Total Energy Study:

Final Report on a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals

Vermont Public Service Department

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Table of Contents

1 Introduction and summary

In 2005, the Vermont General Assembly set aggressive greenhouse gas reduction goals for the State: reducing emissions of greenhouse gases from 1990 levels by 50% by 2028 and, if practicable using reasonable efforts, 75% by 2050.[1] In 2011, the Vermont Comprehensive Energy Plan set out a broad vision for the state to acquire 90% of all energy from renewable sources by 2050 as a pathway to practically eliminate the state's dependence on oil.[2] These goals, the product of broad political and stakeholder deliberation, illustrate the importance Vermont places on addressing the climate challenge while recognizing the potential economic benefits and energy security associated with renewable energy resources. Renewable resources are more likely to be local, and with resources directed toward upfront capital expenditures rather than ongoing fuel costs, the impacts on Vermont's economy are expected to be beneficial.

The Public Service Department ("Department" or "PSD") offers this Total Energy Study ("TES") report identifying and evaluating promising policy and technology pathways that could allow Vermont to reach its renewable energy and greenhouse gas reduction goals. The report, by design, does not pick a "winner" or articulate a single path forward. It is not intended to be or replace the Comprehensive Energy Plan. Instead, by modeling the impacts associated with three routes to 2050 – a revenue-neutral Carbon Tax Shift, a Total Renewable Energy and Efficiency Standard (TREES), and TREES with a local energy requirement – it highlights key opportunities and risks to Vermont as the State moves toward meeting its goals. This report raises several key questions that should be addressed in the development of the next update of the Comprehensive Energy Plan, scheduled to be drafted with substantive public and stakeholder engagement throughout 2015.

The fundamental conclusion of this Total Energy Study is that **Vermont can achieve its greenhouse gas emission reduction goals and its renewable energy goals while maintaining or increasing Vermont's economic prosperity. However, to do so will require significant changes in energy policy, fuel supply, infrastructure, and technology.**

The TES was a phased process commencing in January 2013 involving decision-makers, expert stakeholders and the general public, structured to facilitate significant stakeholder and public engagement. Public and interagency input informed development of a wide set of scenarios that might meet the State's goals. The PSD then narrowed those scenarios based on a set of qualitative criteria that produced a manageable number of potential scenarios for further quantitative analysis.[3] The TES was structured around the development and evaluation of these discrete sets of policies and technology pathways. Policy sets are the tools deployed by the State (in concert with policies adopted at the National, regional, and local level) to shape deployment of potential technology pathways. Technology

[1] 10 V.S.A. § 578(a)
[2] Vermont 2011 Comprehensive Energy Plan. http://publicservice.vermont.gov/publications/energy_plan/2011_plan
[3] For a discussion of the criteria used, see Appendices B and C.

pathways describe ways that the state could meet its objectives in terms of hardware deployed (for example, how much electric power, and from which sources; how many cars powered by what fuels by what date; how many homes weatherized; etc.). Technology pathways strongly shape overall cost and economic impacts.

The scenarios selected for quantitative analysis were overarching in that they tested fundamental changes in the energy policy and technology structure reaching throughout Vermont's energy system and broader economy in the timeframe of 2012 through 2050. The Dunsky Energy Consulting ("Dunsky" or "DEC") team's analysis (see Section 2.1 and Appendix C) showed that Vermont's energy goals are technically achievable, using a number of different technology pathways. Across all of the scenarios examined, the aggregate present value costs to the energy system were found to be in the range of $38 to $90 per ton of CO_2e greenhouse gas (GHG) emission reduction. The impacts on the broader Vermont economy were found to be narrow in range, and relatively small in scale (see Section 2.2 and Appendix D). If the policies examined perform as intended and other jurisdictions pursue comparable action against climate change alongside Vermont, the annual average increase in Gross State Product ("GSP") is estimated to fall in the range of $69 million to $363 million (in constant 2014 dollars), with the high end of that range representing less than three quarters of a percent increase over baseline GSP levels.

The following sections first provide an overview of the policy modeling approach then highlight the greenhouse gas, renewable energy, and economic impacts of the modeled scenarios. Next, the key insights resulting from this analysis are described, including a short summary of the pillars of the possible transformation of Vermont's energy infrastructure. Finally, the report details questions raised by this process that the PSD plans to address during development of the next Comprehensive Energy Plan.

Supporting analysis for this Total Energy Study is embedded in five reports. These reports:

- Examine available policies (Appendix A, produced by the Regulatory Assistance Project);
- Describe a framework for and a focusing of those policies (Appendix B, submitted to the Legislature in December, 2013);
- Quantitatively examine three policy and technology scenarios for the energy sector (Appendix C, produced by Dunsky Energy Consultants);
- Estimate the macroeconomic implications of those three scenarios for the state as modeled with REMI software (Appendix D); and
- Summarize the input received from the public and stakeholders throughout the process (Appendix E).

