios, with biodiesel replacing diesel in heavy duty vehicles and electricity replacing gasoline in light duty vehicles.

The statewide demand in the $90x50_{VEIC}$ scenario is shown in Figure 1. 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

[1] 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.

electric end uses are three to four times more efficient than the combustion versions they replace.

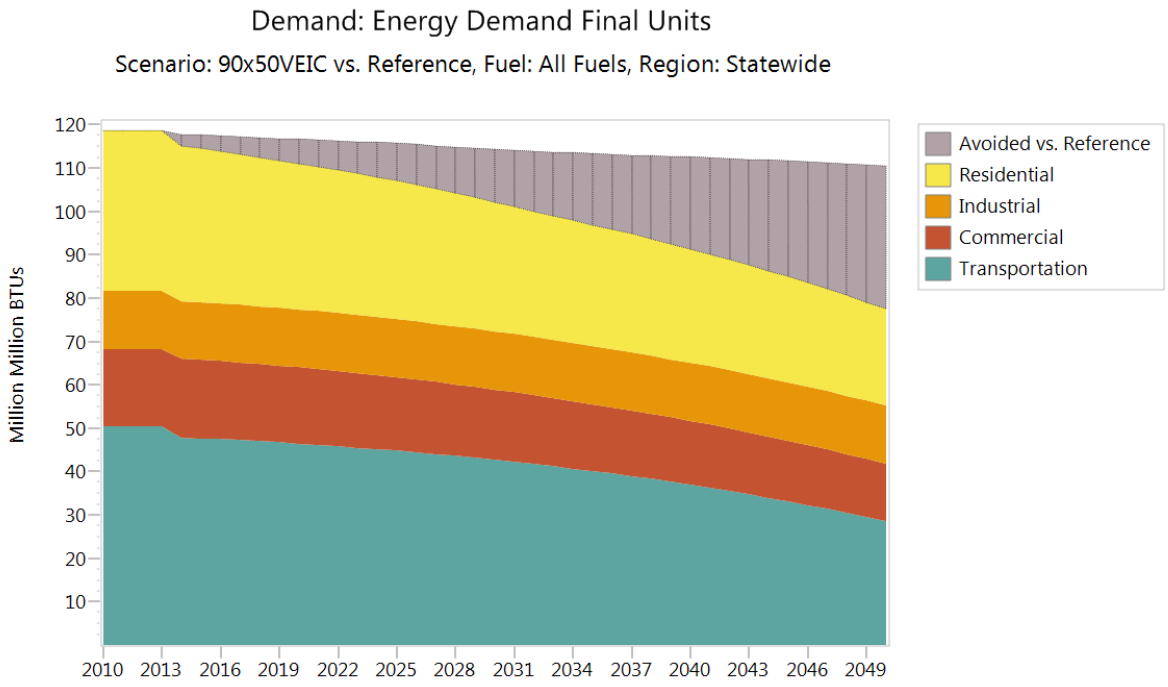
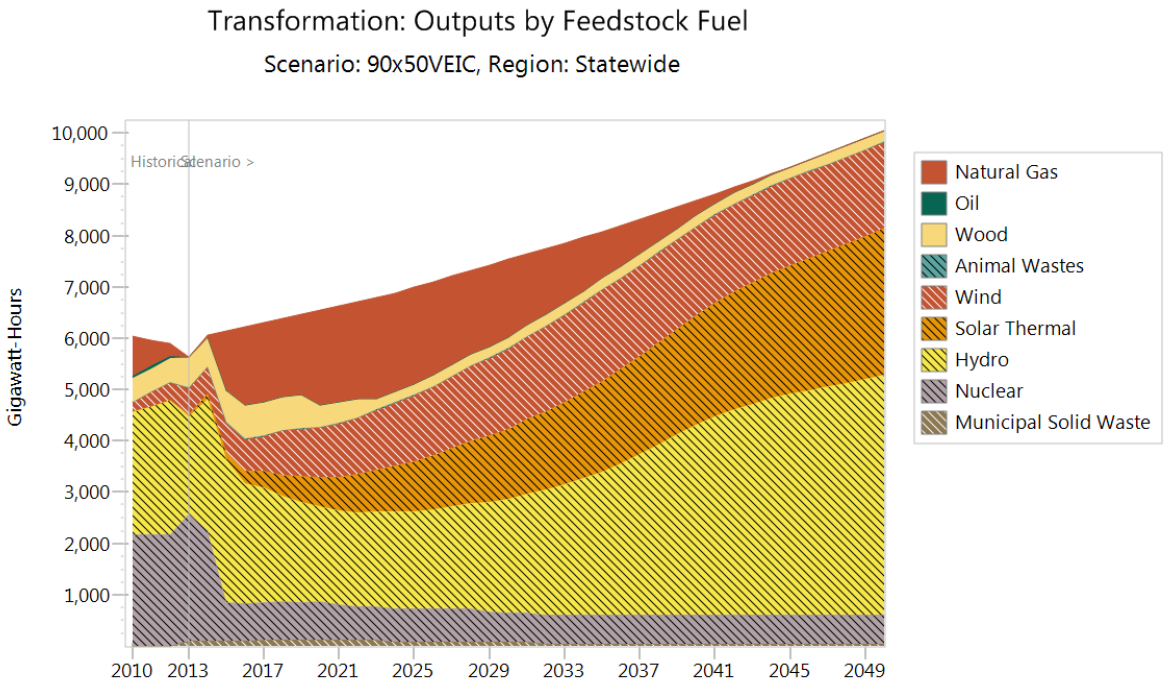


Figure 1 - Statewide Energy Demand by Sector

The statewide electricity supply is shown in



. Committed supply forms the foundation of this graph, but it is relatively short term. When those commitments end, the model meets the growing electricity demand with natural gas electricity from the New England market. To meet the 90% goal, wind and solar ramp up, but hydro also increases dramatically. Most of the increase is assumed to come from Quebec, though 93 MW of in-state development is included in the model. [2]

[2] Barg, Lori. The Undeveloped Hydroelectric Potential of Vermont, 2007, http://www.vtenergyatlas-info.com/wp-content/uploads/2010/02/DPS-Undeveloped-Hydro-Potential-FINAL-VERSION.pdf

