2018 Chittenden County ECOS Plan

Supplement 6 – Energy Analysis, Targets, & Methodology
Second Public Hearing Draft 04/06/2018

For a healthy, inclusive, and prosperous community

This plan is the Regional Plan, Metropolitan Transportation Plan, and Comprehensive Economic Development Strategy in one.

This plan can be found online at: www.ecosproject.com/plan

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Energy Analysis, Targets, & Methodology

INTRODUCTION

Part 1 of Supplement 6 includes the data required for the 2018 Chittenden County ECOS Plan to meet the State of Vermont's energy planning standards and to inform the region's advancement of the state's energy goals (described in Regional Analysis Supplement 2). To meet state energy goals, the region is planning for a major shift away from fossil fuels in the transportation and heating sector to renewable ~~electric~~ sources of energy, efficiency in all sectors, and increase in-state renewable energy generators.

The analysis in this section estimates current energy use and provides targets for future energy use across all sectors (transportation, heating, and electricity). The data estimates also include renewable energy generation targets. Chittenden County's targets represent the ~~show~~ the portion of renewable energy generation the region anticipates being sited in Chittenden County. The Department of Public Service anticipates meeting the 90X2050 goal by generating half of the State's electricity needs in-state and also through imported energy. ~~'s targets for renewable energy generation~~. Please note that these data are a starting point for Chittenden County to consider its energy future. This information should provide the framework for a discussion about changes that will need to occur within Chittenden County to ensure that State energy goals are met.

The data in this section are intended to provide an overview of current energy use and a sense of the trajectories and pace of change needed to meet the State's energy goals. Targets for each sector are also provided to demonstrate milestones along the way toward meeting 90% of total energy needs with renewable energy. The data targets are intended to be a demonstration of one possible scenario to reach 90% renewable by 2050 and are not intended to prescribe a future.

Targets for future energy use are drawn from the Long-range Energy Alternatives Planning (LEAP) analysis for Chittenden County, completed by the Vermont Energy Investment Corporation (VEIC). The LEAP model is an accounting framework that shows one possible path for Chittenden County to meet the state energy goals.

Additionally, the renewable energy generation targets contained in this supplement provide an estimate of additional renewable energy generation to meet the 2050 target. These targets account for existing generation currently sited or permitted within the region's boundaries and are technology neutral. Meaning the region has the flexibility to meet the targets through the development of various renewable energy technologies (e.g. biomass, solar, or wind).

Part 1 of this supplement includes estimates of existing and future energy consumption for the transportation, heating, and electric sectors.

Part 2 of this supplement explains the various methodologies used by CCRPC to set targets and report data.

Part 3 of this supplement explains the methodology used by VEIC to complete the LEAP model.

1. EXISTING DATA AND FUTURE PROJECTIONS

Current Energy Use

The data below are from various data sources and represent actual current consumption and generation, rather than estimates from the Long-Range Energy Alternatives (LEAP) model found in the section on projected energy use.

Transportation Energy

Table 1 provides an overview of the passenger vehicle fleet composition by fuel source in Chittenden County and serves as a proxy for transportation energy use. In 2015, Chittenden County was home to about 106,936 fossil fuel burning light duty vehicles. As of July 2017, Chittenden County had 542 electric vehicles registered. Chittenden County has seen a dramatic increase of electric vehicle ownership as the number of electric vehicles in the County has doubled since 2014. The number of electric vehicles in the County includes all electric and plug-in hybrid vehicles.

TABLE 1. CURENT MUNICIPAL TRANSPORTATION ENERGY USE

Current Transportation Energy Use	
Fossil Fuel Burning Light Duty Vehicles, 2015	106,936
Electric Light Duty Vehicles, July 2017	542
Sources: VTrans, American Community Survey, Drive Electric Vermont, DMV	

Thermal Energy

Table 2 and T~~t~~able 3 below describe how homes are heated in Chittenden County. Chittenden County is served by Vermont Gas and ~~access to~~ natural gas is available in most of ~~the~~ the ECOS Plan's areas planned for growth. As such, over half of the homes are heated with natural gas. Areas outside the Vermont Gas service area rely on delivered fuels for space heating such as fuel oil, kerosene, or propane. About 26% of home heat their homes with one of these fuel sources.

TABLE 2. CURRENT THERMAL ENERGY USE FROM DELIVERED FUELS

Current Thermal Energy Use from Delivered Fuels, 2015	
Number of homes heating with Fuel oil, Kerosene	9,751 homes (15% of homes)
Number of homes heating with Propane	7,218 homes (11% of homes)
Percentage of Households Heating with Delivered Fuels	26% of homes
Sources: American Community Survey 2016 1-Year Estimate, Energy Information Administration, CCRPC Employment Database	

TABLE 3. CURRENT THERMAL ENERGY USE

Current Thermal Energy Use from Natural Gas, 2015	
Total Residential Natural Gas Consumption (MMBtu)	3,565,606
Percentage of Municipal Natural Gas Consumption	45%
Homes Heating with Natural Gas	37,9073 (57% of homes)
Total Commercial/Industrial Natural Gas Consumption (MMBtu)	4,100,603
Percentage of Municipal Natural Gas Consumption	55%
Total Municipal Natural Gas Consumption (MMBtu)	7,666,209
Sources: Vermont Gas	

Weatherization

The State of Vermont's energy goals include a goal to weatherize 25% of homes by 2020. For Chittenden County (with 68,525 housing units in 2016), this means approximately 17,000 homes weatherized by 2020. The best available data source for~~rom~~ home weatherization is Efficiency Vermont. Efficiency Vermont only monitors home weatherization programs done through the Home Performance with ENERGY STAR® (HPwES) program. HPwES is a comprehensive whole-house approach to diagnosing and addressing thermal and health/safety issues in the home to ensure a more energy efficient, comfortable, safe, and healthy home. A project is a collection of one or more energy efficient measures that have been implemented at a customer's physical location. A customer can be associated with one or more projects and in some cases, a project may be associated with multiple customers. Efficiency Vermont's data does not capture do-it-yourself projects or projects that do not go through the HPwES program. Table 4 below indicates the number of energy efficiency projects completed. It is not intended to represent the number of home weatherized.

TABLE 4. RECENT RESIDENTIAL ENERGY EFFICIENCY PROJECTS

Recent Residential Energy Efficiency Projects			
	2014	2015	2016
Home Performance with ENERGY STAR® Leads	342	339	294
Home Performance with ENERGY STAR® Projects	137	125	119
Total Residential Projects (includes Home Performance with ENERGY STAR® projects)	770	1,387	1,533

Source: Efficiency Vermont, October 2017

Electricity

An estimate of current electricity consumption by residential and commercial/industrial sector in Chittenden County is shown in Table 5.

TABLE 5. ELECTRICITY CONSUMPTION

	2015
Residential Electric Energy Use (MWh)	425,335
Commercial and Industrial Electric Energy Use (MWh)	1,483,006
Total Electric Energy Use (MWh	1,908,341
Source: Efficiency Vermont, Burlington Electric Department	

TABLE 6. COST BY FUEL TYPE

Type	Price
Electricity/Heat Pump	$18.32/MMBTU
Natural Gas	$14.88/MMBTU
Fuel Oil	$20.14/MMBTU
Source: Vermont Fuel Price Report, November 2016	

Current Renewable Energy Generation

As shown in T~~t~~able 7, Chittenden County's current renewable generation capacity is ~~there is currently~~ 137 MW ~~of electricity generation capacity from renewable energy generation facilities in Chittenden County~~. This capacity results in approximately 511,242 MWh of electricity generation per year. Renewable electricity generation is sourced from solar, wind, hydroelectric, and biomass facilities located inside Chittenden County, including McNeil Generating Station, half of the capacity of Georgia Mountain Community Wind, Winooski One Hydro Dam, and numerous solar array projects.

TABLE 7. EXISTING RENEWABLE ELECTRICITY GENERATION

Existing Renewable Electricity Generation			
	Sites	Power (MW)	Energy (MWh)
Solar	2,785	40	49,806
Wind	23	10	31,136
Hydroelectric	6	36	164,136
Biomass (Wood)	14	51	266,164
Total*	2,785	137	511,242

Source: Community Energy Dashboard, October 2017

**The total existing renewable energy generation varies from the existing renewable energy generation reported in the renewable energy targets sections due to variations in the way the data is counted. These sites represent facilities that have been permitted.*

Projected Energy Use Targets

Projected future energy use targets are drawn from the Long-range Energy Alternatives Planning (LEAP) analysis for Chittenden County, completed by the Vermont Energy Investment Corporation (VEIC). LEAP is an accounting framework that shows one possible path for Chittenden County and its municipalities to meet the State's energy goals required for enhanced energy plans. LEAP aggregates existing energy use data and forecasts the demand for energy and sources of energy over time, based on a set of anticipated economic and policy changes. For example, demographic projections are one component of projecting future energy use. LEAP is well suited for examining how energy systems might evolve over time to meet certain goals (in this case, Vermont's goal to gain 90% of energy from renewable sources by 2050). These targets show the direction and magnitude of change needed meet local, regional and state energy goals and are not intended to be used in a regulatory context. For more detail on the LEAP Model, see the sections on ~~LEAP Energy Modeling Methodology~~the LEAP model in the discussion of CCRPC's methodology and VEIC's methodology below.

Transportation Energy Targets

The transportation energy targets for Chittenden County represent an ambitious electrification of the ~~pathway for electrifying the~~ transportation sector in an effort to increase the amount of renewable energy used to power passenger vehicles. To meet the energy goals, ~~By 2050,~~ transportation energy from light duty vehicles will need to decrease ~~by~~ 72% by 2050.~~,~~ This will primarily be achieved by converting to more efficient~~ly powered~~ electric vehicles from fossil fuel vehicles. The LEAP model shows that ~~Based on the LEAP modeling~~ to achieve this reduction,~~,~~ 89% of passenger vehicles ~~will~~must be electric ~~to realize a significant reduction in transportation energy~~. Electrifying the light duty sector will also lead to a ~~13%~~dramatic increase in electricity use in the transportation sector and a significant decrease in gasoline consumption. ~~have the effect of increasing electricity in the transportation sector by 13% and reducing the amount of biofuel blended fuel with gasoline as gasoline consumption declines significantly.~~ The LEAP model estimates that ~~the changes in~~ the heavy-duty sector ~~will be due to a transition to the use of biodiesel~~ transition to biodiesel as its primary fuel source.~~.~~ Biodiesel energy use is projected to increase to about 96% for heavy duty fleet vehicles by 2050.

TABLE 8. TRANSPORTATION ENERGY TARGETS

Projected Transportation Energy Use, 2025-2050			
	2025	2035	2050
Total Light Duty Transportation Energy Use (MMBtu)	6,299,000	3,990,000	1,739,000
Electricity Used for Light Duty Transportation (MMBtu)	84,000	579,000	1,222,000
Light Duty Electric Vehicles (% of Vehicle Fleet)	6%	41%	89%
Fossil Fuel/Biofuel Blended* Energy Used for Light Duty Transportation (MMBtu)	6,215,000	3,411,000	517,000
Fossible Fuel/Biofuel Blend*Light Duty Vehicles (% of Vehicle Fleet)	94%	59%	11%
Heavy-Duty Transportation Energy Use from Biodiesel (Percent of Total)	33%	58%	96%
Heavy-Duty Transportation Energy Use from Fossil Fuels (Percent of Total)	67%	42%	4%
**This measures biofuel blended with fossil fuels. A common example is gasoline with ethanol mixed in.*			
Sources: VTrans, LEAP Model			

Thermal Energy Targets, Commercial Sector

The thermal targets for Chittenden County in 2050 estimates a 16% reduction in total commercial and industrial thermal energy use. ~~In other words, commercial and industrial buildings will be using less energy for space heating purposes.~~ This will primarily be achieved through weatherization and the use of ~~renewable sources of heat~~more efficient heating technologies. These targets also estimate that renewable sources of heat will become more common.~~.~~ By 2050, 40% of businesses are projected to be using heat pumps and 11% of businesses will be using wood heating.