2 Overview of policy scenario modeling

The Department selected three overarching policy approaches aimed at reaching Vermont's energy goals and compared them to a baseline business-as-usual scenario. Discussions throughout the stakeholder process informed the Department's selection of which policy scenarios to model. A full description of the process to select the scenarios can be found in Appendix B (the 2013 Legislative

Report on the TES) and Appendix C (the report from Dunsky Energy Consulting). The Department recognizes that it is challenging to model energy system and economic impacts decades into the future, and model results are shaped by the models' abilities and the input assumptions. Models can, however, be used to gain insights and draw conclusions from observed trends, including the scale and direction of changes due to policy intervention. When modeling policy scenarios, the Department analyzed model outputs for broad and robust conclusions rather than for precise numerical results.

While understanding the potential technology pathway will be critical to meeting Vermont's goals, the policy approaches were not linked to specific technologies. Instead, the Department made an active choice to be "technology agnostic" in order to evaluate the modeling results of the policy approaches without restriction. The Dunsky team performed emissions, energy resource, and energy system cost modeling using the Framework for Analysis of Climate-Energy-Technology Systems (FACETS) model[4] for the following scenarios.

Baseline:

- A business-as-usual ("BAU") scenario was calibrated to mimic Vermont's current energy policy to serve as a base case to which estimates of impacts from other policy scenarios could be compared. It was built on a database that includes relevant local, state, regional, and national energy system resources, including Canadian options, and modeled projections of how shares of different fuels would shift based on lowest total cost, assuming no technical constraints or market failures.[5] This BAU case should not be confused with a base fossil fuel case, as Vermont is already significantly implementing renewable energy policies and efficiency programs. The results show the makeup of Vermont's energy system if we continue along our current path with no significant policy changes. Absent policy intervention, the total amount of energy consumed annually in Vermont is projected to decrease slightly from 2012 to 2050, but not at a pace significant enough to meet Vermont's goals. The total share of renewable energy in Vermont's fuel mix does not increase significantly.

Policy Scenarios:

- The "Carbon Tax Shift" scenario tested the implementation of a revenue-neutral tax on greenhouse gases emitted from energy resources across all sectors offset by a corresponding tax

[4] FACETS is based on the TIMES (The Integrated MARKAL-EFOM System) model generator. A TIMES model represents the entire energy system of a country or region as a network, including all forms of energy extraction, transformation, distribution, end-uses, and trade. Each stage in the network has many different specific technologies available, each characterized by economic and technological parameters. The model also tracks greenhouse gas and criteria air pollutant emissions. The model calculates through the network to find the least-cost options for meeting all demands for useful energy services. More detail is available in Appendix C.

[5] While the total consumption levels in the BAU appear to be reasonable, the shares of various fuels in the BAU are somewhat uncertain since in the real world, considerations other than fuel cost projections factor into consumers' fuel choice, including availability (e.g. natural gas distribution), awareness, split incentives, and other market failures. As such, the BAU case in this study is valuable for comparison purposes but should not be used as inputs to other evaluation.

reduction or rebate in other areas of the economy. Various rates of a potential carbon tax were analyzed in order to determine the level necessary to reach Vermont's GHG emission goals.

- The "TREES[6] Basic" scenario tested policies requiring all Vermont energy distributors to source an escalating percentage of their supply from renewables or efficiency, with tradable certificates.
- The "TREES Local" scenario tested policies similar to TREES Basic, but also requires an increasing share of all energy to be sourced from in-state, Vermont renewable energy or efficiency resources.

During policy scenario modeling it became apparent that the price and availability of liquid biofuels was a critical variable in determining the technology pathway that resulted from each policy scenario. Thus, each policy scenario was modeled using a low biofuel price and separately using a high biofuel price (which also serves as a proxy for a lack of available liquid biofuels). More discussion on this key risk is included in Section 4.1 below.

Finally, modeling of policy approaches over 35 years into the future has inherent limitations. Key limitations identified by the Department include:

- The FACETS model's assumption that market actors are "rational" in that they will choose the most cost-effective option available, with little to no delay. There are a number of real world barriers that frustrate translation of this model assumption to reality.
- Data and modeling limitations required omission of a number of policies that are expected to reduce Vermont's energy demand. For example, transportation mode shifting and land use policies ("smart growth") are expected to reduce Vehicle Miles Traveled.
- While FACETS includes forecasted technological advances, innovation cannot be predicted. New technologies or breakthrough innovations, or a rapid change in fuel prices due to geopolitical events or new resource discoveries cannot be projected. For example, a breakthrough in energy storage technologies could dramatically change the economics of fuel switching opportunities. The results presented in the TES represent a least cost way of achieving Vermont's goals using a reasonable set of projections for future availability, cost, and performance of existing or currently anticipated technologies.
- The greenhouse gas impacts of fossil fuels described in the TES are from a "burner tip" perspective; they represent the amount of emissions emitted at the point of combustion or end use. They do not include the emissions associated with the entire lifecycle of fuel source emissions from production to end use. An exception to this is that solid and liquid biofuels were assumed to have GHG emissions equal to the fossil fuel emissions from combustion of fossil fuels used in their production, and none associated with combustion of the biofuel itself as

[6] The TREES acronym stands for Total Renewable Energy and Efficiency Standard. The TREES policies function similarly to a Renewable Portfolio Standard. However, TREES is broader in that it requires energy suppliers in all energy sectors – including electricity, natural gas, delivered fuels, and liquid transportation fuels – to source a growing proportion of energy from renewable resources and/or demand reductions via energy efficiency.

sustainable harvesting and production practices were assumed to result in an equivalent sequestration of carbon during this study period.