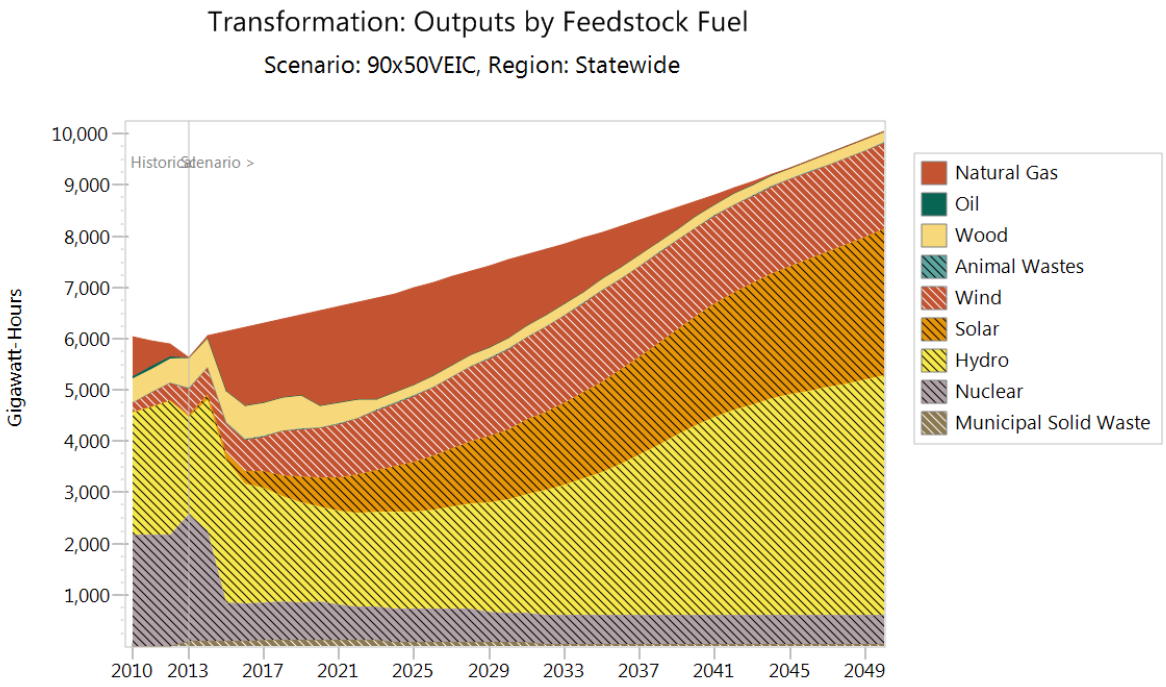


Figure 2 - Statewide Electricity Supply by Fuel

Regional Models

The demand in the statewide model was broken in to the Bennington, Two Rivers, and Northwest regions, and rest of state. 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.

The supply model was not broken into regions, as no region is going to host a small share of the Seabrook nuclear reactor that provides some of their electricity for example. Instead, to aid in planning and discussion, each region's "share" of *new* (installed after 2015) in-state generation by 2050 is shown in Table 1. The capacity is allocated according to the region's 2050 modeled electricity consumption. This table excludes new energy purchased from Hydro Quebec, the natural gas generation from the New England grid, and the small amount of nuclear energy that utilities are currently committed to buy.

Table 1 - Regional share of Electricity Consumption and Capacity

Region	Year	Electricity Consumption (1000 GWh)	New Wind (MW)	New Hydro (MW)	New Solar (MW)
Statewide	2010	5,623	-	-	-
	2025	6,991	200	25	445
	2035	8,073	400	50	926
	2050	10,044	400	93	1,647
Northwest	2010	523	-	-	-
	2025	658	21	3	47
	2035	782	42	5	98
	2050	1,063	42	10	174
Two Rivers	2010	487	-	-	-
	2025	599	17	2	38
	2035	687	34	4	78
	2050	847	34	8	139
Bennington	2010	318	-	-	-
	2025	381	9	1	21
	2035	421	19	2	44
	2050	473	19	4	77
Rest of State	2010	4,281	-	-	-
	2025	5,323	152	19	337
	2035	6,143	303	38	701
	2050	7,610	303	70	1,248

The numbers in the table above reflect an initial draft of one possible way to achieve 90% of total energy from renewables. There are other combinations and new generation would not necessarily be distributed according to regional consumption. However, they do give a sense of scale and a basis for discussion.