TABLE 9. PROJECTED COMMERCIAL AND INDUSTRIAL THERMAL ENERGY USE

Projected Commercial and Industrial Thermal Energy Use, 2025-2050			
	2025	2035	2050
Total Commercial and Industrial Thermal Energy Use (MMBtu)	3,504,140	3,337,690	2,952,240
Percent of Commercial and Industrial Establishments Weatherized by Target Year	20%	22%	39%
Energy Saved by Weatherization by Target Year (MMBtu)	188,369	261,179	629,430
Commercial and Industrial Establishments Using Air Source Heat Pumps (%)	22%	35%	40%
Commercial and Industrial Thermal Energy Use by Air Source Heat Pumps (MMBtu)	284,140	561,690	839,240
Commercial and Industrial Establishments Using Wood Heating (%)	9%	10%	11%
Commercial and Industrial Thermal Energy Use Attributable to Wood Heating (MMBtu)	424,000	584,000	855,000
Sources: LEAP Model, Department of Public Service, Department of Labor			

Thermal Energy Targets, Residential Sector

Thermal energy use in Chittenden County homes is projected to decrease by 41% from 2025 to 2050. Residential buildings will use less energy for space heating due to an increase in the percent of buildings that are weatherized and greater efficiency in heating technology. To achieve the projected energy savings ~~from the thermal fitness of buildings~~, at least 75% of homes in Chittenden County need to be weatherized by 2050. Additionally, the number of homes relying on heat pumps ~~, which are powered by electricity and are a more efficient way to heat a building compared to delivered fuels,~~ needs to increase to 55%. Heat pumps are powered by electricity and are a more efficient way to heat a building compared to delivered fuels. Wood heating also plays an importation role in reducing thermal energy use and increasing the amount of renewable fuel sources for the thermal sector. The LEAP model estimates that at least 13% of homes need to rely on wood heat for space heating. However, the

LEAP model estimates a lower percentage of wood heat use in Chittenden County than in other parts of Vermont, due to the relatively low percentage of households currently heating with wood.

TABLE 10. PROJECTED RESIDENTIAL THERMAL ENERGY USE

Projected Residential Thermal Energy Use, 2025-2050			
	2025	2035	2050
Total Residential Thermal Energy Use (MMBtu)	5,647,000	4,788,000	3,315,000
Percent of Residences Weatherized by Target Year	10%	22%	75%
Energy Saved by Weatherization by Target Year (MMBtu)	194,400	434,000	1,629,000
Percent of Residences Using Air Source Heat Pumps	18%	35%	55%
Residential Thermal Energy Use from Heat Pumps (MMBtu)	366,000	753,000	1,104,000
Residences Using Wood Heating (%)	14%	14%	13%
Residential Thermal Energy Use from Wood Heating (MMBtu)	1,037,000	1,038,000	912,000
Sources: LEAP Model, Department of Public Service			

Electricity Targets

Total electricity use is targeted to increase by 60% from 2025 to 2050 (Table 11). This will likely be driven by conversions to electric heat pumps and electric vehicles. These consumer changes will cause electricity use to grow. At the same time, total energy use ~~(energy, not electricity)~~ will decrease, and electricity will become a larger proportion of the state's total energy use (~~become more efficient,~~ see Tables 12 and 13 for more information). ~~This is~~Total energy use will be reduced because technologies will be increasingly efficient and because using electricity for transportation and heating is more efficient than using ~~electric cars and electric heating sources are more efficient than using~~ other energy sources, such as fossil fuels.

TABLE 11. PROJECTED ELECTRICITY

Projected Electrical Energy Use, 2025-2050			
	2025	2035	2050
Without Industrial (MWh)	1,248,257	1,503,928	1,916,869
Industrial Only (MWh)	344,000	488,000	631,000
Total (MWh)	1,592,257	1,991,928	2,547,869
Total Electric Energy Saved (MWh)	107,000	216,000	404,000
Residences that have increased their Electric Efficiency	30%	58%	98%
Commercial and Industrial Establishments that have Increased Their Electric Efficiency	30%	58%	98%

Source: LEAP Model

**Please note that industrial electricity use is recognized as the most difficult element to project in the LEAP model, because of regional discrepancies in data from the commercial and industrial sector. Therefore, projected electricity use and total energy use are reported two ways: with industrial electricity use included and excluded.*

Total Energy Use Targets

One goal of enhanced energy planning is for energy use per capita to be reduced by more than 1/3 between 2015 and 2050. Though electricity is anticipated to increase, overall total energy will decrease because electricity is 3 to 4 times more efficient than fossil fuel energy.

The LEAP model reports an energy pathway that leads to a 1/3 reduction in energy use per capita for the state as a whole. However, because of Chittenden County's concentration of the State's largest employers, especially commercial/industrial establishments with high energy loads, Chittenden County as a whole, and a few of its largest municipalities, do not meet this goal individually when industrial electricity use is included in the projections. However, because the LEAP model includes this 1/3 reduction at a statewide level, these targets still represents a future that is consistent with this goal.

TABLE 12. PROJECTED TOTAL ENERGY USE PER CAPITA WITH INDUSTRIAL ENERGY USE

Projected Total Energy Use Per Capita (Including Industrial Electricity Use*) 2015-2050				
	2015	**2025**	**2035**	**2050**
Total Energy Use (MMBtu)	22,045,372	21,514,597	20,196,019	18,937,166
Population	161,382	169,580	174,764	183,172
Total Energy Use Per Capita (MMBtu)	137	127	116	103
Reduction in Total Energy Use Per Capita since 2015	--	-7%	-15%	-24%

Source: LEAP Model

**Please note that industrial electricity use is recognized as the most difficult element to project in the LEAP model, because of regional discrepancies in data from the commercial and industrial sector. Therefore, projected electricity use and total energy use are reported two ways: with industrial electricity use included and excluded.*

TABLE 13. PROJECTED TOTAL ENERGY USE PER CAPITA WITHOUT INDUSTRIAL ENERGY USE

Projected Total Energy Use Per Capita (Excluding Industrial Electricity Use) 2015-2050				
	2015	**2025**	**2035**	**2050**
Total Energy Use (MMBtu)	21,699,644	20,581,541	18,656,047	16,482,202
Population	161,382	169,580	174,764	183,172
Total Energy Use Per Capita (MMBtu)	134	121	107	90
Reduction in Total Energy Use Per Capita since 2015	--	-10%	-21%	-33%

Source: LEAP Model

**Please note that industrial electricity use is recognized as the most difficult element to project in the LEAP model, because of regional discrepancies in data from the commercial and industrial sector. Therefore, projected electricity use and total energy use are reported two ways: with industrial electricity use included and excluded.*

Renewable Energy Generation Targets and Potential

As seen in T~~t~~able 14, total in-state electricity consumption is estimated to be 10 million MWh in 2050. ~~Energy planners at the state level~~ The Department of Public Service ~~are~~ anticipat~~ing~~es that fifty-percent of this electricity will be generated within Vermont and the other half will be imported from out of state generators. To advance the state goals, CCRPC developed a range for estimating the region's share of the state's renewable energy generation. On the low end, Chittenden County needs to produce a total of 756,250 MWh by 2050. The low range target reflects that Chittenden County's share of the ~~has about 15% of the~~ state's energy resource areas for wind and solar generation and its share of the state's population is about 15%. The high range total target~~,~~ (1,265,134 MWh) ~~is representative~~ ~~of~~reflects that Chittenden County's share of the state's population ~~at~~is 25%. Once the total low and high targets for renewable energy generation were estimated, the existing renewable energy generation was subtracted from the total. The remaining amount is the new generation that needs to be sited within Chittenden County by 2050 to meet the renewable energy generation targets.

TABLE 14. RENEWABLE ENERGY GENERATION TARGET

Renewable Energy Generation Target	MWh
State Projected Electricity Demand (2050)	10,000,000
In-State Generation Target (2050)	5,000,000
State Imported Generation (2050)	50%
Low Target for Renewable Energy Generation in Chittenden County -15% of State	
Total Target	756,250
Existing Renewable Energy Generation	501,196
New Generation Needed	255,054
High Target for Renewable Energy Generation un Chittenden County -25% of State	
Total Target	1,265,134
Existing Renewable Energy Generation	501,196
New Generation Needed	763,938

Note: The Department of Public Service reports 556,623 MWh for the County. See Methodology for Renewable Energy Generation Targets for an explanation on why CCRPC is reporting a lower number.

TABLE 15. RENEWABLE ENERGY GENERATION TARGETS BY MILESTONE YEARS

Renewable Electricity Generation Targets						
	2025		2035		2050	
	Low	High	Low	High	Low	High
Generation Targets – Any Technology (MWh)	72,872	218,268	145,745	436,536	255,054	763,938
Sources: LEAP Model and CCRPC Modeling						

Chittenden County has sufficient energy resource area to meet the above generation targets. Solar and wind potential acreage (shown in T~~t~~able 15) is based on a mapping exercise completed by the Vermont Center for Geographic Information(VCGI), with modifications by CCRPC. The wind potential data is from the MA Technology Collaborative and is a model of predicted wind energy potential based on wind speed models. The solar energy potential data essentially identifies potential areas where optimal solar radiation is available based on east, west, and south facing aspect and slopes less than 14%.

Environmental and regulatory constraints are also accounted for in the analysis of wind and solar potential to identify prime and base areas. Prime areas are locations with high energy potential ~~and~~that are free from state/local known constraints. Base areas are locations with high energy potential and with a presence of state/local possible constraints. See below for an explanation of how CCRPC defined constraints in the region and see Supplement 3 for the list of constraints that ~~are~~were included in the analysis.

To determine the amount of renewable energy potential from the wind and solar acreage described above, conversion factors were applied to the base and prime areas to estimate the amount of capacity available for meeting Chittenden County's targets. See the discussion in the data analysis methodology for more information.

TABLE 16. LAND AVAILABLE FOR WIND AND SOLAR GENERATION

Land Available for Wind and Solar Generation		
	Prime Potential	Base Potential
Solar	8,657 acres (2% of county)	67,371 acres (19% of county)
Wind	12,042 acres (3% of county)	107,090 acres (31% of county)
Source: CCRPC and the Department of Public Service		

Table 17 describes the~~at~~ various technology and solutions available for Chittenden County to meet the renewable energy targets. These include roof top solar, ground mounted solar, wind turbines, biomass for heating, and hydro-electric energy. Given the regulatory complexities of siting new hydropower, this plan only identifies existing hydropower sites where equipment could be upgraded or expanded to provide additional generation. Because estimating the power generated from the use of biomass for heating or co-generation is site specific, only the number of acres of woody biomass ~~were~~was included below.

TABLE 17. PROJECTED RENEWABLE ELECTRICITY GENERATION POTENTIAL

Projected Renewable Electricity Generation Potential		
	Power (MW)	Energy (MWh)
Rooftop Solar*	103	126,328
Ground-Mounted Solar* – Prime	1,082	1,327,057
Ground-Mounted Solar* – Base	1,123	1,377,066
Wind – Prime	482	1,476,788
Wind – Base	4,284	13,133,457
Hydro	See Hydro Map	
Biomass	129,073 acres	
Methane	Unknown	Unknown
Other	Unknown	Unknown

Source: CCRPC and the Department of Public Service

*Rooftop solar potential is calculated by assuming that a certain percentage of rooftops can hold solar systems. Ground-mounted solar potential reports how much land could be developed with solar based on its aspect and elevation, and does not remove space taken up by impervious surfaces like roofs. Therefore, rooftop solar potential cannot be added to ground-mounted solar potential, as this would lead to some generation potential being double counted.

Given that the renewable energy targets are technology neutral, various scenarios are presented below to demonstrate several different ways Chittenden County can realize the targets.

Scenarios to Meet Generation Targets

To meet the low target, can we…

Produce 75% of the Low Target with Solar?

We have 7x the amount of prime solar or 54x the amount of base solar needed to meet this goal

Produce 25% of the Low Target with Wind?

We have 23x the amount of prime wind or 206x the amount of base wind needed to meet this goal

Produce 100% of the Low Target with Solar?

We have 5x the amount of prime solar or 40x the amount of base solar needed to meet this goal

Produce 100% of the Low Target with Wind?

We have 6x the amount of prime wind or 52x the amount of base wind needed to meet this goal

To meet the high target, can we…

Produce 75% of the High Target with Solar?

We have 2x the amount of prime solar or 18x the amount of base solar needed to meet this goal

Produce 25% of the Low Target with Wind?

We have 8x the amount of prime wind or 69x the amount of base wind needed to meet this goal

Produce 100% of the High Target with Solar?

We have 2x the amount of prime solar or 14x the amount of base solar needed to meet this goal

Produce 100% of the High Target with Wind?