- Lack of data limited the analysis with regard to efficiency and fuel-switching opportunities in the industrial sector. This required modeling of the sector as simply reactive to fuel prices. The model did not examine technological or fuel shifts that may have been less expensive. In this respect, costs of meeting state policy goals are likely overestimated, as we know industries are already performing some fuel-switching in response to both price and policy signals.
- It is uncertain how the effects of climate change will impact Vermont and its economy during the study period.[7] The analysis did not include a forecast of how actions taken to adapt to the effects of climate change will impact Vermont's economy and energy sector.

Despite these limitations, the modeled policies provide indicative information regarding the relative impacts of differing policy approaches, provide insights to the key risks to Vermont in meeting its goals, and illuminate key questions to address in the upcoming Comprehensive Energy Plan update.

2.1 Energy system impacts

The modeled BAU scenario through 2050 shows that if Vermont continues along its current policy pathway, we will not meet our energy or GHG goals. Vermont cannot achieve the significant reductions in greenhouse gas emissions targeted in the statewide goals, nor the associated economic and environmental benefits, without implementing new policies and technologies at scale.

The analysis completed by Dunsky Energy Consulting finds that achieving the goal of a 75% reduction in greenhouse gas emissions by 2050 is achievable under all three Energy Policy scenarios. There is, however, a slight trade-off in the other goals, where a Carbon Tax Shift also achieves the mid-term GHG goals of 50% by 2028, but falls short of the renewable energy goal. Conversely, both TREES policies as modeled[8] effectively achieve the long-term GHG and renewable energy goals, but fall short of the mid-term GHG goal. Exhibit 1 shows the progress toward each goal under each policy scenario.

[7] The Vermont Climate Assessment (http://vtclimate.org) summarizes the current state of knowledge regarding climate change impacts in Vermont.

[8] TREES scenarios were modeled starting at current renewable energy levels and ramping linearly to meet the goal of 90% renewable by 2050. A TREES scenario could be structured to meet the 2028 goal as well, by utilizing a different ramp rate. However, this alternate TREES structure was not modeled.

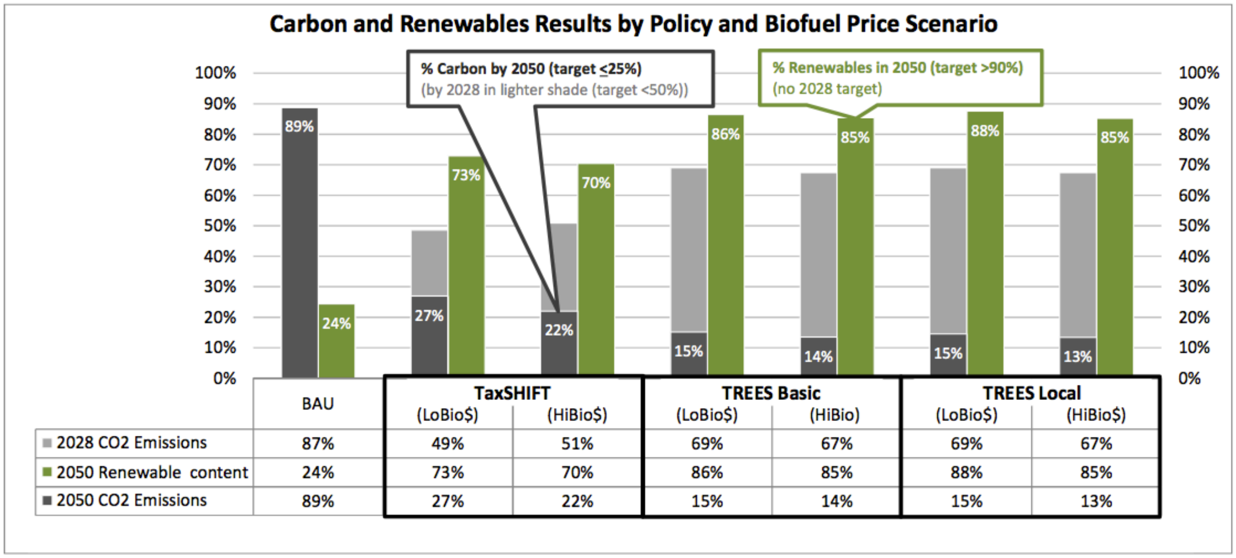

Exhibit 1. Progress toward greenhouse gas and renewable energy goals in 2050 by policy set and assumption regarding biofuel prices.

The FACETS model produced calculations of the least cost energy portfolios under each policy scenario, including the BAU case. Exhibit 2 shows the model results for Vermont's total energy portfolio in 2015, 2028, and 2050 under each of the policy scenarios. In the BAU case, the total amount of energy consumed is projected to decrease slightly, while the quantity of renewable energy in the fuel mix does not change significantly. In contrast, total energy demand in each of the policy cases falls by between 25% and 38% by 2050, while electricity usage increases. On a primary energy basis, electricity use declines by 2028 in 5 of the 6 scenarios as fossil fuel combustion-based generation technologies are replaced by more efficient renewables. Increased electric service demand then drives the electric primary energy up by 2050. Aside from the continued use of some nuclear electricity in the Carbon Tax Shift cases, the mix of non-GHG-emitting electric generation technologies under each scenario is driven more by the FACETS model's assumptions on price and availability than by policy-related differences. FACETS also does not maintain the exact balance of supply and demand for electricity at each moment in time; in effect it assumes a larger regional grid with a diversity of electricity sources at any given time. As such, the model does not support conclusions regarding the specific mix of wind, solar, and hydroelectricity used in each scenario, and instead should only be relied upon to consider the total amount of renewable electricity relative to non-renewable resources. Appendix C contains extensive additional data regarding the results of energy system modeling.