Vermont Energy Investment Corporation

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Northwest

Total Demand

Figure 27: State Energy Demand by Fuel

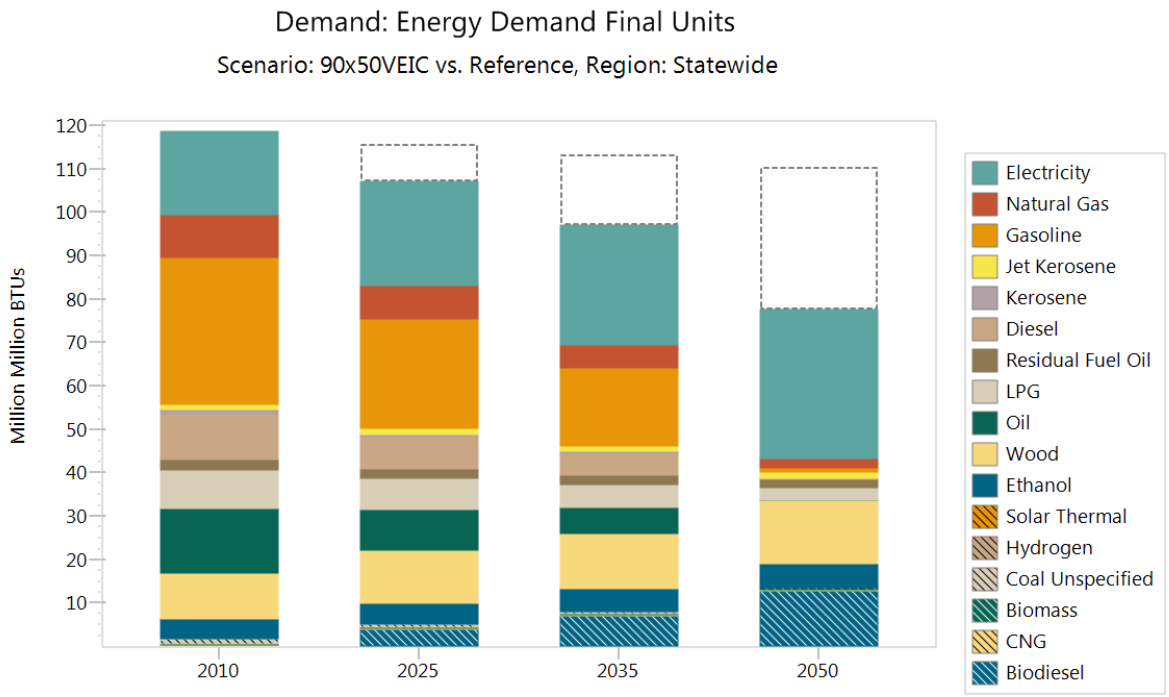

Table 26: State Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC vs. Reference, Region: Statewide				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Avoided vs. Reference	-	8.627	16.427	33.054
Electricity	19.206	23.878	27.573	34.306
Natural Gas	9.947	7.690	5.281	2.188
Gasoline	33.734	25.380	17.963	0.890
Jet Kerosene	1.180	1.255	1.305	1.380
Kerosene	1.041	0.643	0.392	-
Diesel	10.531	7.392	4.994	0.230
Residual Fuel Oil	2.340	2.231	2.132	1.972
LPG	8.947	7.067	5.402	2.901
Oil	14.798	9.510	5.897	0.046
Wood	10.730	12.051	12.872	14.533
Ethanol	4.575	4.823	5.109	5.522
Solar Thermal	0.006	0.051	0.087	0.157
Hydrogen	-	-	-	-
Coal Unspecified	1.170	0.731	0.439	-
Biomass	0.080	0.149	0.196	0.275
CNG	0.230	0.247	0.264	0.300
Biodiesel	0.110	3.949	6.994	12.766
	118.624	107.049	96.900	77.467

Figure 28: Northwest Demand by Fuel

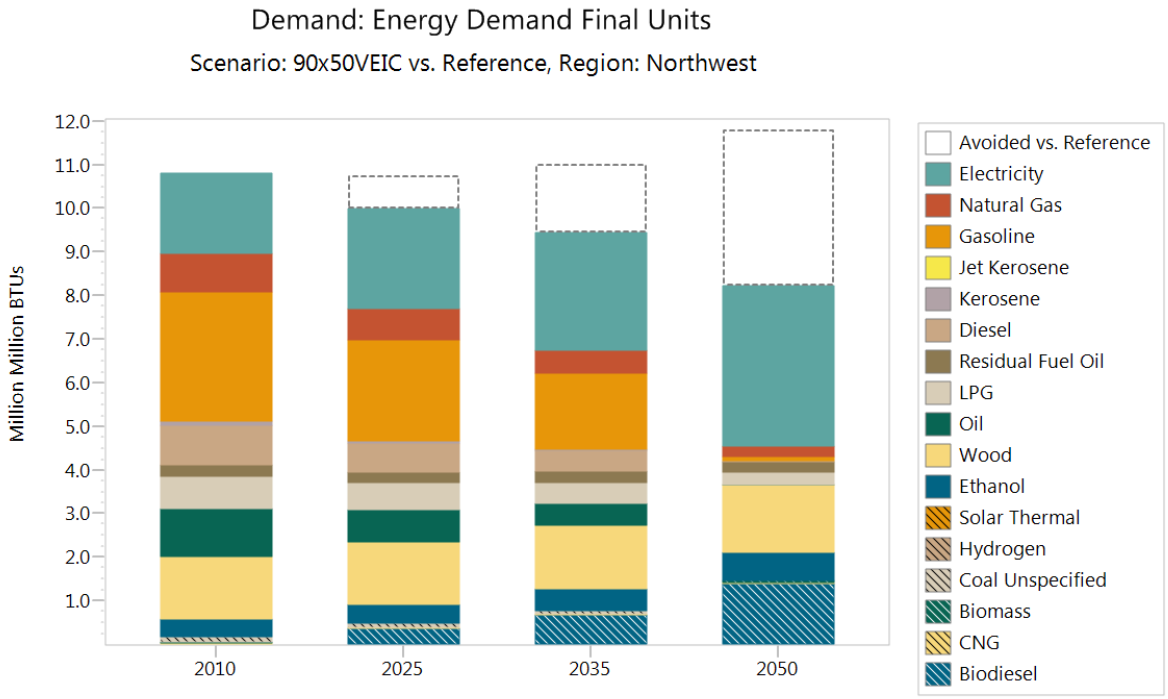

Table 27: Northwest Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC vs. Reference, Region: Northwest				
Units: Million Million BTUs				
Fuels	2010	2025	2035	2050
Avoided vs. Reference	-	0.778	1.568	3.580
Electricity	1.832	2.293	2.716	3.676
Natural Gas	0.897	0.717	0.519	0.248
Gasoline	2.965	2.303	1.742	0.100
Jet Kerosene	-	-	-	-
Kerosene	0.083	0.053	0.035	-
Diesel	0.920	0.666	0.480	0.026
Residual Fuel Oil	0.265	0.257	0.249	0.237
LPG	0.736	0.608	0.492	0.285
Oil	1.098	0.741	0.492	0.004
Wood	1.427	1.430	1.466	1.557
Ethanol	0.402	0.438	0.495	0.623
Solar Thermal	0.000	0.004	0.008	0.017
Hydrogen	-	-	-	-
Coal Unspecified	0.140	0.088	0.053	-
Biomass	0.006	0.013	0.018	0.031
CNG	0.020	0.022	0.026	0.034
Biodiesel	0.010	0.348	0.657	1.387
Total	10.803	9.981	9.446	8.224