We have 2x the amount of prime wind or 17x the amount of base wind needed to meet this goal

Supporting Maps

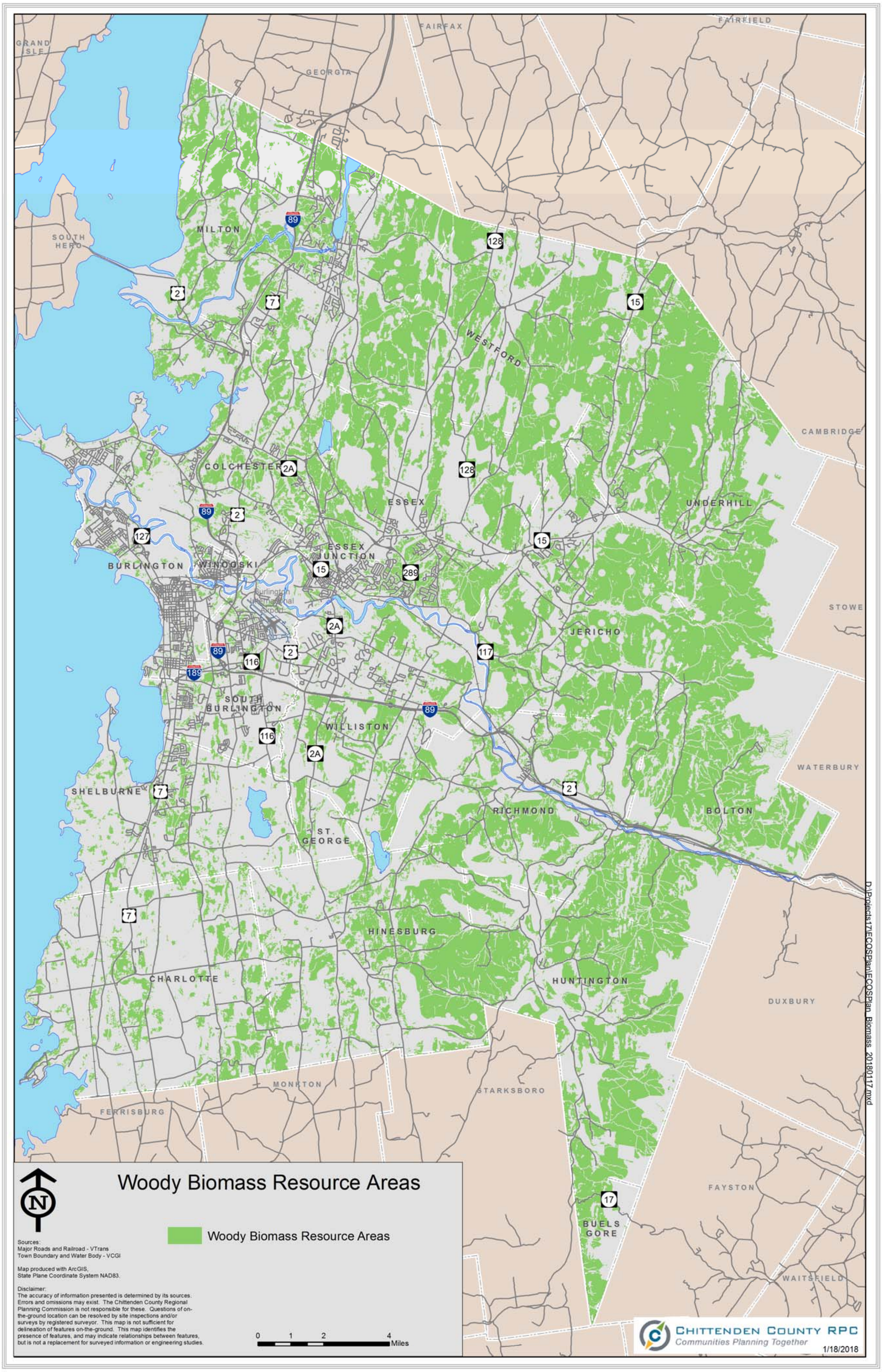
Map 1 shows "woody biomass resource areas" in Chittenden County. The McNeil Generating Station in Burlington is the region's largest user of biomass for energy generation. Most of the wood fueling the McNeil Station in Burlington comes from within 60 miles of the station and is a byproduct of other forestry operations. At full load, approximately 76 tons of wood chips are consumed per hour (about 30 cords). This far exceeds Chittenden County's abilities to produce biomass. A study conducted in 2010 showed that even if Chittenden County's entire annual wood harvest was put towards the McNeil Station, and all non-constrained forest land were harvested at a comparable rate, the McNeil Station could only run for 57 days on wood from Chittenden County. Large amounts of available wood can be found in other parts of Vermont, and neighboring counties in New Hampshire, Massachusetts and New York.[1] Wood products from both inside and outside Chittenden County will likely continue to provide fuel for the McNeil Station and other biofuel heat and electricity needs. Please keep in mind the woody biomass resource areas do not account for state/local known constraints.

Map 2 shows existing hydroelectric generation facilities in Chittenden County. Given the regulatory complexities of siting new hydropower, this plan only identifies existing hydropower sites where equipment could be upgraded or expanded to provide additional generation.

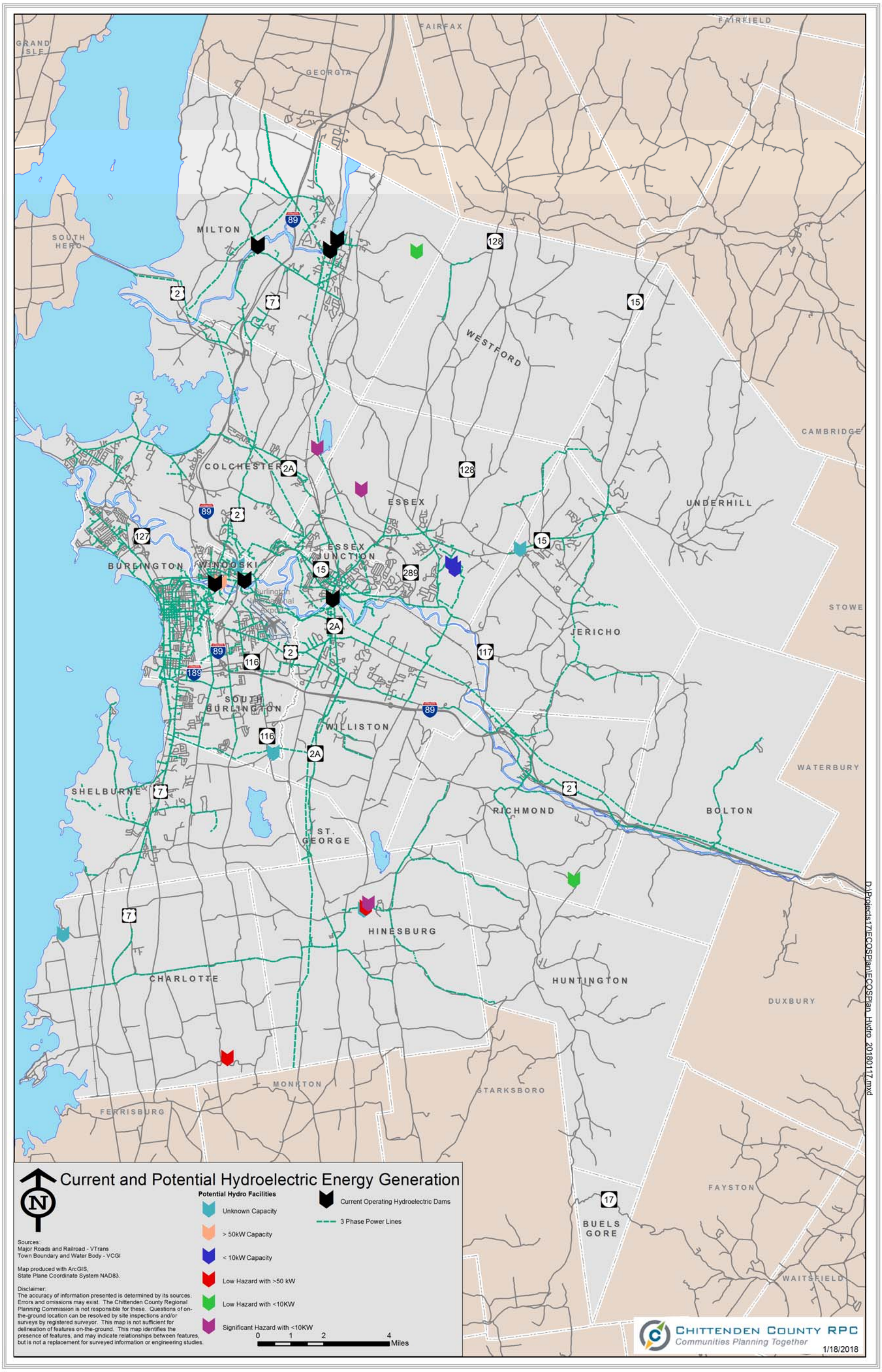
Maps of solar and wind generation potential, existing renewable generation in Chittenden County and constraints on renewable energy generation can be found in the main section of the ECOS Plan.

[1] https://www.biomasscenter.org/images/stories/VTWFSSUpdate2010_.pdf and https://www.burlingtonelectric.com/more-mcneil

MAP 1-WOODY BIOMASS RESOURCE AREAS



MAP 2-HYDRO ELECTRIC GENERATION



2. LEAP RESULTS AND TARGET METHODOLOGY

This section explains the process of transforming the raw data from the LEAP model into results that clearly show the type of changes that will be needed for Chittenden County to meet its energy goals.

LEAP is an accounting framework that shows one possible path for Chittenden County and its municipalities to meet the State's energy goals required for enhanced energy plans. LEAP aggregates existing energy use data and forecasts the demand for energy and sources of energy over time, based on a set of anticipated economic and policy changes. For example, demographic projections are one component of projecting future energy use. LEAP is well suited for examining how energy systems might evolve over time to meet certain goals (in this case, Vermont's goal to gain 90% of energy from renewable sources by 2050). LEAP reports targets in terms of total energy used for various sectors in various years, as shows below. See the section on VEIC's Methodology to understand the assumptions and inputs that were utilized in development of the LEAP model results.

TABLE 18. MTP SCENARIO TOTAL REGIONAL RESIDENTIAL HEATING CONSUMPTION

MTP SCENARIO TOTAL REGIONAL RESIDENTIAL HEATING CONSUMPTION THOUSAND MMBTUS				
BRANCHES	**2015**	**2025**	**2035**	**2050**
BIODISTILLATES	28	125	231	425
CORD WOOD	854	756	662	522
ELECTRIC RESISTANCE	347	268	163	24
HEAT PUMP	49	281	561	787
HEAT PUMP WATER HEATER	14	85	192	317
KEROSENE	93	68	43	-
LPG	957	768	569	251
NATURAL GAS	2,667	2,169	1,462	599
OIL	1,158	846	529	-
WOOD PELLETS	132	281	376	390
TOTAL	6,299	5,647	4,788	3,315

TABLE 19. MTP TOTAL REGIONAL COMMERCIAL HEATING CONSUMPTION

MTP Scenario Total Regional Commercial Consumption Thousand MMBTUs				
Branches	**2015**	**2025**	**2035**	**2050**
Biofuel	20	127	238	423
Distillate Fuel Oil	733	549	341	12
Electric Use	1,362	1,484	1,585	1,780
LPG	542	494	433	342
Natural Gas	1,938	1,570	1,146	481
Residual Fuel Oil	75	56	34	-
Wood and wood waste consumption	266	424	584	855
Total	4,937	4,704	4,361	3,892

TABLE 20. TOTAL HEAVY DUTY VEHICLE ENERGY CONSUMPTION

MTP Scenario Total Regional Heavy-Duty Vehicle Consumption Thousand MMBTUs				
Branches	**2015**	**2025**	**2035**	**2050**
Biodiesel	125	637	1,159	1,992
CNG	54	49	46	40
Diesel	1,731	1,245	764	27
LPG	24	21	18	13
Total	1,934	1,952	1,986	2,071

TABLE 21. TOTAL LIGHT DUTY VEHICLE ENERGY CONSUMPTION

MTP Scenario Total Regional Light Duty Vehicle Consumption Thousand MMBTUs				
Branches	**2015**	**2025**	**2035**	**2050**
Gasoline	6,457	5,382	2,840	242
Ethanol	862	603	343	43
Electricity	6	84	579	1,222
Diesel	217	142	80	3
Biodiesel	19	88	148	229
Hydrogen	-	-	-	-

Total	7,561	6,299	3,990	1,739

TABLE 22. TOTAL ELECTRICITY CONSUMPTION BY BRANCH

MTP Scenario Electric Consumption by Branch				
Branches	**2015**	**2025**	**2035**	**2050**
Central AC	5	5	5	5
Electric Appliances	62	66	71	84
Electric CDs etc	35	32	30	27
Electric Kitchen Range	6	7	8	10
Electric Lighting	124	92	69	47
Heat Pump Cooling	2	11	23	34
Misc Electric	135	144	165	212
Plug Load	7	6	6	6
Room Air Conditioning	9	8	7	3
Total	385	371	384	428

For the results reported by LEAP at the county level to be meaningful, they need to be reported in more accessible ways. The data were disaggregated to each municipality, and then reported in real-world metrics (for example, reporting on the percent of cars in each municipality that are electric vehicles, rather than reporting the total electricity used in the transportation sector at the county level). The

To do this, CCRPC utilized a tool from the Department of Public Service to translate the LEAP data into more a useable format. This will ~~that~~ make it easier for municipalities and the county to ~~will translate into tracking~~track progress made over time. ~~For example, the targets for transportation fuel switching are reported in number of electric cars instead of just the raw amount of electricity used for transportation.~~ These targets were reported for both the region and for each municipality. The municipal level data ~~is~~ are reported for each municipality in an individualized data guide. Guides for all municipalities ~~contained within a data guide and~~ can be found here.