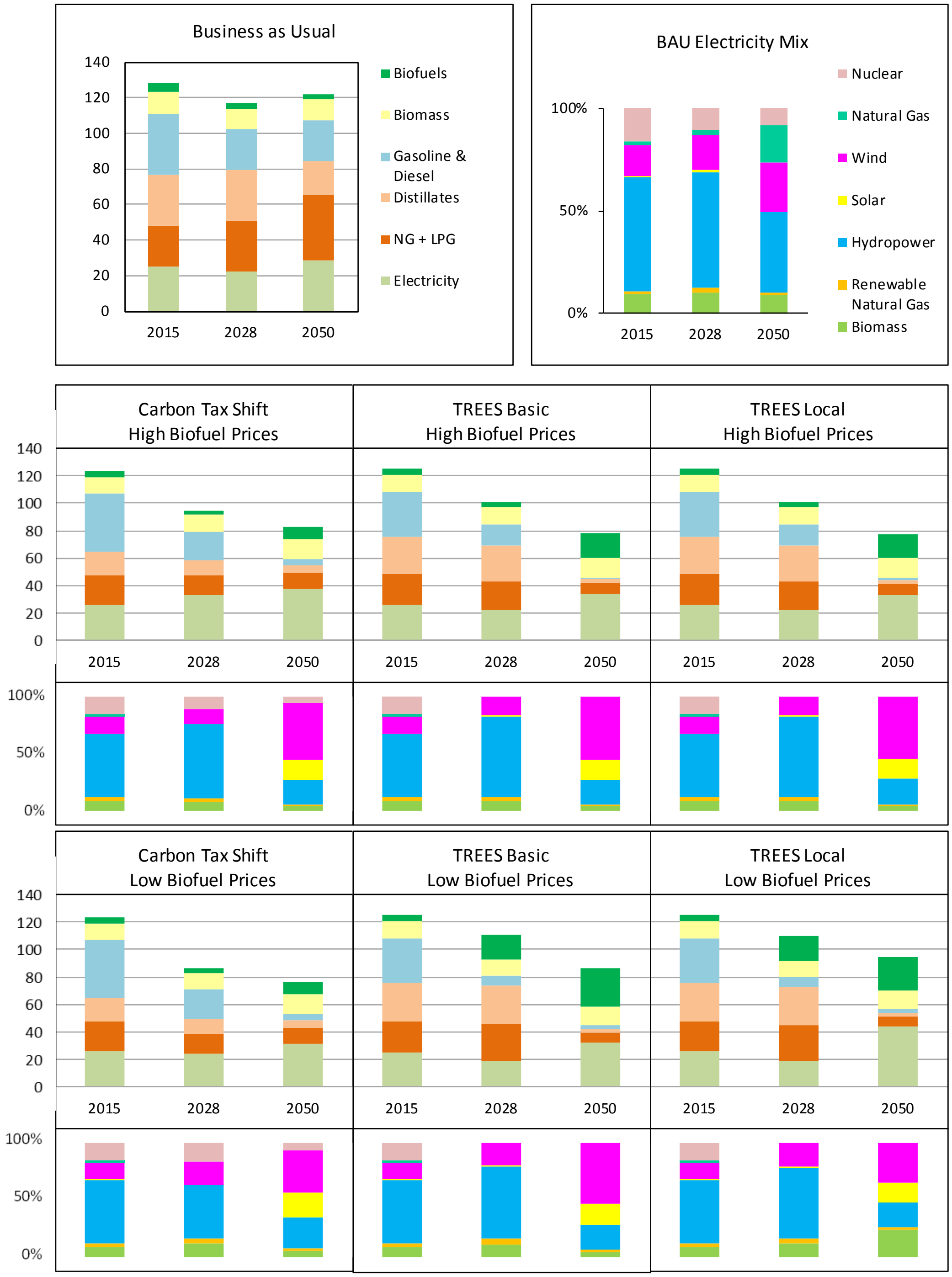

Exhibit 2. Total energy portfolios in 2015, 2028, and 2050 by scenario. For each scenario, the upper chart shows the TBTU of primary energy by fuel (including electricity), while the lower chart divides the electric portion by generation type.

Exhibit 3 presents the policy-driven costs to the energy system in terms of both the percent increase in total costs needed to meet Vermonters' energy service needs (including capital, operating, and fuel costs) as well as the average cost of reducing emissions per ton of total emission reductions over the period (in present value 2013 costs), relative to the BAU. Implementing the modeled policy options creates modest energy system costs. Exhibit 3 shows that, depending on the policy option as well as future biofuel prices, achieving the goals will add between 2.2% and 5.5% to the direct cost of meeting Vermonters' energy needs. While much of this range is associated with biofuel price sensitivity, the choice of policy approach also influences cost. The magnitudes identified here represent only direct energy-related costs, as determined by energy system modeling; they do not include any secondary economic effects addressed in Section 2.2 below, such as changes in consumer and business behavior in response to different fuel prices.