Residential

Figure 29: Statewide Residential Demand by Fuel

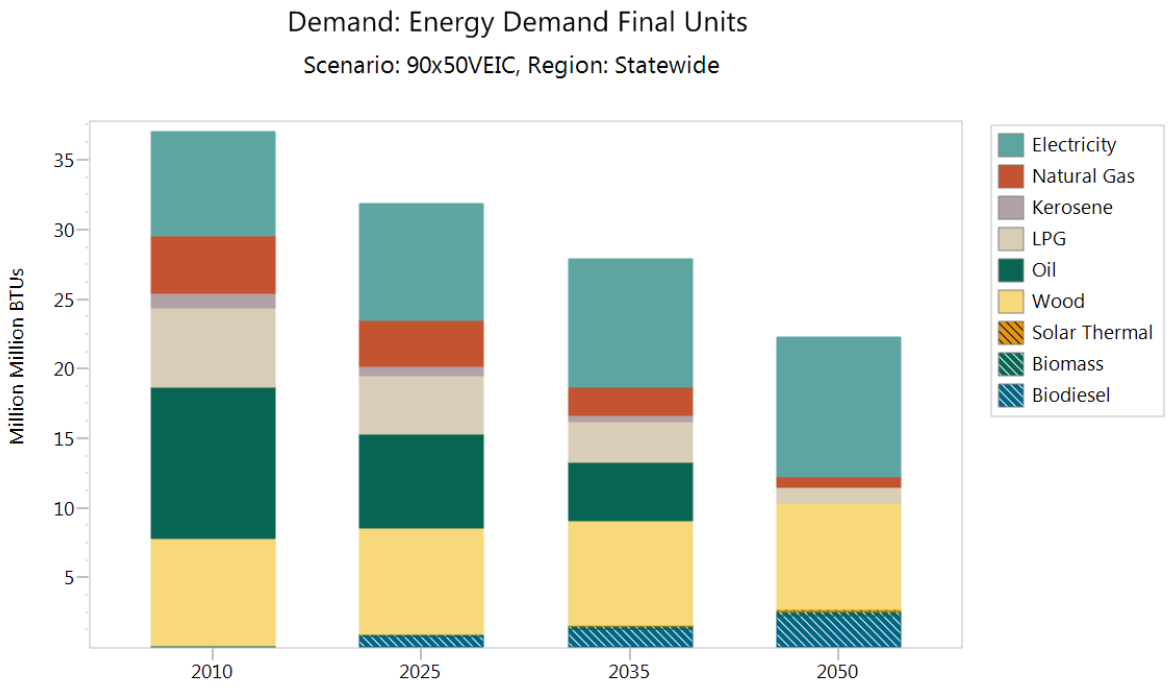

Table 28: Statewide Residential Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Statewide				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	7.496	8.401	9.246	10.055
Natural Gas	4.147	3.339	2.065	0.708
Kerosene	1.041	0.643	0.392	-
LPG	5.667	4.179	2.947	1.106
Oil	10.898	6.770	4.197	-
Wood	7.730	7.621	7.525	7.696
Solar Thermal	0.006	0.051	0.087	0.157
Biomass	0.080	0.149	0.196	0.275
Biodiesel	-	0.736	1.272	2.258
Total	37.064	31.890	27.928	22.255

Figure 30: Northwest Residential Demand by Fuel

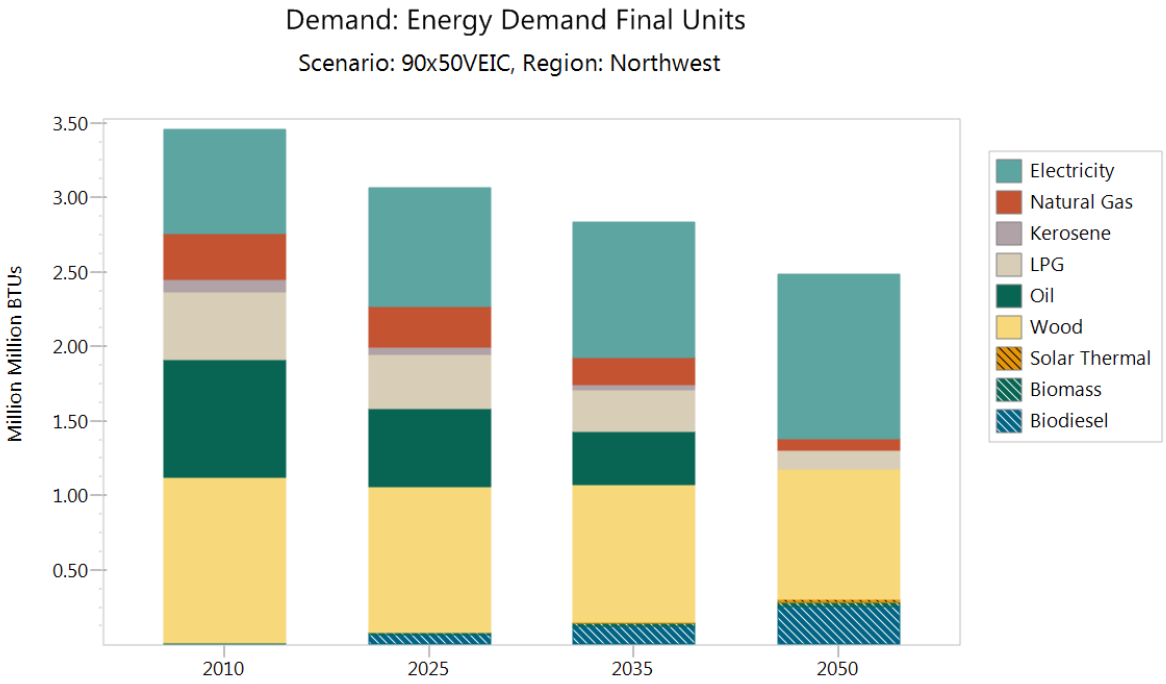

Table 29: North West Residential Demand by Fuel;

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Two Rivers				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	0.703	0.800	0.914	1.110
Natural Gas	0.305	0.270	0.180	0.077
Kerosene	0.083	0.053	0.035	-
LPG	0.458	0.361	0.279	0.125
Oil	0.786	0.522	0.356	-
Wood	1.115	0.979	0.926	0.874
Solar Thermal	0.000	0.004	0.008	0.017
Biomass	0.006	0.013	0.018	0.031
Biodiesel	-	0.063	0.119	0.251
Total	3.457	3.065	2.836	2.486