Reporting Transportation Energy Use

Transportation energy use from the LEAP model is divided between each municipality based on that municipality's share of regional vehicle registrations in 2015. See below for more details on the LEAP model.

- Fossil fuel and electric vehicles in 2015: Vermont Department of Motor Vehicles, sorted by zip codes on vehicle registrations and fuel type
    - Williston and St. George share a zip code, and DMV data were broken down proportionately. St. George has 7% of the combined population of the two municipalities, and Williston has 93%.
    - Essex and Essex Junction share a zip code, and DMV data were reported together (data from several other sources, including the Department of Labor, were only available for Essex and Essex Junction combined).

- For Jericho, Richmond and Bolton, ACS data on vehicles available per household were used, as zip code boundaries cannot be easily broken down to correspond with town boundaries.

- Average annual number of miles travelled by a fossil fuel LDV in the region: 9,269
- Average fuel economy of fossil fuel burning LDV fleet in the region: 22
- Percentage of ethanol blended into area fuel supplies "at the pump" in the region: 9%
- Btu in a gallon of fossil fuel, computed as a weighted average of the individual heat contents of gasoline (95) and diesel (5%): 121,259
- Btu in a gallon of ethanol: 84,710
- Average annual number of miles travelled by EVs in the region: 7,000
- Average fuel economy of electric vehicles today, in miles per kWh: 3
- The number of Btu in a kWh of electricity at the point of use, aka site energy. (Note that all electricity numbers in the LEAP scenario are reported as site energy): 3,412
- Growth rate of vehicle ownership, 2015-2050: 0.4%
    - This was the growth rate of vehicle registrations in Chittenden County between 2011-2015.

TABLE 23. EXAMPLE CALCULATION: ELECTRIC VEHICLES

	2015	2025	2035	2050
Electricity Used for Transportation (from LEAP Model)	57.0 MMBtu	767.5 MMBtu	5,158.5 MMBtu	10,678.0 MMBtu
	= County Total * Municipal Share			
Energy Use of Average Electric Vehicle (Increases over time due to predicted technology improvement)	10.54 MMBtu	9.66 MMBtu	8.78 MMBtu	7.91 MMBtu
Municipal Electric Vehicles	5	80	587	1,355
	= Total Electricity Used for Transportation / Electricity Use per Electric Vehicle			

Reporting Thermal Energy Use

Thermal residential energy use from the LEAP model is divided between each municipality based on that municipality's share of regional households in 2015. Thermal commercial/industrial energy use from the LEAP model is divided between each municipality based on that municipality's share of total regional commercial/industrial thermal energy use in 2015. See below for more details on the LEAP model.

- Current number of residential buildings: CCRPC ECOS Plan Population and Household Forecasts, EPR
    - Growth rate between 2015 and 2050: 0.63%
- Current number of commercial and industrial establishments: Vermont Department of Labor
    - Data were reported for each municipality, with the exception of Essex and Essex Junction, which are combined in the DOL database. Data were reported for the two municipalities combined.
- Growth rate of commercial and industrial establishments, 2015-2050: 2.23%
    - This was the rate of commercial and industrial establishment growth between 2010-2015
- Average annual heating load of area residences: 110 MMBtu
    - Department estimate of the average square footage of conditioned residential space in the state. All else equal, higher average residence sizes than this will be associated with higher average area heat loads (and vice versa): 1,600-1,900
    - Percent of residences in the state that were built before 1930. All else equal, a higher percentage than this in your area will likely be associated with higher average area heating loads (and vice versa): 26%
    - Percentage of residences in the State with 6 rooms or more. All else equal, a higher percentage than this in your area will likely be associated with higher average area heating loads (and vice versa): 50%
    - Approximate percentage of residences in the State with 4 bedrooms or more. All else equal, a higher percentage than this in your area will likely be associated with higher average area heating loads (and vice versa): 20%
    - Number of people per household in State. All else equal, a higher number than this will likely be associated with higher average area heating loads (and vice versa): 2.30
    - Public Service Department estimate of the percentage of residences in the State that have been weatherized throughout the 2000s. All else equal, a higher percentage than this in your area will likely be associated with lower average area heating loads (and vice versa): 10%
- Average annual heating load of commercial establishments in area: 695
- Current Natural Gas Consumption: Reported by Vermont Gas

- The number of homes using wood heat is calculated by breaking down the projected energy used by wood heat in the LEAP model, based on the average area residential heating load. The number of homes using heat pumps is calculated by breaking down the projected energy used by heat pumps in the LEAP model, based on the average area residential heating load.
    - Average area residential heating load changes over time to account for increasing home weatherization.

TABLE 24. EXAMPLE CALCULATION: RESIDENTIAL WEATHERIZATION

2015	2025	2035	2050
110 MMBtu	105 MMBtu	100 MMBtu	83 MMBtu

- The number of businesses using wood heat is calculated by breaking down the projected energy used by wood heat in the LEAP model, based on the average area business heating load. The number of businesses using heat pumps is calculated by breaking down the projected energy used by heat pumps in the LEAP model, based on the average area business heating load.
    - Average area business heating load changes over time to account for increasing business weatherization.

TABLE 25. EXAMPLE CALCULATION: COMMERCIAL WEATHERIZATION

2015	2025	2035	2050
695 MMBtu	665 MMBtu	662 MMBtu	637 MMBtu

- Percent residences weatherized is calculated by dividing the LEAP model's projections of total heat energy saved by the weatherization of homes by the amount of energy projected to be saved by a typical home weatherization
    - The typical amount of heat energy that will be saved through future Residential weatherization investments: 28 MMBtu
- Percent businesses weatherized is calculated by dividing the LEAP model's projections of total heat energy saved by the weatherization of businesses by the amount of energy projected to be saved by a typical business weatherization
    - The typical amount of heat energy that will be saved through future business weatherization investments: 139 MMBtu

TABLE 26. EXAMPLE CALCULATION: WOOD HEAT

	2015	2025	2035	2050
Total Heat Energy from Wood (LEAP Model)	8150.6 MMBtu	8540.7 MMBtu	8590.5 MMBtu	7727.3 MMBtu
	= County Total * Municipal Share			
Average Household Heating Load (Decreases over time due to predicted increases in efficiency and weatherization)	110 MMBtu	105.28 MMBtu	99.72 MMBtu	82.75 MMBtu
Total Homes Using Wood Heat	74	84	86	93
	= Total Heat Energy from Wood / Average Household Heating Load			

Reporting Electric Energy Use

- Current electrical usage: 2013 consumption data from Efficiency Vermont, except for Burlington (see below), reported by town
    - In Burlington, actual 2013 consumption data were reported by Burlington Electric Department
- Total electric energy saved by municipality is determined by multiplying the total amount of electric energy saved projected by the LEAP model by the municipality's percentage of total county-wide electric energy use
- The percentage of residences that have increased their electric efficiency is determined by dividing the total electric energy saved in the municipality by the average electric savings from an electrical efficiency upgrade.
    - Average electric savings from an electrical efficiency upgrade: 400 kWh
- Current number of residential buildings: American Community Survey data
    - Growth rate between 2015 and 2050: 0.63%
- The percentage of businesses that have increased their electric efficiency: assumed to be the same as residences, per Department of Public Service guidance.

TABLE 27. EXAMPLE CALCULATION: ELECTRIC EFFICIENCY UPGRADES

	2015	2025	2035	2050
Total Electricity Saved via Efficiency Upgrades	74,700 kWh	888,100 kWh	1,792,800 kWh	3,353,200 kWh
	= County Total * Municipal Share			
Average Electricity Savings from Efficiency Upgrade	400 kWh	400 kWh	400 kWh	400 kWh
Total Homes Upgrading Electric Efficiency	14	171	245	645
	= Total Electricity Saved / Average Savings per Household			

Calculating Existing Generation and Generation Potential

Existing Electric Energy Generation

Data on generation sites, power and energy generation are available from the Vermont Energy Atlas. The Atlas reports sites and capacity (power) from Certificates of Public Good filed in each municipality. Some large facilities report actual energy generation to the Department of Public Service, which is included in the Energy Atlas.

Solar Energy Potential

The methodology for estimating ground-mounted solar potential is to divide the number of acres available as prime and base resources by 8 acres per MW for prime solar and 60 acres per MW for base solar. Then to estimate the amount of production using the formula below.

Solar MWh of energy = (number of MW) * (8760 hours per year) * (0.14 capacity factor)

Wind Energy Potential

The methodology for estimating wind potential is to divide the number of acres available as prime and base resources by 25 acres per MW. Then to estimate the amount of production using the formula below.

Wind MWh of energy = (number of MW) * (8760 hours per year) * (0.35 capacity factor)

Rooftop Solar Energy Potential

The approach to estimate the generation potential from rooftop solar is shown below. Because the number of structure with solar compatible rooftops will vary based upon physical characteristics and technical constraints, only a portion of rooftops are assumed to be suitable for rooftop solar.

TABLE 28. ROOFTOP SOLAR ASSUMPTIONS

Type of structure	Percent Suitable	Average size of rooftop system
Residential	25%	4 kW
Small Commercial (<40sf)	25%	20 kW
Large Commercial (>40 sf)	50%	200 KW

Calculating Renewable Energy Generation Targets

Regional Solar and Wind Targets

To determine how much renewable energy generation Chittenden County should plan to generate by 2050, a low and high target has been developed. Chittenden County has a large proportion of the State's population and a small proportion of the state's prime wind and solar generation areas. Because of this, the low target uses the average of Chittenden County's proportion of the population and its proportion of the state's prime wind and solar areas. The high target uses just the County's proportion of the state's population. Then, the existing renewable energy generation was subtracted out of each of the total low and total high targets to estimate the amount of new generation needed for each range. The final targets, therefore, reflects the additional generation the region needs to meet the 90X2050 goal.

The targets are technology neutral, meaning that they can be met with any mix of technologies. These targets reflect Chittenden County's share of the renewable energy production that will be needed to meet the goal of 90% renewable energy by 2050. See Table 29 below for the targets.

The existing renewable energy generation for the region is a total of the existing renewable energy generation reported on the Community Energy Dashboard for each town. Please note the total renewable energy generation utilized in establishing the regional target is less than the total generation reported by the Department of Public Service. The existing renewable energy generation for the County is a sum of each municipalities' total existing renewable energy generation sited within a municipalities' borders, so that each jurisdiction's generation was accounted for more accurately. For example, Milton includes half of Georgia Mountain Community Wind because two turbines are within the town of Milton.

Municipal Generation Targets

To better understand how the region can achieve its 2050 renewable energy generation targets, the CCRPC used a methodology to determine generation targets for each municipality in its region. These targets break down the regional generation targets to the municipal level, based on population and electricity consumption and account for existing generation within a municipality's borders.

To calculate town-level targets, the CCRPC first considered a municipality's share of the region's population and averaged that with the municipality's share of the region's electricity consumption. These averaged proportions approximate each municipality's responsibility to develop new generation based on existing conditions and demand. As such, both the low and high county targets, described above, are divided out to each municipality based on the averaged proportions. Then, the existing renewable energy generation is removed to provide an estimate of the amount of new renewable energy generation needed. The municipal targets are technology neutral, meaning that they can be met with any mix of renewable energy generation technology.

As seen in Table 29 below, a ✓ indicates that a municipality has met the target with existing renewable energy generation within the boundaries of the jurisdiction.

Once the renewable energy targets were estimated, two scenarios were modeled to determine how municipalities can potentially meet their targets. One scenario assumes 100% solar technology to meet the target and the other scenario assumes 100% wind technology. Tables ~~24~~ 30 and ~~25~~ 31 show the results of these scenarios. It is important to note that a municipality may choose to meet its target through a variety of different renewable energy technology types (e.g. wind, hydro, or biomass). This analysis is only intended to provide examples of possible scenarios for meeting the targets. In reality, a municipality will need to plan for meeting the target with a variety of technologies.

Overall, the region could meet the regional target using 100% solar energy. However, Essex Junction, Essex Town, and South Burlington would be unable to meet the high target in a scenario where solar technology was the only source of renewable energy generation. Essex Junction and Essex Town would not meet the high target through solar generation because of the high proportion of the regional target allocated to them. These jurisdictions are allocated a higher proportion of the regional target because of the high amount of energy consumption at Global Foundries (these municipalities consume 43% of the region's electricity). South Burlington has a large proportion of the region's population, but a small proportion of solar resource area; because a large area of the city is mapped as a constraint area associated with state-significant natural communities and rare, threatened, and endangered species.

The region could also meet the regional target using 100% wind energy. Additionally, all towns can meet the target if both prime and base wind resources are utilized. Therefore, the region can meet the renewable energy target with a combination of solar and wind technologies, as well as other renewable energy generation technologies.