POLICY OPTION		**COSTS**			
		% change re: BAU		$/ton	
	BIOFUEL PRICES:	LOW	HIGH	LOW	HIGH
Tax Shift		2.6%	4.5%	$42	$67
TREES Basic		2.2%	5.4%	$38	$89
TREES Local		3.3%	5.5%	$56	$90

Exhibit 3. Policy-driven costs in the energy system compared with the BAU case.

DEC's FACETS energy system modeling also produced an informative account of Vermont's carbon emission abatement cost curve, shown in Exhibit 4. This figure shows the amount of carbon emission reductions achievable at different levels of cost, measured per ton of emission reductions. As the text in the Exhibit describes, in the low biofuel price case nearly half of the required emission reductions can be achieved at a cost, relative to BAU, of less than $50 per ton. A perfectly-functioning carbon tax set at a certain level would be expected to achieve GHG reductions up to the level at which the costs of changing the energy system are equal to the cost of paying the tax. A tax of $50/ton in the low biofuel price scenario leads to nearly a 50% GHG emission reduction. In contrast, the last 10% of the reductions required to hit the 75% reduction target would cost between $300 and $450 per ton, so the low biofuel price carbon tax shift scenario models a tax rising to $450/ton by 2050. The average cost of emission reductions is much lower than the cost of eliminating the final ton necessary to achieve a target.

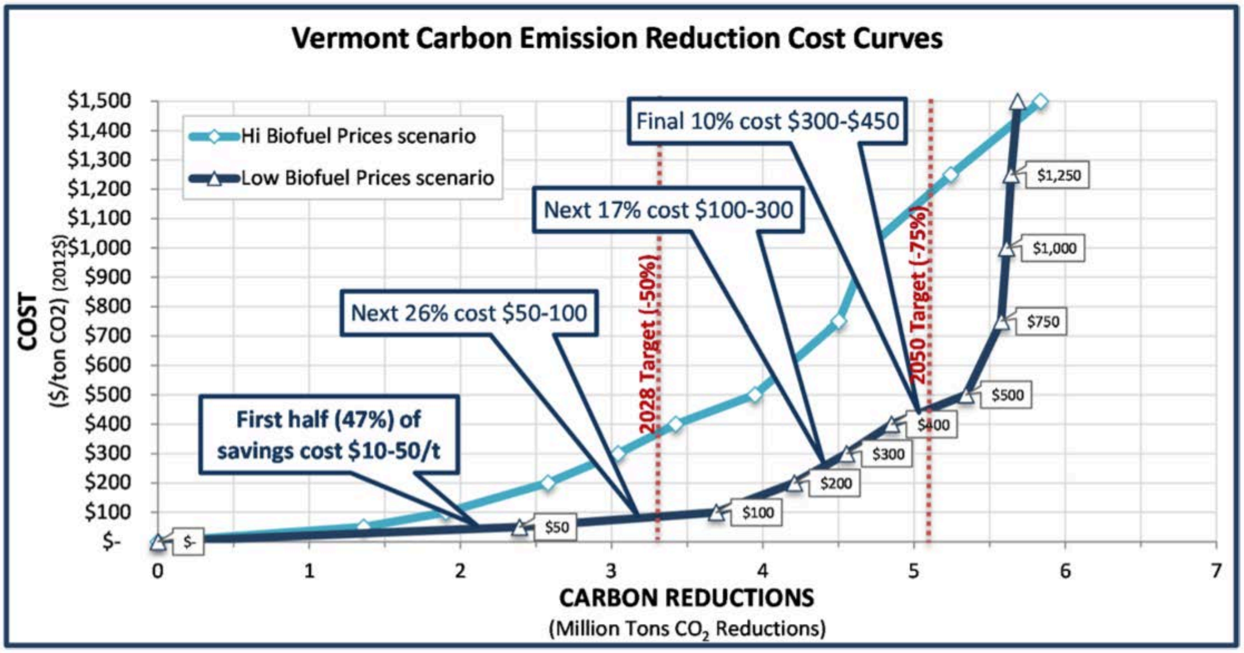

Exhibit 4. Vermont carbon emission costs per ton of CO_2 reduction in the high and low biofuel price scenarios.

2.2 Impacts on the Vermont economy

DEC's energy system modeling provided the Department with significant information regarding the changes in energy-related costs that could result under each policy scenario, including shifts in expenditures on types of fuel and different levels of capital and operating expenditures. However, these energy sector costs are not the end of the story with respect to economic impacts. The cost of energy pervades the entire economy, so changes in energy expenditures should also be expected to affect the broader economy. These expected effects include increased growth in the sectors which produce clean energy; increased productivity with increased energy efficiency; reduction in output by those sectors directly linked to fossil fuels; and changes to overall business competitiveness linked to changes in the cost of doing business in Vermont relative to other jurisdictions. In order to examine these effects in greater detail, the Department used PI+, a regional economic impact modeling software licensed by Regional Economic Models Incorporated, commonly referred to as "REMI." The Department constructed a variety of policy simulations each designed to represent possible outcomes of the FACETS model runs in both the high and low biofuel price scenarios. Appendix D summarizes the REMI methodology and describes the results of the REMI analysis in greater detail.