Single Family Space Heating

Figure 31: Statewide Single Family Heating Energy Demand by Fuel

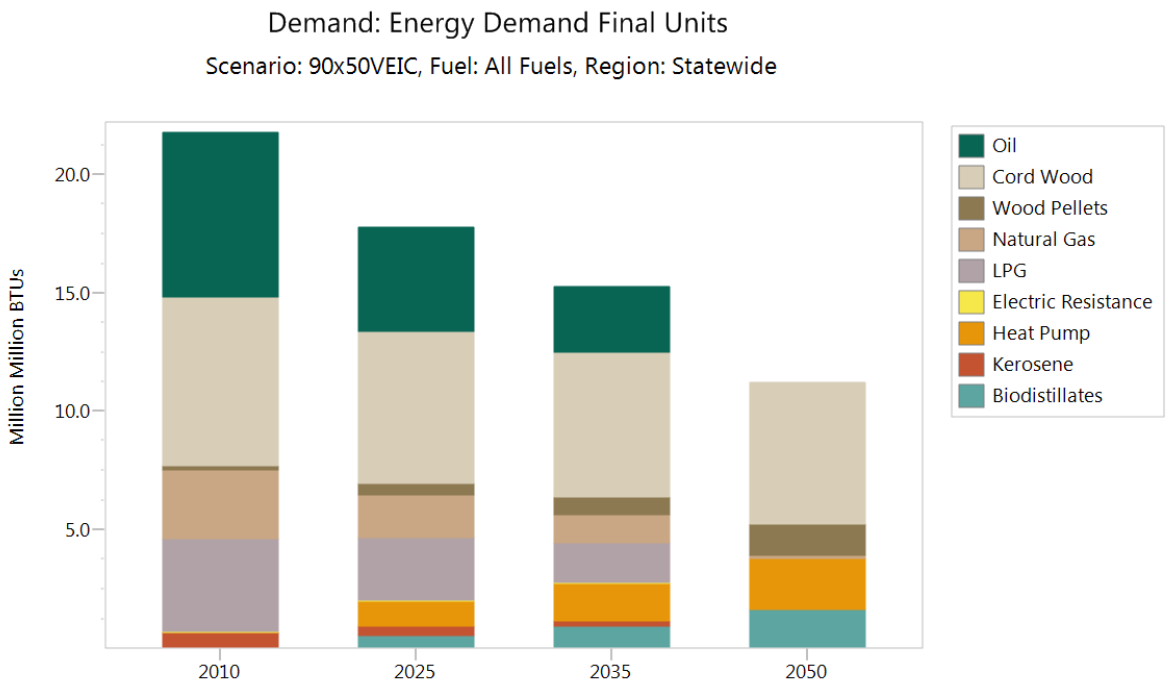

Table 30: Statewide Single Family Heating Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Fuel: All Fuels, Region: Statewide				
Units: Million Million BTUs				
Branches	**2010**	**2025**	**2035**	**2050**
Oil	6.971	4.400	2.762	-
Cord Wood	7.136	6.411	6.154	6.015
Wood Pellets	0.189	0.500	0.757	1.285
Natural Gas	2.916	1.804	1.186	0.151
LPG	3.898	2.659	1.670	-
Electric Resistance	0.073	0.046	0.029	-
Heat Pump	0.000	1.048	1.587	2.174
Kerosene	0.608	0.384	0.241	-
Biodistillates	-	0.500	0.871	1.575
Total	21.791	17.751	15.257	11.201

Figure 32: Northwest Single Family Heating Energy Demand by Fuel

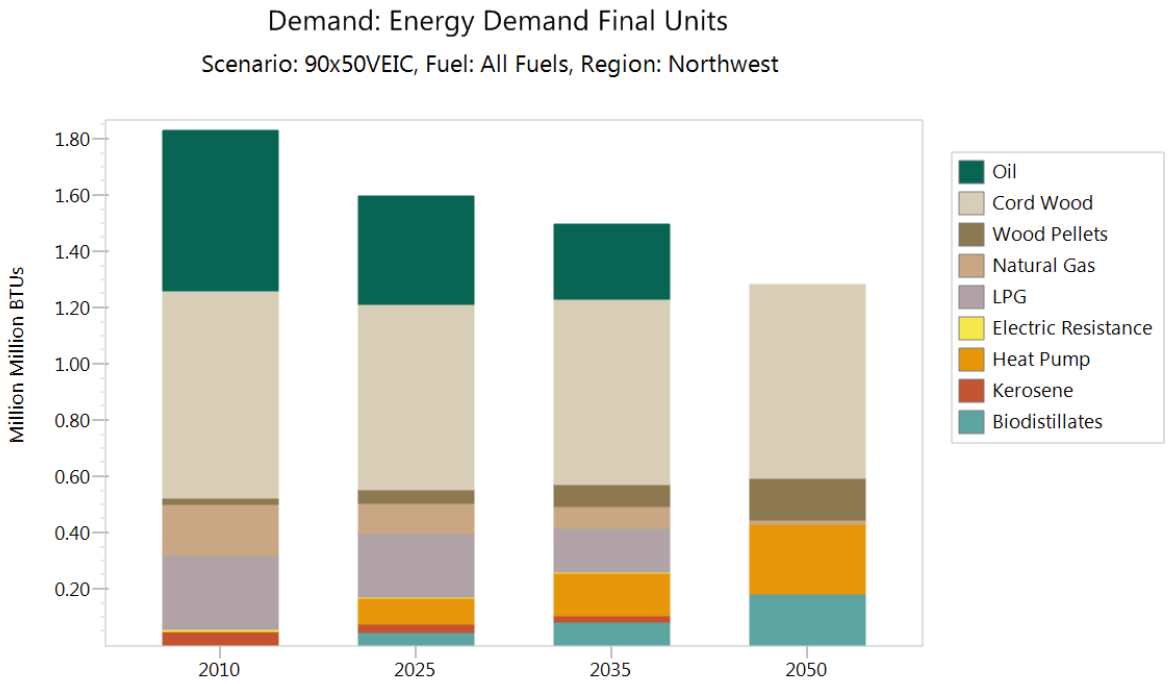

Table 31: Northwest Single Family Heating Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Fuel: All Fuels, Region: Northwest				
Units: Million Million BTUs				
Branches	**2010**	**2025**	**2035**	**2050**
Oil	0.570	0.385	0.267	-
Cord Wood	0.736	0.661	0.659	0.687
Wood Pellets	0.023	0.048	0.075	0.147
Natural Gas	0.182	0.106	0.079	0.017
LPG	0.263	0.227	0.158	-
Electric Resistance	0.006	0.004	0.003	-
Heat Pump	0.000	0.090	0.150	0.248
Kerosene	0.048	0.033	0.023	-
Biodistillates	-	0.043	0.082	0.180
Total	1.828	1.597	1.496	1.280