Overall the region is in a good position to increase renewable energy generation. CCRPC will work on an annual basis to track progress towards meeting the renewable energy targets and will revisit the targets when the ECOS Plan is updated to ensure that the targets align with current population and electricity consumption.

TABLE 29. MUNICIPAL RENEWWABLE ENERGY TARGETS

Town Name	Population	Population Share	Electricity Use (2016) kWh	Electricity Share	Average of Population and Electricity Use	Total Low Target (MWh)	Total High Target (MWh)	Existing Renewables (MWh)	Low Range New (MWh)	High Range New(MWh)
Bolton	1,236	1%	6,438,601	0%	1%	4,218	7,057	328	3,890	6,729
Buels Gore	39	0%		0%	0%	92	154	6	86	148
Burlington	42,570	27%	337,120,744	18%	22%	168,431	281,769	285,442	✓	✓
Charlotte	3,822	2%	17,731,242	1%	2%	12,607	21,090	5,059	7,548	16,031
Colchester	17,293	11%	130,883,974	7%	9%	67,204	112,427	2,086	65,119	110,341
Junction + Town	20,419	13%	812,560,922	43%	28%	211,386	353,629	43,750	167,636	309,879
Hinesburg	4,472	3%	21,863,227	1%	2%	14,975	25,051	1,457	13,517	23,594
Huntington	1,875	1%	6,006,362	0%	1%	5,644	9,442	629	5,016	8,814
Jericho	5,043	3%	19,583,562	1%	2%	15,869	26,547	1,347	14,523	25,201
Milton	10,610	7%	73,247,256	4%	5%	39,817	66,610	102,752	✓	✓
Richmond	4,115	3%	18,449,817	1%	2%	13,445	22,491	4,485	8,960	18,006
Shelburne	7,566	5%	52,476,876	3%	4%	28,443	47,582	4,648	23,795	42,934
South Burlington	18,536	12%	209,096,439	11%	11%	85,841	143,604	13,988	71,853	129,616
St. George	764	0%	2,785,411	0%	0%	2,368	3,961	312	2,056	3,649
Underhill	3,061	2%	10,831,229	1%	1%	9,420	15,759	765	8,656	14,995
Westford	2,013	1%	7,193,338	0%	1%	6,209	10,387	411	5,798	9,976
Williston*	9,054	6%	115,680,384	6%	6%	44,647	74,691	3,435	41,213	71,256
Winooski	7,223	5%	42,522,563	2%	3%	25,633	42,882	30,297	✓	12,584
County Total	**159711**	**100%**	**1,884,471,945**	100%	**100%**	**756,250**	**1,265,134**	**501,196**	**255,054**	**763,938**

TABLE 30. 100% SOLAR SCENARIO

Town Name	Prime Solar Acres	Prime Solar Potential (MW)	% of Total Acreage in Prime Solar	Potential Solar Capacity from Prime Solar (MWh)	Can Meet Low Target with Prime Solar Potential ?	Can Meet High Target with Prime Solar Potential?	Base Solar Acres	Base Solar Acres Potential (MW)	% of Total Acreage in Base Solar	Potential Solar Capacity from Base Solar (MWh)	Can Meet Low Target with Prime + Base Solar Potential?	Can Meet High Target with Prime + Base Solar Potential?
Bolton	173	22	1%	26,517	1	1	1,138	19	4%	23,271	1	1
Buels Gore	9	1	0%	1,393	1	1	91	2	3%	1,861	1	1
Burlington	71	9	1%	10,808	1	1	2,042	34	30%	41,738	1	1
Charlotte	291	36	1%	44,536	1	1	10,647	177	40%	217,625	1	1
Colchester	737	92	3%	112,970	1	1	4,813	80	20%	98,378	1	1
Junction + Town	883	110	9%	135,323	0	0	7,716	129	64%	157,707	1	0
Hinesburg	833	104	3%	127,684	1	1	5,237	87	21%	107,049	1	1
Huntington	409	51	2%	62,751	1	1	1,923	32	8%	39,300	1	1
Jericho	575	72	3%	88,219	1	1	3,855	64	17%	78,791	1	1
Milton	942	118	3%	144,409	1	1	7,783	130	23%	159,085	1	1
Richmond	548	69	3%	84,018	1	1	1,793	30	9%	36,655	1	1
Shelburne	436	54	3%	66,835	1	1	4,840	81	30%	98,930	1	1
South Burlington	206	26	2%	31,547	0	0	3,107	52	29%	63,507	1	0
St. George	62	8	3%	9,543	1	1	423	7	18%	8,646	1	1
Underhill	795	99	2%	121,934	1	1	4,487	75	14%	91,707	1	1
Westford	792	99	3%	121,478	1	1	3,904	65	16%	79,801	1	1
Williston*	738	92	4%	113,111	1	1	3,277	55	16%	66,992	1	1
Winooski	156	20	17%	23,984	1	1	295	5	31%	6,023	1	1
County Total	8,657	1,082	2%	1,327,057	1	1	67,371	1123	19%	1,377,066	1	1

TABLE 31. 100% WIND ENERGY SCENARIO

Town Name	Prime Wind Acres	Prime Wind Potential (MW)	% of Total Acreage in Prime Wind	Potential Capacity from Wind (MWh)	Can Meet Low Target with Prime Wind Potential ?	Can Meet High Target with Prime Wind Potential?	Base Wind Acres	Base Wind Acres Potential (MW)	% of Total Acreage in Base Wind	Potential Capacity from Base Wind (MWh)	Can Meet Low Target with Prime + Base Wind Potential?	Can Meet High Target with Prime + Base Wind Potential?
Bolton	88	4	0%	10,833	1	1	2,880	115	11%	353,169	1	1
Buels Gore	56	2	2%	6,917	1	1	1,722	69	54%	211,166	1	1
Burlington	200	8	3%	24,501	1	1	2,767	111	41%	339,385	1	1
Charlotte	414	17	2%	50,731	1	1	19,056	762	72%	2,336,982	1	1
Colchester	693	28	3%	85,032	1	0	3,666	147	15%	449,546	1	1
Junction + Town	125	5	0.6%	15,278	0	0	3,307	132	15%	405,570	1	1
Hinesburg	1110	44	4%	136,080	1	1	10,824	433	43%	1,327,422	1	1
Huntington	1892	76	8%	232,045	1	1	6,564	263	27%	805,005	1	1
Jericho	447	18	2%	54,815	1	1	4,889	196	22%	599,538	1	1
Milton	1197	48	4%	146,757	1	1	11,729	469	35%	1,438,489	1	1
Richmond	1710	68	8%	209,715	1	1	2,905	116	14%	356,260	1	1
Shelburne	1108	44	7%	135,899	1	1	9,082	363	57%	1,113,875	1	1
South Burlington	413	17	4%	50,598	0	0	5,107	204	48%	626,301	1	1
St. George	116	5	5%	14,247	1	1	1,500	60	64%	183,985	1	1
Underhill	366	15	1%	44,942	1	1	10,139	406	31%	1,243,438	1	1
Westford	477	19	2%	58,538	1	1	4059	162	16%	497,739	1	1
Williston*	1570	63	8%	192,521	1	1	6,775	271	34%	830,837	1	1
Winooski	60	2	6%	7,339	1	0	120	5	13%	14,750	1	1
County Total	12,042	482	3%	1,476,788	1	1	107,090	4284	31%	13,133,457	1	1

Constraints and Suitability Methodology

State Constraints

The Department of Public Service has distributed energy planning standards, which establish known and possible constraints at the state level. Regions and municipalities can make constraints more restrictive (i.e. turn a possible constraint into a known constraint) but not less restrictive (i.e. turn a known constraint into a possible constraint). CCRPC has not made any changes to state constraints.

Local Constraints

Because one of the purposes of Act 174 is to give local land use policies greater weight in the Public Utilities Commission process, CCRPC's ECOS Plan includes local constraints in the energy siting maps and policies. In late 2016, CCRPC staff discussed the possibility of substantial deference for municipal land use policies with planning commissions and municipal staff, and asked municipalities to provide a list of "constraints" that they would like to see given substantial deference. The CCRPC Long Range Planning Committee Energy Subcommittee (the Subcommittee) asked staff to map the constraints provided by the municipalities. Municipalities requested known constraints (areas in which they wanted no renewable energy development), possible constraints (areas on which they wanted renewable energy development to be limited or impacts to be mitigated or minimized). All requested constraints were mapped in early 2017 and reviewed by the Subcommittee.

Based on feedback from the Department of Public Service, it was determined that for constraints on energy to be consistent with the Act 174 energy planning standards, the constraints had to be restrictive of all development, not just renewable energy development. With this in mind, CCRPC staff screened the constraints originally requested by municipalities and determined that a number of them originally requested as known constraints were not equally restrictive of all development. These constraints were considered possible constraints, based on the description below. If no supporting policies or regulations could be located to support a request for a possible constraint, the constraint was not included at all.

These local constraints are included in the ECOS Plan due to their importance at the local level. The ECOS Plan classified local constraints based on the following methodology. However, the description of constraints below is for classification only, and these descriptions are not the definitions of known and possible constraints as discussed in the policies of the ECOS Plan.

Known Constraints: Zoning districts or resource areas where development is prohibited with no exceptions. Typically, phrases such as "development *shall not* take place" are used to denote these areas.

Possible Constraints: Zoning districts or resource areas such as those in which:

- Development is not completely prohibited, but impacts of development should be "minimized", "avoided," "limited," "avoided *where possible,*" mitigated or similar;
- Development is allowed only following conditional use review;
- The goals of the zoning district are such that large-scale energy development may not be appropriate, such as scenic overlay districts;

These constraints are identified in an adopted municipal plan or municipal land use regulation such as zoning regulations or subdivision regulations, in effect as of December 1, 2017.[2] Over the next few years CCRPC will be working with municipalities to complete energy planning, and will continue to review municipal plans through CCRPC's *Guidelines and Standards for Confirmation of Municipal Planning Processes and Approval of Municipal Plans*. CCRPC will check to ensure that any local policies don't preclude municipalities from meeting their energy generation targets and complying with the state energy goals. CCRPC will determine on a case by case basis if an edit is needed to the *ECOS Plan*.

CCRPC staff evaluated constraints based on the requests of the municipality. Not every development constraint in Chittenden County is reflected in the regional energy planning process, because some municipalities did not request any known or possible constraints (no requests from Buel's Gore, Huntington or St. George), or only requested that some of their resource protections considered.

While there was some overlap between the constraints requested by each municipality, no constraints emerged as being universal restrictions to development across the county. Therefore, no region-wide constraints were added.

Constraints are discussed in Strategies 3 and 4 of the ECOS Plan, which address the protection of natural resources.

Suitability Methodology

Constraints represent areas in which development, including energy generation, is restricted. However, areas in which development is generally appropriate still have different levels of *suitability* for different types and scales of renewable energy generation. This may be due to conflicts between energy generation and other types of planned development, or infrastructure capacity issues. Therefore, we have incorporated considerations of scale into our siting policy statements in Chapter 3 to address suitability.

[2] Subject to change based on ECOS hearing and adoption schedule.

~~2.~~3. LEAP MODELING METHODOLOGY

This section describes the Long-range Energy Alternatives Planning (LEAP) System energy modeling tool used to analyze energy scenarios which is the basis for the future energy estimations presented in the previous section. Detailed sources and assumptions are included at the end of this section.

The LEAP is an accounting framework that aggregates existing energy use data and forecast efforts to analyze the demand for energy and sources of energy over time. LEAP is well suited for examining how energy systems might evolve over time as scenarios can be created to consider different economic and policy modifications associated with future energy use.

LEAP allows for total energy systems to be documented and modeled across transportation, electric and thermal (heating) demands. Prior work funded by the US Department of Energy's SunShot Solar Market Pathways program developed LEAP scenarios consistent with statewide goals for renewable energy use which formed the basis for CCRPC's LEAP scenarios. CCRPC then worked with Vermont Energy Investment Corporation (VEIC) to pivot off the original LEAP Scenario to develop scenarios that are specific to Chittenden County.

The LEAP tool provides a robust framework to consider energy demand which can be customized according to data available, level of aggregation desired and different fuels and vehicle efficiencies. VEIC has developed LEAP model scenarios for Vermont with transportation energy demand based on population, travel demand and vehicle efficiency/fuels.

Targets for future energy use are drawn from the state-wide LEAP analysis. Historic information was primarily drawn from the Public Service Department's Utility Facts 2013[3] and EIA data. Projections came from the Total Energy Study (TES)[4], the utilities' Committed Supply[5], and stakeholder input. Each sector has a "demand driver" unit used to measure activity in the sector. These drivers are multiplied by the energy intensity of the activity to calculate energy demand.