The REMI tool is, however, imperfect for this type of policy analysis. Therefore, PSD's modeled economic impacts can be treated as estimates of the likely scale and direction of possible outcomes, rather than as predictions. Comparative results from different REMI simulations can provide greater insight than any one model result, because they can illustrate how changes in policy or approach can affect results. As discussed below, for example, simulations run with and without a change in Vermont's net competitive position with respect to business costs for energy (reflecting whether other jurisdictions take comparable action to reduce climate change and adopt renewable energy) indicate the impact of this competitive pressure and inform policy discussions regarding the importance of collective action across jurisdictions.

Two particular shortcomings of the REMI tool are worth highlighting here. The first is that REMI is based on sectors as defined by the North American Industry Classification System (NAICS). These sectors do not sufficiently distinguish clean energy businesses from other similar businesses. Sector-specific and employment figures from REMI analysis therefore lack the resolution to fully identify the clean energy sector growth resulting from policy changes. To address this situation in the near term, the Vermont Clean Energy Development Fund has developed a Clean Energy Industry Report[9] based on business surveys. This report identified more than 15,000 clean energy workers in 2014, with expected growth of 12% in the next year. Note that this near-term growth precedes adoption of any changes in public policy of the sort contemplated in this report, and as expressed earlier is already incorporated in the BAU analysis.

REMI models are based on a smoothed approximation of the economy that lacks business cycles and short-term volatility. REMI is therefore unable to capture the impact of any changes in the resilience of the state's economy that might result from changes in energy supply and demand. For example, Vermont's current dependence on oil makes it sensitive to the dynamics of the global price of oil, which has shown a great deal of volatility in the last several decades. Under the policy scenarios examined here, that dependence is dramatically reduced. REMI cannot calculate a value to this independence and the associated economic resilience. Economic modeling using REMI is also unable to capture the potential rewards of being a first mover in energy policy. Such policy could attract and foster firms that become significant net exporters into other jurisdictions. If those jurisdictions follow Vermont's lead in adopting strong clean energy policies, such clean energy firms will find greater potential markets.

Despite REMI's limitations, the model is useful to glean general insights associated with the effects on Vermont's economy through evaluation of differences between scenarios that varied across policy sets and biofuel price cases, and also in how revenue streams associated with carbon tax revenue or renewable certificates were handled. This analysis supports four conclusions:

1. The net economic impacts of implementation of any of the policies examined here are likely to be positive if the policies are designed and implemented well.
2. If other jurisdictions also take strong action to reduce GHG emission and adopt renewable energy alongside Vermont, the net impact of these policies in Vermont is more positive.
3. The net economic impacts are expected to be small on the scale of the Vermont economy.
4. The clean energy sector is likely to thrive if these policies are implemented.

The remainder of this section examines each of these conclusions in detail, presenting the supporting evidence for each.

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[9] http://publicservice.vermont.gov/sites/psd/files/Topics/Renewable_Energy/CEDF/Vermont%20Clean%20Energy%20Industry%20Report%20FINAL.pdf

2.2.1 Positive impacts of well-implemented policies

Well-implemented policies result in net positive economic impacts under all three policy sets, whether low-cost biofuels are available to meet policy targets or not. Exhibit 5 summarizes the REMI results for each of these six cases, compared with the BAU case for the total study period (2015-2050) as well as three sub-periods.

	Gross State Product				Employment
Scenario	2015-2025	2025-2035	2035-2050	2015-2050	2015-2050
Carbon Tax Shift: High Bio	+0.17%	+0.87%	+0.83%	+0.69%	+1.26%
Carbon Tax Shift: Low Bio	+0.08%	+0.15%	+0.32%	+0.23%	+0.44%
TREES Basic: High Bio	+0.03%	+0.70%	+0.53%	+0.45%	+0.90%
TREES Basic: Low Bio	+0.11%	+0.11%	+0.34%	+0.23%	+0.45%
TREES Local: High Bio	+0.09%	+0.58%	+0.58%	+0.47%	+0.85%
TREES Local: Low Bio	+0.11%	+0.13%	+0.40%	+0.27%	+0.51%

Exhibit 5. Difference from BAU in modeled average annual Gross State Product and average annual employment levels for each of six scenarios, assuming the best-performing implementation of each policy.

The findings for GSP in Exhibit 5 show that the modeled policies are likely to bring a relatively minor positive impact on the overall scale of economic activity in Vermont. The associated benefits of that change can be seen more clearly in the job creation that takes place in each of the policies. This rise in employment spans a range of around 2,260 to 6,400 more jobs each year on average over the whole period, depending on the specific policy and the prevailing price of biofuels (See Appendix D). As a percentage change from baseline levels, average employment increases are slightly greater than increases in GSP. Thus the moderate GSP growth in each TES policy scenario comes with a higher pace of job creation, suggesting a slight policy bias toward labor-intensive industry. Requiring increased energy locality, through the TREES Local policy, results in somewhat increased energy system costs while more money stays local, resulting in a small increase in overall GSP.