Commercial

Figure 33: Statewide Commercial Energy Demand by Fuel

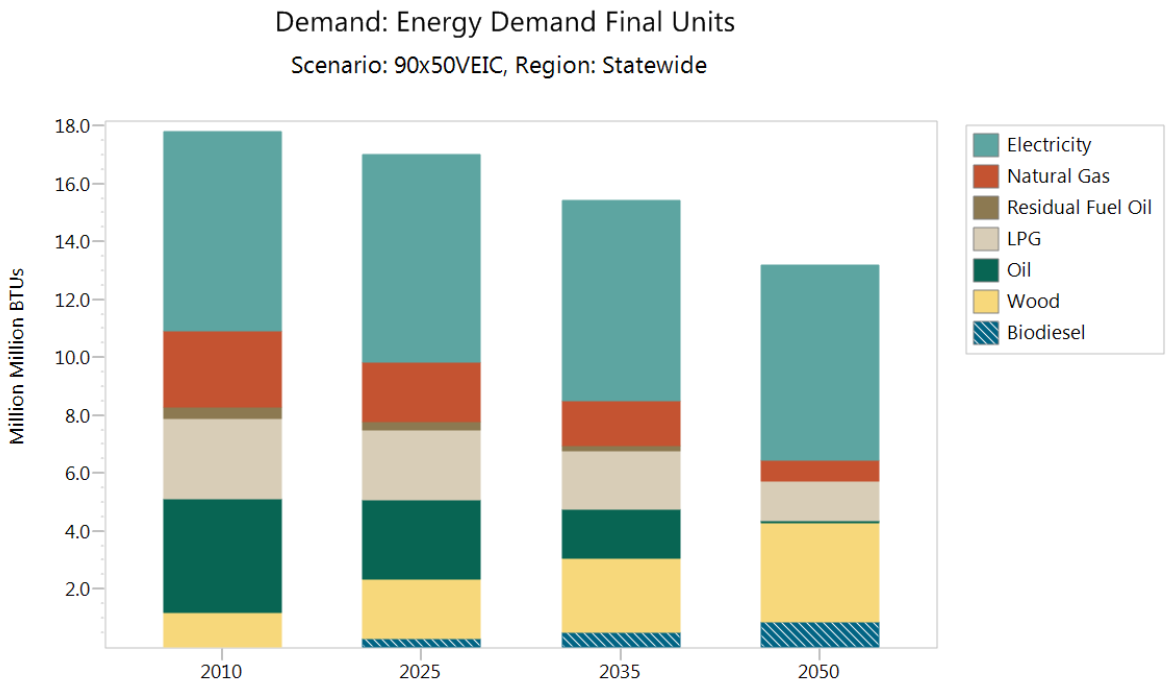

Table 32: Statewide Commercial Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Statewide				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	6.900	7.155	6.943	6.737
Natural Gas	2.600	2.069	1.547	0.730
Residual Fuel Oil	0.400	0.279	0.172	-
LPG	2.800	2.432	2.014	1.375
Oil	3.900	2.740	1.700	0.046
Wood	1.200	2.030	2.547	3.437
Biodiesel	-	0.298	0.508	0.859
Total	17.800	17.004	15.431	13.186

Figure 34: Northwest Commercial Energy Demand by Fuel

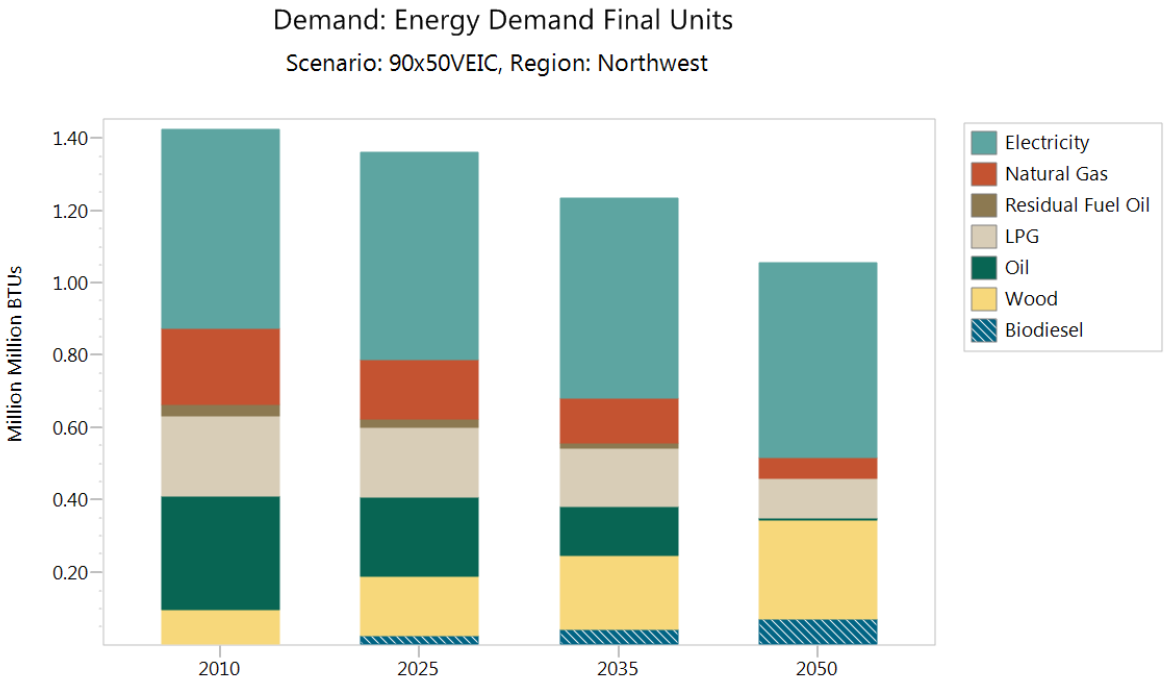

Table 33: Northwest Commercial Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Northwest				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	0.552	0.572	0.555	0.539
Natural Gas	0.208	0.166	0.124	0.058
Residual Fuel Oil	0.032	0.022	0.014	-
LPG	0.224	0.195	0.161	0.110
Oil	0.312	0.219	0.136	0.004
Wood	0.096	0.162	0.204	0.275
Biodiesel	-	0.024	0.041	0.069
Total	1.424	1.360	1.234	1.055