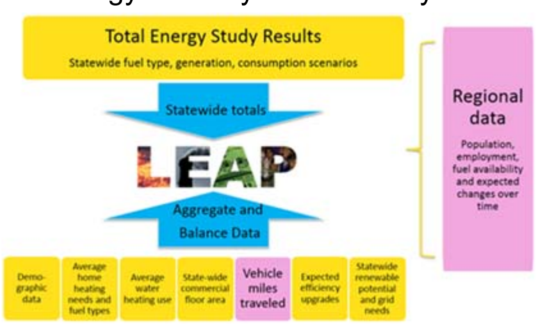


Figure 1 illustrates inputs to LEAP in the context of the Total Energy Study as well as region-specific adjustments made to scenarios constructed for this plan's LEAP analysis (indicated by pink shading).

FIGURE 1. LEAP ENERGY MODELING IN REGIONAL CONTEXT

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

[4] 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.

[5] 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

LEAP Regionalization Approach

The statewide LEAP model was disaggregated into RPC regions as part of a project done in conjunction with Bennington County Regional Commission, the Vermont PSD and RPCs across the state, including CCRPC.

Residential energy demand was distributed according to housing unit estimates. 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 building sector, it was assumed Chittenden County's share of total statewide commercial building square footage was related to Chittenden County's share of total statewide employment, estimated at 27%, and commercial fuel use per employee had 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 remainder of commercial fuel use was allocated to create equal consumption by employee across the state.

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. Delivered fuels (i.e. propane, oil, and kerosene) were distributed among regions without access to natural gas, as it was assumed that other delivered fuels were primarily used for combustion purposes, and that purpose could likely be served more cheaply with gas.

Transportation energy usage was developed from the 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 TES FACETS data. There were some changes to the FACETS data, which are discussed in the vehicle category details below.

Demographic and Economic Forecast

The number of people and households in the region is a fundamental input to LEAP. The initial LEAP model created for the Solar Market Pathways work used the *Vermont Population Projections 2010-2030* prepared by the Vermont Department of Aging and Independent Living (DAIL).[6] The 0.48% annual growth rate was assumed constant through 2050.

LEAP scenario inputs were updated following CCRPC Board approval of updated regional population forecasts in March 2017 (Table 32 below).

[6] 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.

TABLE 32. CHITTENDEN COUNTY POPULATION FORECAST (MARCH 2017)[7]

Year	Chittenden County Population	Average Annual Growth Rate
2010	156,545	--
2015	161,382	0.61%
2020	165,803	0.54%
2025	169,580	0.45%
2030	172,596	0.35%
2035	174,764	0.25%
2040	176,179	0.16%
2045	178,927	0.31%
2050	183,172	0.47%

Persons per household were assumed to decrease from 2.4 in 2010 to 2.17 in 2050. The number of households were calculated based on population and household size to provide the basic unit for residential energy consumption in the model.

LEAP Inputs by Energy Sector

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.

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.

[7] CCRPC. *Chittenden County Municipal Population Forecast - Revised*. March 8, 2017. http://www.ccrpcvt.org/our-work/our-plans/ecos-regional-plan/

Additional information came from the following data sources:

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

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 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 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.

Appliances and Other Household Energy Use:
EnergyStar appliance estimates and the Efficiency Vermont Electric Usage Chart 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. Projected change in the energy demand from the commercial sector was based on commercial sector data derived from modeling performed for the Vermont Total Energy Study[8] (TES) prepared by the Vermont Public Service Dept. in 2014. The demand driver for the commercial sector is commercial building square feet which is expected to grow 17% from 2010 to 2050.

Industrial
Industrial use was entered directly from the results of the TES data. Total industrial consumption by fuel was applied directly from the TES directly, growing from 1.1 TBtu in 2010 to 1.4 TBtu in 2050.

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.

~~Projected change in the energy demand from the commercial sector was based on commercial sector data derived from modeling performed for the Vermont Total Energy Study (TES)[8] prepared by the Vermont Public Service Dept. in 2014. The demand driver for the commercial sector is commercial building square feet which is expected to grow 17% from 2010 to 2050.~~

~~Total industrial consumption by fuel was applied directly from the TES directly, growing from 1.1 TBtu in 2010 to 1.4 TBtu in 2050.~~

Transportation

Transportation energy use was based on population projections, estimates of per capita vehicle miles traveled (VMT), and forecasts of vehicle efficiency and energy sources.

Light Duty Vehicles
Light Duty Vehicles (LDVs) are generally passenger cars, light trucks and sport utility vehicles that are used for household and business-related transportation. LDV efficiency was based on a number of assumptions: gasoline and ethanol efficiency were derived from the Vermont Transportation Energy

[8] Vermont Public Service Dept. *Total Energy Study*. December 2014. http://publicservice.vermont.gov/publications-resources/publications/total_energy_study

Profile.[9] 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.[10] Baseline plug-in electric vehicle (EV) efficiency was derived from a weighted average of EVs currently registered in Vermont and was then was assumed to increase at a rate of 0.6% annually as EV technology is expected to improve as it matures.

The miles traveled per LDV for the base year 2015 analysis was calculated using data from the Vermont Agency of Transportation on statewide vehicles per capita and annual miles traveled by vehicle class in Chittenden County.[11] LDVs were assumed to travel 9,630 miles per vehicle. The total number of LDVs in Chittenden County was based on a ratio of total LDVs from TES Transportation Data and Census population.

The number of EVs was sourced from Drive Electric Vermont data on EV registrations by make and model, including an estimate of the percentage driven in electric mode for plug-in hybrid vehicles which can run on battery electricity or gasoline. Drive Electric Vermont also provided a forecast of the number of EVs for future scenarios, growing exponentially as a percent of LDV from 0.2% in the base year to 89% in 2050, allowing for nearly all of LDV travel to be powered from renewable electric sources.

Heavy Duty Vehicles

Similar to the LDV vehicle efficiency methods above, HDV efficiency values were collected from different sources to provide a customized LEAP analysis. A weighted average of HDV diesel efficiency was calculated using registration and fuel economy values from the Transportation Energy Data Book.[12] The vehicle efficiency values for diesel and compressed natural gas (CNG) were assumed to be equal.[13] Diesel efficiency was reduced by 10% to represent biodiesel efficiency.[14] Propane efficiency was calculated using a weighted average from the Energy Information Administration Annual Energy Outlook table for Freight Transportation Energy Use.[15]

In the future scenario analysis focused on renewable energy use, including the MTP scenario, it was assumed HDVs will switch to biodiesel or renewable diesel by 2050. Renewable diesel is a relatively new formulation which is a “drop-in” replacement for diesel that does not gel in colder temperatures and is created from bio-feedstocks.[16]

Although there has been some progress toward electrifying HDVs, the current future renewable energy scenario does not include electric HDVs. Electric transit buses are under consideration in Chittenden

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[9] 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

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

[11] Jonathan Dowds et al. *Vermont Transportation Energy Profile*.

[12] Ibid

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

[14] U.S. Environmental Protection Agency: Office of Transportation & Air Quality. *Biodiesel*

[15] 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

[16] 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

County and vehicle manufacturers are developing electric tractor trailer vehicles. The California Air Resources Board indicated a very limited number of electric HDVs were in use within the State of California, but Tesla and other vehicle manufacturers have reported on the development of electric semi-tractors that could reduce the costs and energy of freight transport if they reach the marketplace. [17, 18]

The total number of HDVs was derived from TES Transportation Data on HDV energy use.[19] HDV miles were calculated based on VTrans traffic research data for Chittenden County shown in T~~t~~able 33~~27~~ below. The total number of HDVs and HDV miles per capita were combined with the population assumptions outlined above to calculate miles traveled by HDVs. Total energy consumed by HDVs is based on an average efficiency of 7 miles per gallon increasing to 8.75 miles per gallon by 2050. Use of renewable biofuels in the HDV sectors is predicted to increase from about 1% in 2015 to 85% of vehicles by 2050. This increase in biofuels is based on modeling done for the TES.

TABLE ~~2~~33. ~~7.~~ 2015 CHITTENDEN COUNTY ANNUAL VEHICLE MILES TRAVELED BY LEAP TYPE (MILLIONS)

Light Duty AVMT *Motorcycles, Passenger Cars, Light Trucks*	**Heavy Duty AVMT** *Buses, Combination Trucks, Single Unit Trucks*	**Total AVMT**
1,363,034,000	122,982,000	1,486,018,000

Rail

The passenger rail sector of transportation demand was regionalized to Chittenden County using Amtrak boarding and alighting data to create percentages of rail miles activity by region.[20] The freight rail sector of transportation was based on the share of employees in goods-producing NAICS code sectors in areas served by freight rail. Each region's share of state activity and energy use was held constant across years as a simplifying assumption.

Chittenden County LEAP Scenario Results

Two rounds of LEAP analysis were completed for the CCRPC. The preliminary analysis was completed in April 2017 and is documented in the section below. The LEAP analysis was then updated in November 2017 with two additional scenarios based on CCRPC's transportation model analysis of the 2050 ECOS plan's Metropolitan Transportation Plan (MTP). Results from the MTP analysis are documented in the section following the preliminary analysis with detailed tables of the MTP Scenario in the Target Methodology section.

Preliminary LEAP Analysis

[17] 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
[18] Elon Musk. *Master Plan, Part Deux.* July 20, 2016, https://www.tesla.com/blog/master-plan-part-deux
[19] Jonathan Dowds et al. *Vermont Transportation Energy Profile*
[20] National Association of Railroad Passengers. *Fact Sheet: Amtrak in Vermont.* 2016. https://www.narprail.org/site/assets/files/1038/states_2015.pdf

VEIC developed several scenarios of energy systems in Chittenden County. Figure 1 below illustrates the total energy supply, including the amount produced from renewable sources, for 4 initial scenarios created in April 2017. The **2015 Reference** reflects current conditions in Chittenden County. The **2050 Reference** assumes a continuation of today's energy use patterns, and 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 due to federal fuel efficiency standards and the expansion of natural gas infrastructure. The **2050 CCRPC 90x2050** 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 with advances in 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. The **2050 CCRPC GAS** scenario assumes natural gas usage continues at current 2015 levels to allow for further exploration of options to address natural gas energy consumption and emissions based on current conditions.

FIGURE 1. CHITTENDEN COUNTY ENERGY SUPPLY FOR INITIAL LEAP SCENARIOS

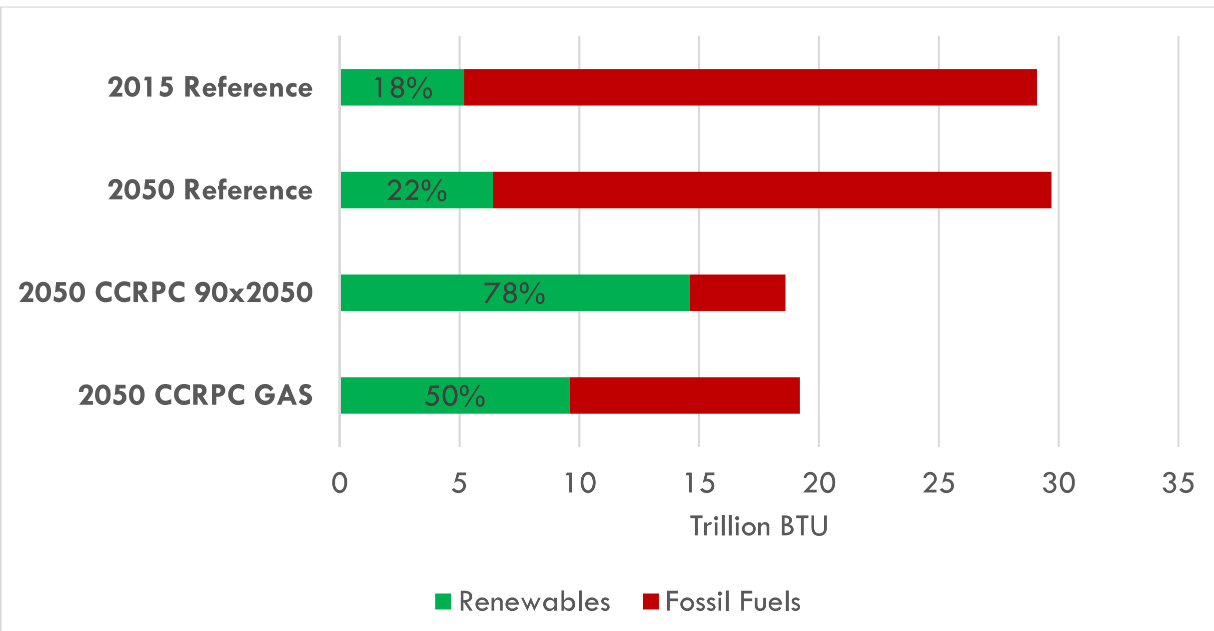


Figure 2 below also summarizes energy use across the same set of scenarios as shown above but excludes aviation fuel. Air transport is an area the CCRPC has little ability to influence or control and the Burlington International Airport serves customers from an area much broader than Chittenden County. Under these conditions Chittenden County is predicted to reach 85% renewable energy use by 2050 under the 90x2050 scenario. This is in line with statewide goals of reaching 90% renewable energy as individual regions may vary in meeting the statewide renewable goal in the CEP.