The Department was able to combine the FACETS and REMI analyses with historical data to produce Exhibit 6, which shows the increasing energy productivity of the Vermont economy over the last four decades, as well as the potential impact of the three policy sets (each with high and low biofuel prices) on the future trajectory, contrasted with the BAU path. The energy productivity under the modeled policy cases exceeds the energy productivity under the BAU case by between 27% and 60%.

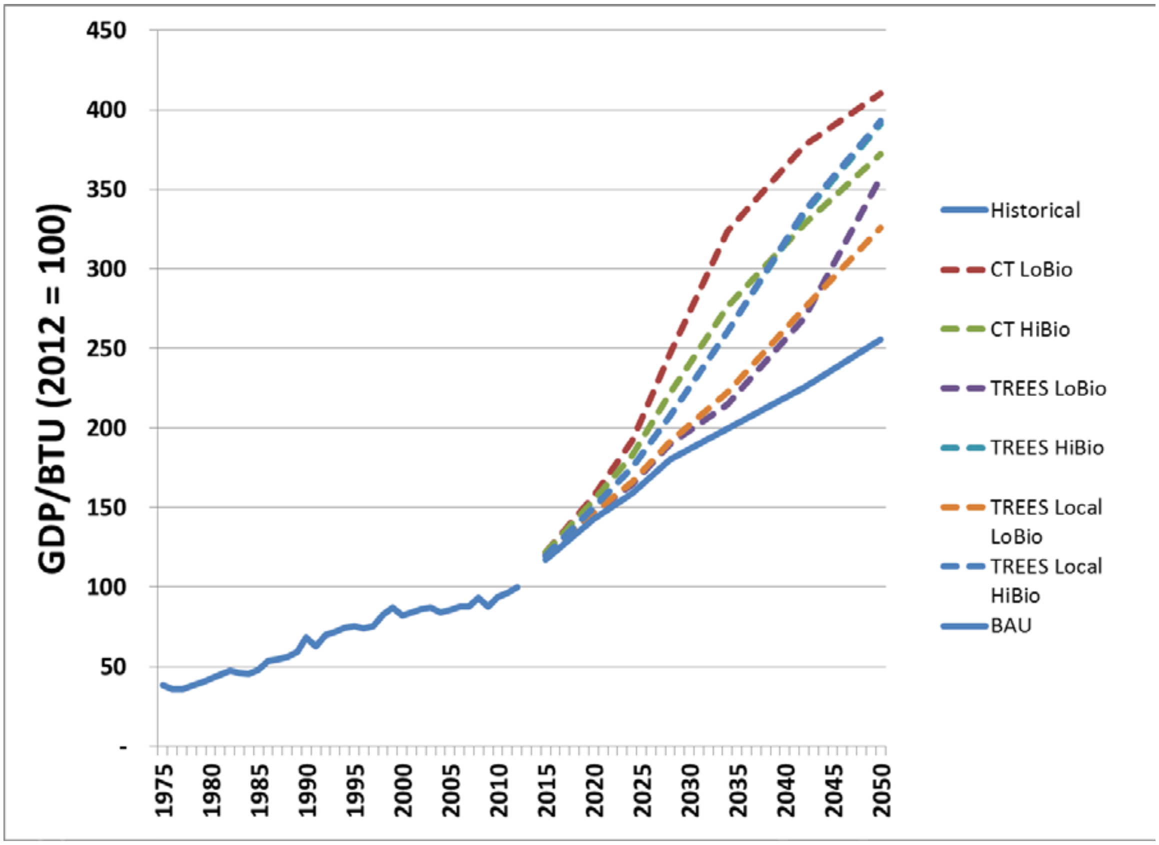

Exhibit 6. Energy productivity (Vermont GDP per BTU of primary energy), normalized to 2012=100. Historical data is from EIA and PSD; modeled data is from FACETS and REMI for each of the 6 policy cases and the BAU.

These results reflect well-implemented policies. REMI modeling enabled the Department to examine the potential impacts of other implementations, and show that net economic results can vary due to changes in implementation. For example, if carbon tax revenue is returned only to households, and not to businesses, net economic performance may suffer in a high biofuel price environment where the costs of renewable energy take a larger toll on Vermont business market share. This reflects a net transfer of money from businesses to households. Due to the high dependence of the Vermont consumer economy on other states and countries, households do not spend enough additional money in Vermont to make up for the business sector's net loss. For details regarding the range of implementations and assumptions tested, and further details regarding the REMI modeling methodology, please see Appendix D.

2.2.2 The importance of action in other jurisdictions

REMI modeling allowed the Department to compare policy sets' economic impacts with and without comparable action in other states. Action in other jurisdictions matters because of its effect on the competitiveness of Vermont firms. Our modeling examined two extremes—no action anywhere else or exactly comparable action—while the real world is likely to fall in between. The difference in modeled economic outcomes supports a conclusion that Vermont should be aware of the actions taken by others when designing our policies and that our state benefits when others take action. Exhibit 7 summarizes the net economic impact for well-implemented policy sets with ("together") and without ("alone") comparable action elsewhere. The economic improvement in the high biofuel price cases is larger in the "together" cases because these have both a more local energy mix—with associated economic activity—and no loss of competitive position.