Industrial

Figure 35: Statewide Industrial Energy Demand by Fuel

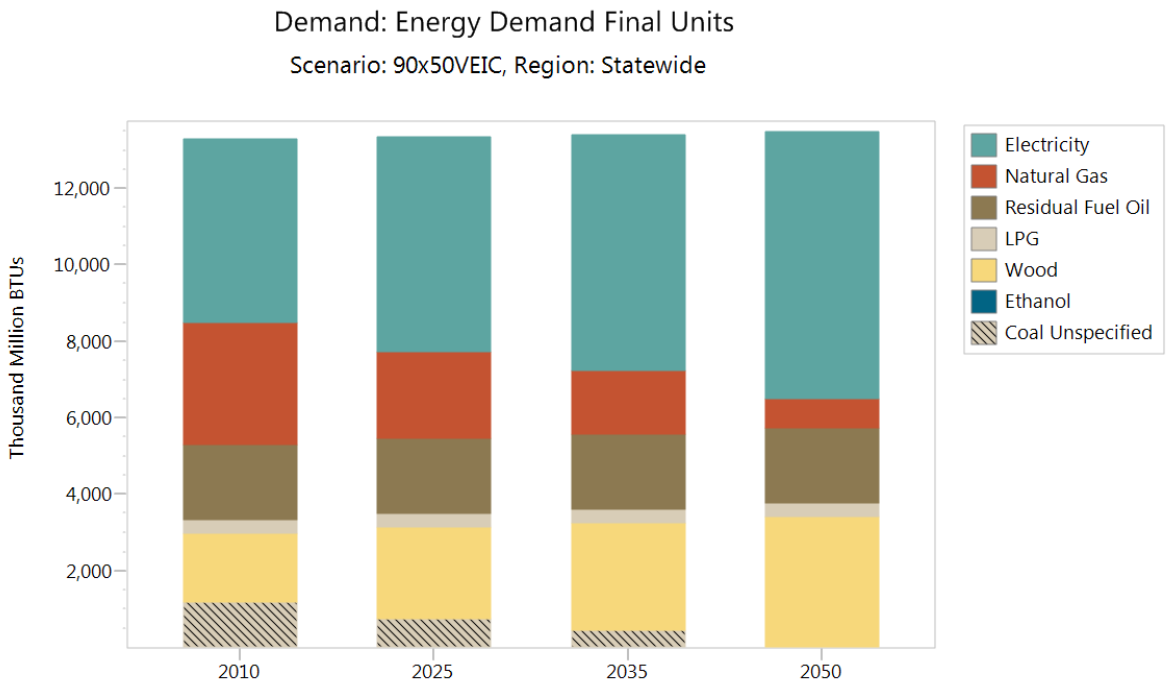

Table 34: Statewide Industrial Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Statewide				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	4.800	5.625	6.175	7.000
Natural Gas	3.200	2.281	1.669	0.750
Residual Fuel Oil	1.940	1.952	1.960	1.972
LPG	0.370	0.366	0.364	0.360
Wood	1.800	2.400	2.800	3.400
Ethanol	-	-	-	-
Coal Unspecified	1.170	0.731	0.439	-
Total	13.280	13.356	13.406	13.482

Figure 36: Northwest Industrial Energy Demand by Fuel

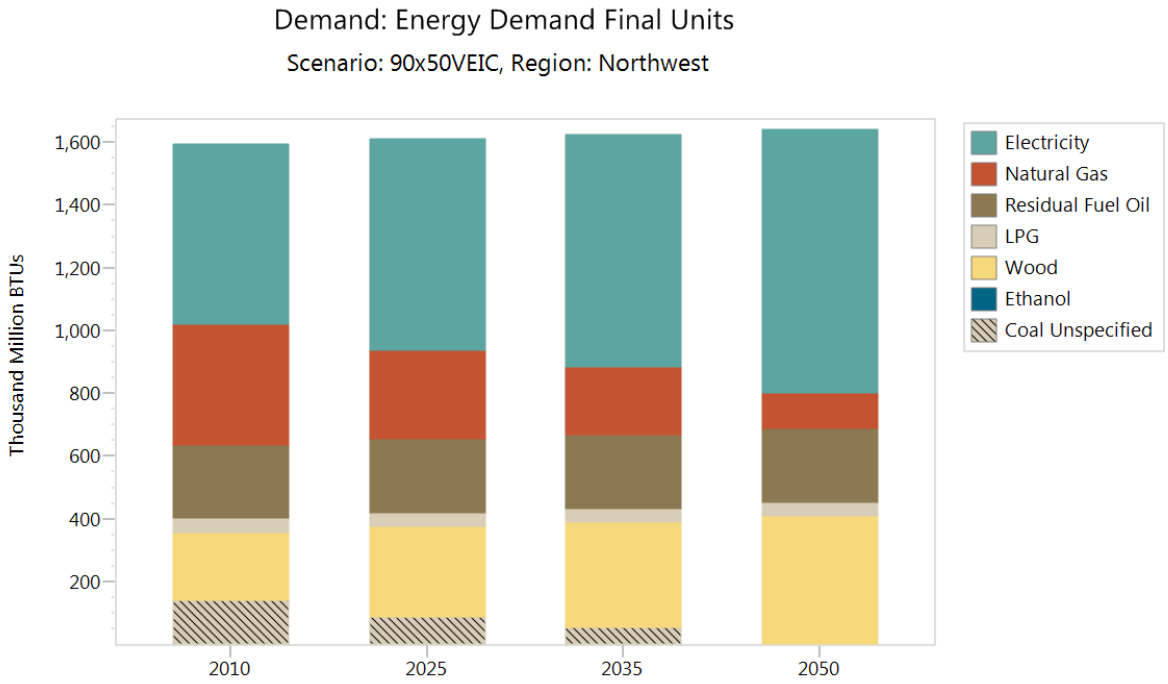

Table 35: Northwest Industrial Energy Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Northwest				
Units: Million Million BTUs				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	0.576	0.675	0.741	0.840
Natural Gas	0.384	0.282	0.214	0.113
Residual Fuel Oil	0.233	0.234	0.235	0.237
LPG	0.044	0.044	0.044	0.043
Wood	0.216	0.288	0.336	0.408
Ethanol	-	-	-	-
Coal Unspecified	0.140	0.088	0.053	-
Total	1.594	1.611	1.623	1.640