FIGURE 2. CHITTENDEN COUNTY ENERGY SUPPLY BY LEAP SCENARIO – EXCLUDING AVIATION FUEL

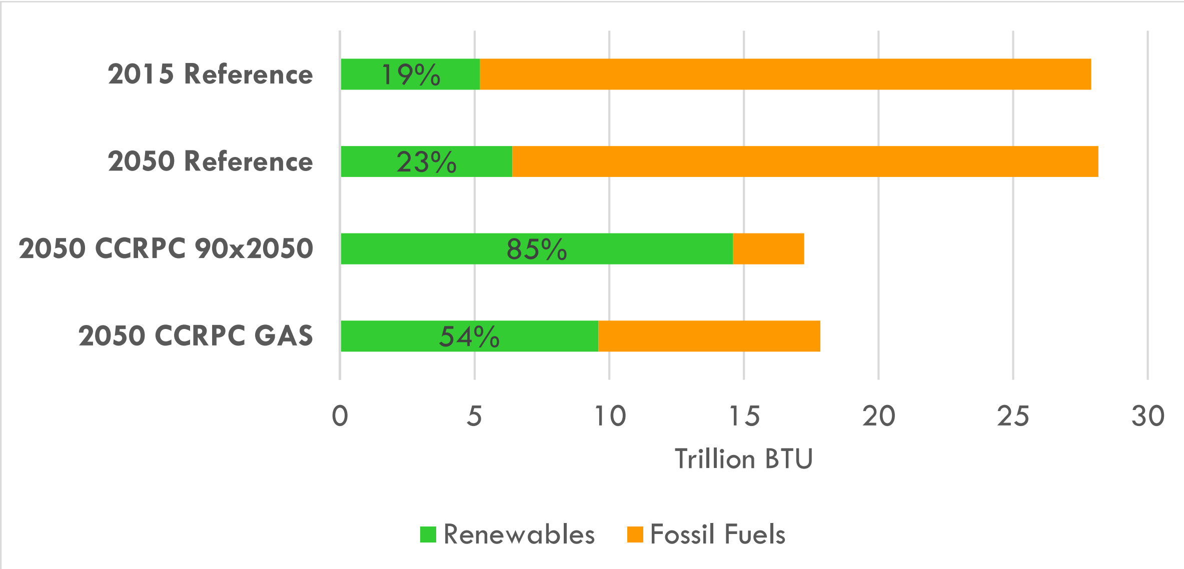
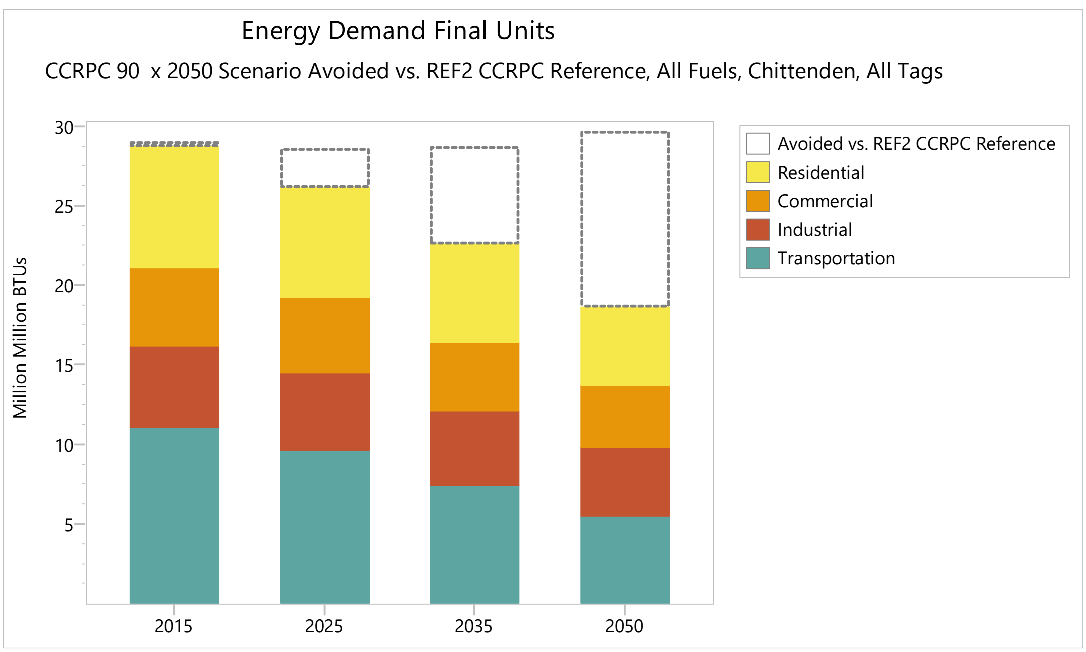


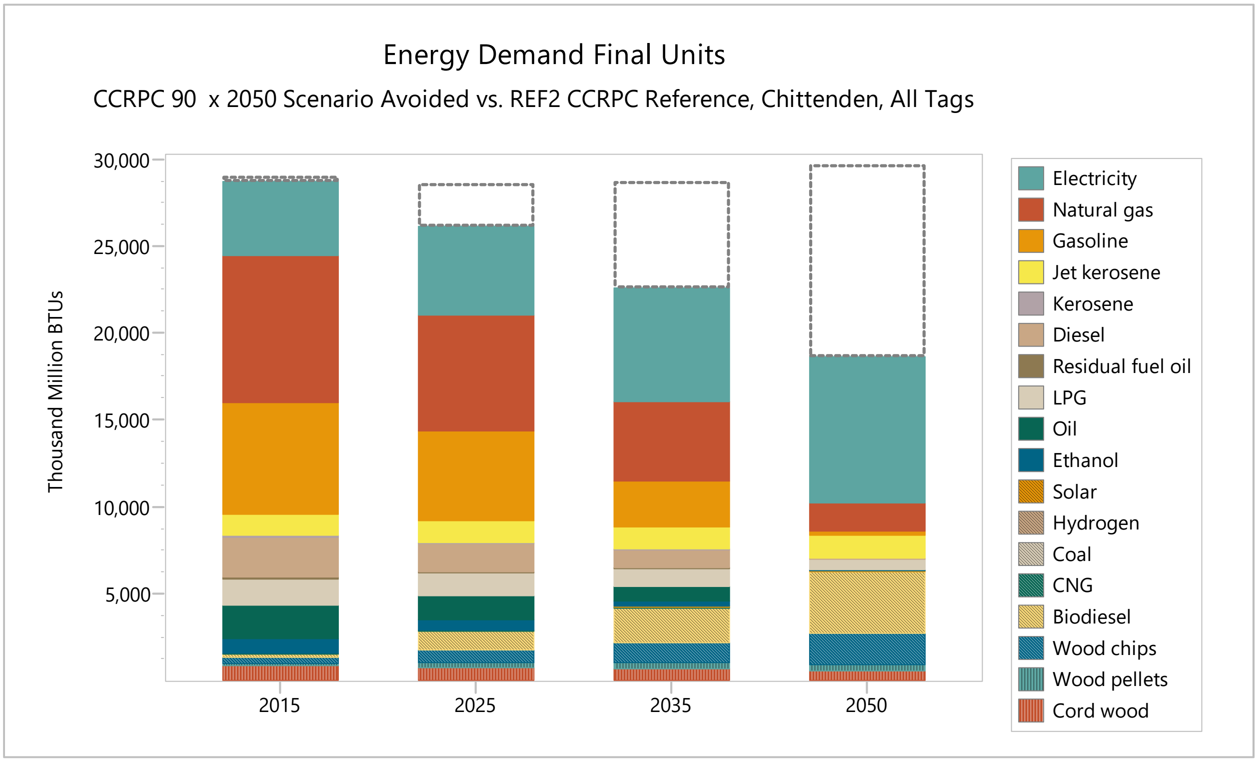
Figure 3 below shows the shift in energy use by end use sector over time under the 90x2050 scenario. The empty boxes at the top of the bars indicate the energy use avoided compared to the reference case.

FIGURE 3. CCRPC 90X2050 SCENARIO ENERGY USE OVER TIME, BY SECTOR



Another view of the 90x2050 scenario shifts in energy and fuel use over time is included in Figure 4 below. Under this scenario renewably generated electricity comprises the largest share of fuel use in the region.

FIGURE 4. CCRPC 90X2050 SCENARIO ENERGY USE OVER TIME, BY FUEL



~~The appendix includes several tables with detailed information on energy use by sector and fuel for the reference and 90x2050 scenarios.~~

MTP LEAP Analysis

Following the development of the initial LEAP scenarios, VEIC revisited the analysis based on anticipated changes in the 2050 Metropolitan Transportation Plan update. Data from the CCRPC regional transportation model analysis of the recommended 2050 MTP scenario as well as the 2050 reference (aka "business as usual") scenario were reviewed. Additional LEAP scenarios were created for both of these 2050 scenarios by adjusting the VMT per vehicle inputs for light and heavy-duty vehicles based on transportation model outputs.

The CCRPC transportation model combines land use patterns (reflected by housing and employment), transportation system characteristics and travel behavior to estimate travel patterns in the county. Among the outputs of the model are estimates of VMT by trip type and type of vehicle.

HBW VMT
HBO VMT
NHB VMT
L_COMM VMT

FIGURE

M_COMM VMT
H_COMM VMT
IX Medium Truck VMT
XI Medium Truck VMT
IX Heavy Truck VMT
XI Heavy Truck VMT
IX Passenger VMT
XI Passenger VMT
XX Passenger VMT
XX Medium Truck VMT
XX Heavy Truck VMT

~~FIGURE~~ 5 below illustrates the different types inter and intra county trips. Trips completely within Chittenden County are internal to internal, trips from Chittenden County to destinations outside are internal to external, trips from outside the county to inside are external to internal and trips that begin and end outside the county are external to external. Table 34~~28~~ below is a ~~color-coded~~ list of VMT reporting data for all vehicle trip types in the model. The travel associated with Chittenden County residents and vehicles is flagged with both the internal-to-internal and internal-to-external trips. ~~highlighted in green to reflect light duty vehicle travel. Medium and heavy vehicle internal VMT are similarly highlighted in yellow~~.

FIGURE 5. CHITTENDEN COUNTY WORKER FLOW TRIP TYPES, 2015[21]

TABLE 34~~28~~. CCRPC TRANSPORTATION MODEL TRIP TYPES

HBW VMT	
HBO VMT	Internal Light Duty VMT
NHB VMT	
L_COMM VMT	
M_COMM VMT	
H_COMM VMT	Internal Heavy Duty VMT
IX Medium Truck VMT	
XI Medium Truck VMT	
IX Heavy Truck VMT	
XI Heavy Truck VMT	
IX Passenger VMT	
XI Passenger VMT	External VMT
XX Passenger VMT	
XX Medium Truck VMT	
XX Heavy Truck VMT	

[21] US Census Bureau OnTheMap Application and LEHD Origin-Destination Employment Statistics. https://onthemap.ces.census.gov/

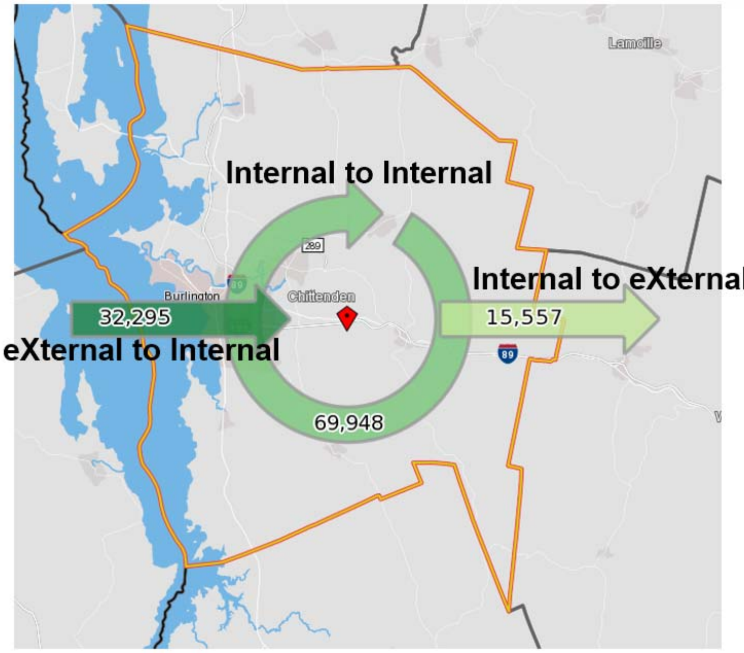


Table ~~29~~ 35 and T~~T~~able ~~30~~ 36 below show the actual light and heavy-duty vehicle VMT estimates from the CCRPC transportation model for the 2015 base year, the 2050 reference and the 2050 MTP scenarios. These estimates of total VMT were divided by the LEAP vehicle populations estimated for 2015 and 2050 shown in ~~t~~Table ~~31~~ 37 to calculate the per vehicle VMT for light and heavy-duty vehicles in T~~T~~able ~~32~~38.

TABLE ~~29~~35. CCRPC TRANSPORTATION MODEL LIGHT DUTY VMT BY TRIP TYPE

Trip Type	2015 Base	2050 Reference	2050 MTP
HBW VMT	530,051	660,950	618,194
HBO VMT	733,531	932,059	865,882
NHB VMT	428,398	532,731	517,195
L_COMM VMT	685,582	949,491	944,088
IX Passenger VMT	622,874	752,315	752,350
Total Internal and IX VMT	3,000,436	3,827,546	3,697,709

TABLE 3~~0~~6. CCRPC TRANSPORTATION MODEL HEAVY DUTY VMT BY TRIP TYPE

Trip Type	2015 Base	2050 Reference	2050 MTP
M_COMM VMT	91,540	125,924	125,119
H_COMM VMT	20,972	31,389	31,425
IX Medium Truck VMT	41,619	50,457	50,444
IX Heavy Truck VMT	21,223	25,703	25,649
Total Heavy Duty Internal and IX VMT	175,354	233,473	232,637

TABLE 37~~1~~. LEAP VEHICLE POPULATION ESTIMATES

LEAP Vehicle Category	2015 Base	2050 Reference	2050 MTP
Light Duty Vehicles (LDV)	136,181	151,281	151,281
Heavy Duty Vehicles (HDV)	2,379	2,898	2,898

TABLE 3~~2~~8. VMT PER VEHICLE ESTIMATES

	2015 Base	2050 Reference	2050 MTP
LDV Daily VMT / Vehicle	22.03	25.30	24.44
HDV Daily VMT / Vehicle	73.70	80.56	80.27

The VMT percent change from 2015 to 2050 was calculated for the 2050 Reference and 2050 MTP scenarios (see Table ~~33~~39). These percent changes were applied to the 2015 base year LEAP estimates of annual VMT by vehicle type to arrive at estimates of annual VMT reflecting the 2050 reference and 2050 MTP scenario analysis in the CCRPC transportation model shown in Table 40~~34~~ and used to update the LEAP analysis for these scenarios.

TABLE 3~~3~~9. PERCENT CHANGE IN VMT PER VEHICLE COMPARED TO 2015 BASE

	2050 Reference	2050 MTP
Percent Change LDV VMT / Vehicle	14.83%	10.94%
Percent Change HDV VMT / Vehicle	9.32%	8.92%

TABLE ~~34~~40. UPDATED LEAP ANNUAL VMT PER VEHICLE ESTIMATES

	2015	2050 Reference	2050 MTP
LDV Annual VMT per vehicle	9,631	11,060	10,685
HDV Annual VMT per vehicle	49,170	53,750	53,558

The results of the MTP LEAP scenario analysis are illustrated below with Figure 6 showing the total energy consumption by scenario. Aviation jet fuel was not included as was discussed in the initial LEAP analysis above. Chittenden County will reach 87% renewable energy consumption under the 2050 MTP Scenario, which is based on the same parameters used in the preliminary 90x2050 scenario LEAP analysis (with the exception of the VMT changes discussed above), including transportation fleet transitions to light duty vehicles powered by renewably generated electricity and heavy-duty vehicles powered by biofuels.

FIGURE 6. LEAP MTP SCENARIO TOTAL ENERGY CONSUMPTION – EXCLUDING AVIATION FUEL

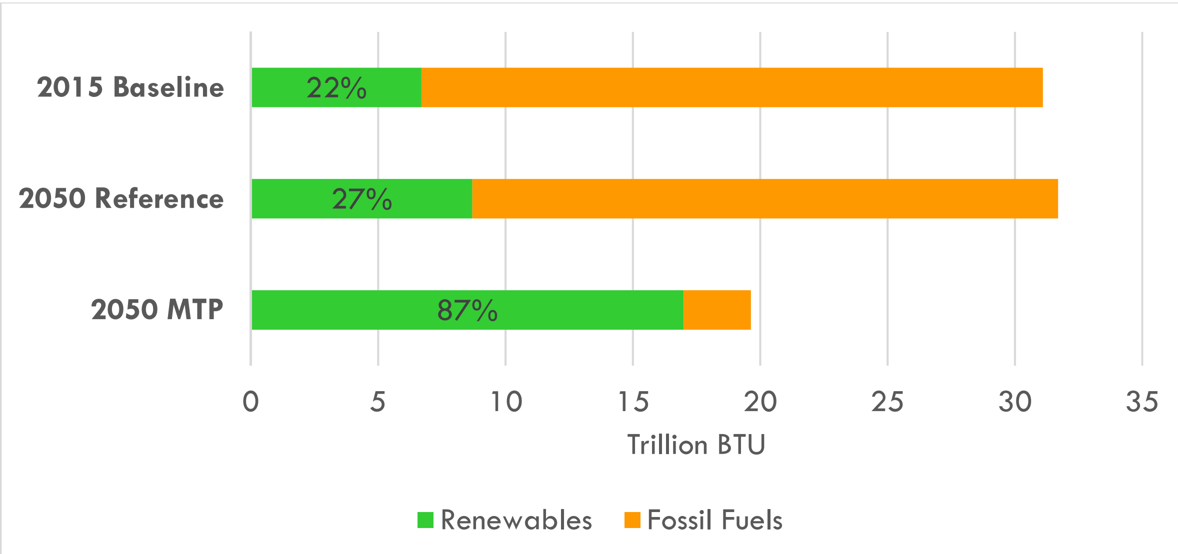


FIGURE 7. CCRPC 2050 MTP SCENARIO ENERGY USE OVER TIME, BY SECTOR

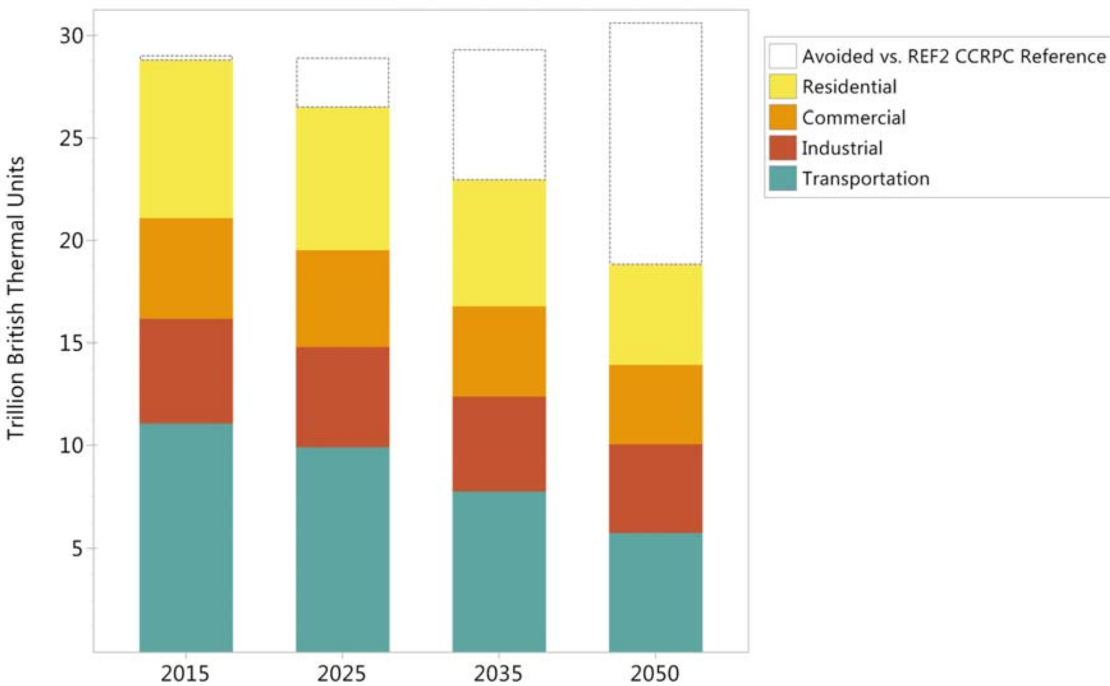
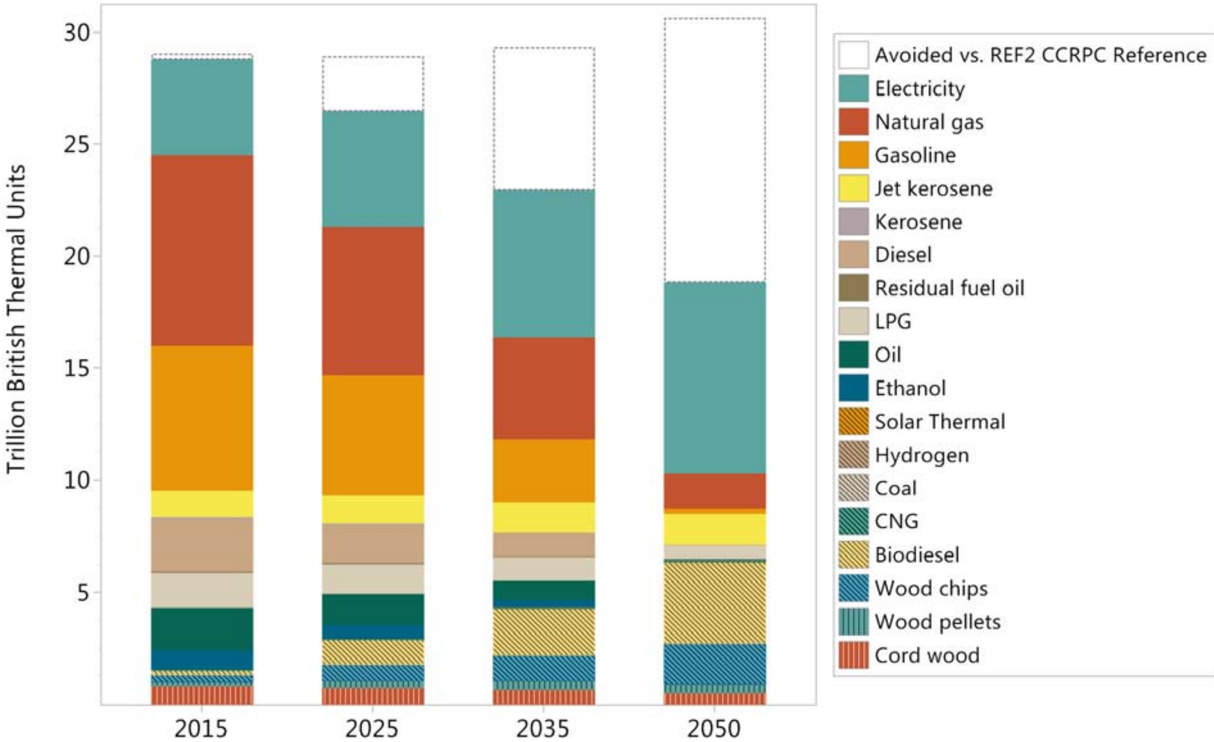


FIGURE 8. CCRPC 2050 MTP SCENARIO ENERGY USE OVER TIME, BY FUEL



The MTP scenario also resulted in a significant reduction in per capita energy use compared to the reference scenario. Table ~~35~~ 41 below includes estimates of per capita energy use across four of the analysis years and indicates a 39% reduction in per capita energy use with the MTP scenario compared to the reference as well as a 42% reduction in per capita energy use compared to the 2015 base.

TABLE 41~~35~~. PER CAPITA ENERGY DEMAND

Per Capita Total Energy Consumption (MMBtu/person)				
	2015	**2025**	**2035**	**2050**
Reference Scenario per Capita	180	171	168	167
MTP Scenario per Capita	178	156	131	103
MTP % change compared to Reference	-1%	-8%	-22%	-39%
MTP % change compared to 2015		-12%	-26%	-42%

~~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[22]~~
- ~~EIA Vermont State Energy Profile[23]~~
- ~~2007-2008 VT Residential Fuel Assessment[24]~~
- ~~EIA Adjusted Distillate Fuel Oil and Kerosene Sales by End Use[25]~~

~~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 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.~~

~~[22] 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.~~
~~[23] U.S. Energy Information Administration, "Vermont Energy Consumption Estimates, 2004," https://www.eia.gov/state/print.cfm?sid=VT~~
~~[24] Frederick P. Vermont Residential Fuel Assessment: for the 2007-2008 heating season. Vermont Department of Forest, Parks and Recreation. 2011.~~
~~[25] 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.~~

- 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 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.[26]

Appliances and Other Household Energy Use:

EnergyStar appliance estimates and the Efficiency Vermont Electric Usage Chart[27] 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.

[26] 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.

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

~~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.~~