Transportation

Figure 37: Statewide Transportation Demand by Fuel

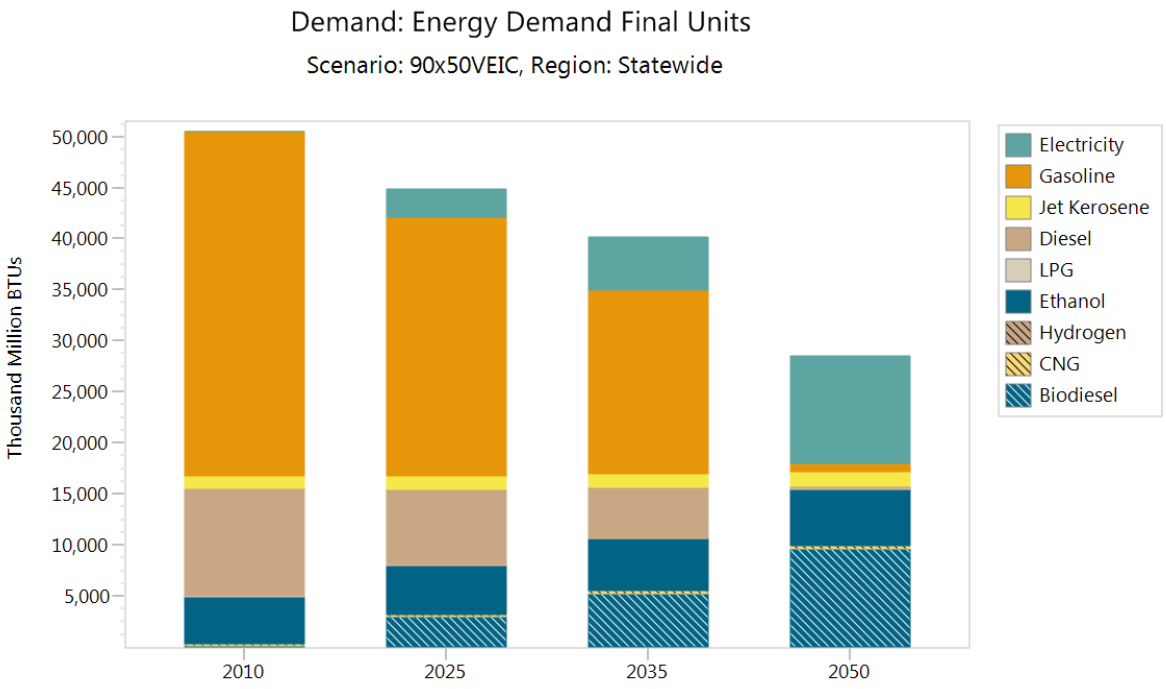

Table 36: Statewide Transportation Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Statewide				
Units: Million Million BTUs				
Demand: Energy Demand Final Units				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	0.010	2.696	5.209	10.514
Gasoline	33.734	25.380	17.963	0.890
Jet Kerosene	1.180	1.255	1.305	1.380
Diesel	10.531	7.392	4.994	0.230
LPG	0.110	0.089	0.077	0.060
Ethanol	4.575	4.823	5.109	5.522
Hydrogen	-	-	-	-
CNG	0.230	0.247	0.264	0.300
Biodiesel	0.110	2.916	5.214	9.648
Total	50.480	44.799	40.135	28.544

Figure 38: Northwest Transportation Demand by Fuel

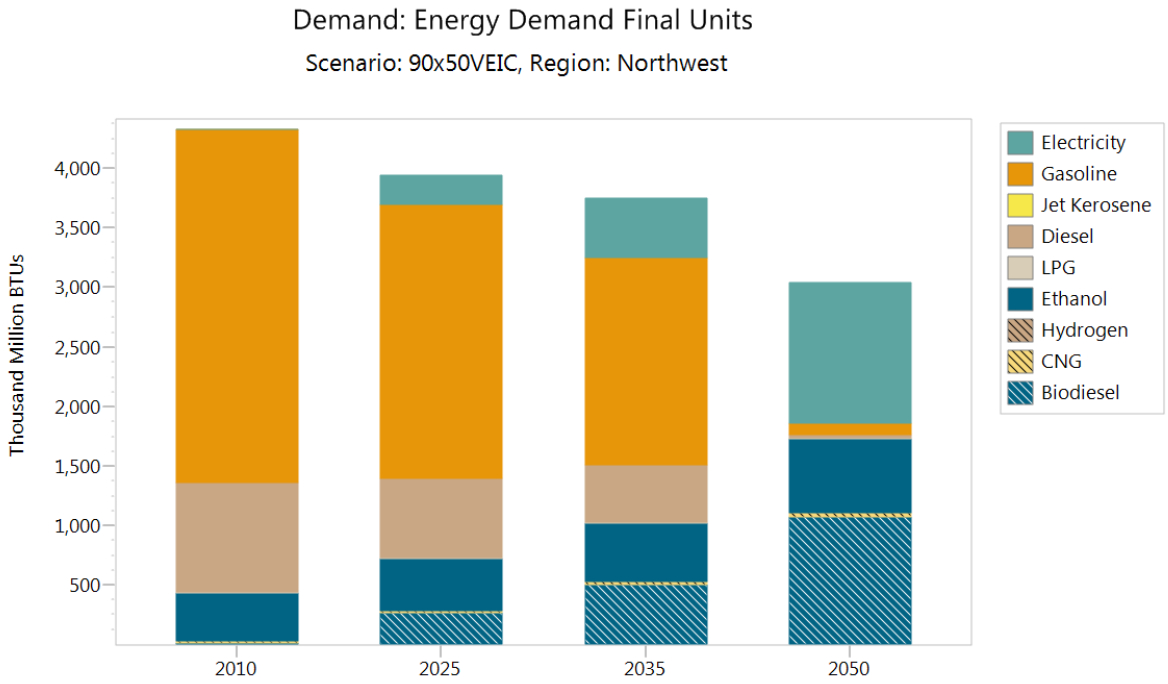

Table 37: Northwest Transportation Demand by Fuel

Demand: Energy Demand Final Units				
Scenario: 90x50VEIC, Region: Northwest				
Units: Million Million BTUs				
Demand: Energy Demand Final Units				
Fuels	**2010**	**2025**	**2035**	**2050**
Electricity	0.001	0.245	0.505	1.186
Gasoline	2.965	2.303	1.742	0.100
Jet Kerosene	-	-	-	-
Diesel	0.920	0.666	0.480	0.026
LPG	0.010	0.008	0.007	0.007
Ethanol	0.402	0.438	0.495	0.623
Hydrogen	-	-	-	-
CNG	0.020	0.022	0.026	0.034
Biodiesel	0.010	0.262	0.498	1.067
Total	4.328	3.944	3.753	3.043