	Together		Alone	
	Δ GSP	Δ Jobs	Δ GSP	Δ Jobs
Carbon Tax Shift: High Bio	+0.69%	+1.26%	+0.28%	+0.41%
Carbon Tax Shift: Low Bio	+0.23%	+0.44%	+0.26%	+0.36%
TREES Basic: High Bio	+0.45%	+0.90%	-0.14%	-0.32%
TREES Basic: Low Bio	+0.23%	+0.45%	+0.17%	+0.39%
TREES Local: High Bio	+0.47%	+0.85%	-0.24%	+0.06%
TREES Local: Low Bio	+0.27%	+0.38%	+0.13%	+0.38%

Exhibit 7. Net economic impacts (relative to the BAU case) on average annual GSP and employment levels for each policy scenario under a "together" case in which all other jurisdictions take comparable action on GHGs and renewable energy, and an "alone" case in which no other jurisdiction takes comparable action.

2.2.3 Net impacts are small on the scale of the economy

Despite the fundamental changes in the energy sector produced by the modeled policy changes, the overall economic scale of impacts is expected to be small, whether positive or negative, when compared with the size of the overall economy. A simplified example can help to illustrate why; see the sidebar. This example does not capture the complex interactions between economic sectors as electricity, building heat, industrial processes, and transportation all shift to new fuels and infrastructure. REMI modeling, however, confirms the overall scale of impact. The range of potential impacts across all scenarios tested—excluding nonsensical

A simplified example of economic impact

Vermonters currently spend around $1 billion per year on gasoline for light-duty transportation; a large portion of this money leaves the state to pay for the commodity fuel. Hypothetically, if all cars and light trucks were replaced by electric vehicles overnight, the resulting annual fuel expenditure might fall to about $315 million. With a highly local supply of renewable electricity, this spending would increase output by Vermont firms by around $250 million. The $1 billion in displaced gasoline purchases would have resulted in around a $170 million increase in output by Vermont firms. In addition to the electricity spending, the annualized capital cost of new electric vehicles could be about $520 million. Capital expenditures on electric vehicles flow largely out of state in the same way as purchases of gasoline, resulting in only a $45 million increase in Vermont output. This leaves $165 million (1000-520-315=165) available for discretionary spending by Vermonters. However, not all of Vermont spending goes to Vermont suppliers. A $165 million increase in discretionary spending raises Vermont output only by around $100 million. Thus the total increase in Vermont output associated with an overnight transition to electric vehicles would total around $225 million (250-170+45+100=225), or under a half of one percent of the roughly $54 billion of output from the Vermont economy in 2013.

implementations such as collecting carbon tax revenue and then just removing it from the economy—stretches only between a -0.04% and +0.03% change in the pace of annual GSP growth.

2.2.4 Impact on the clean energy sector

Despite the inability of NAICS categories to distinguish clean energy business activity from the rest of the economy, there are some industries where our REMI modeling does show that a noticeable effect would be expected from implementation of these policies. In particular, the utilities sector (which includes independent power producers) and forestry sector show significant increases in both jobs and economic activity in the policy cases when compared with BAU. Across policy scenarios, output and employment in the electricity-producing sector was found to increase by 20 to 30 percent on average when liquid biofuel prices are high and 5 to 8 percent on average when biofuel prices are low. (All scenarios assumed liquid biofuels to be imported.) The growth experienced by the solid biomass-producing sector is substantial enough when low-cost biofuels are not available to double baseline levels of sales and employment. When biofuel prices are low, biomass industry growth is slower, and ranges between 40 and 60 percent above baseline values. Collectively, average employment over the 2015-2050 period in these two sectors under in the various policy scenarios grows by as many as 2,500 jobs if biofuel prices are high and 820 jobs if biofuel prices are low. These results are consistent with the economy's increased dependence on electricity and solid biomass in each of the policy cases. In scenarios where liquid biofuels are heavily used, electricity and forestry benefit somewhat less, while retail (which includes activities selling liquid fuels) does somewhat better.

While individual businesses within industries would experience different degrees of positive and negative impacts in each scenario, as a whole most industries see little net impact. However, a small net impact for should not be confused with a lack of change within a sector, rather that positive and negative impacts roughly balance. In fact, significant changes within many industries should be expected to result from the policies examined here. The policy cases would likely result in a net growth of the industries associated with the clean energy economy, though the extent of this growth beyond that identified for electricity-producing and biomass-producing industries is uncertain. More fuel-intensive businesses, such as those within the transportation sector, would face challenges for which the modeled policy instruments alone may not always compensate.

3 Key insights

The fundamental conclusion of this Total Energy Study is that Vermont can achieve its greenhouse gas emission reduction goals and its renewable energy goals while maintaining or increasing Vermont's economic prosperity. However, to do so will require significant changes in energy policy, fuel supply, infrastructure, and technology. The achievement of these goals will result in a more local energy economy, primarily due to increases in both energy efficiency and the use of electricity generated in Vermont.

TES modeling indicates that the primary and initial technological mechanisms used to achieve the state's goals are generally the same across policy sets: increased energy efficiency; increased electrification of both transportation and heating; use of liquid biofuels for heating and transportation if available; an increased share of building heat provided by solid biomass; and a more local and renewable electricity supply. Each of these, with the exception of expanded use of liquid biofuels, results in an increasingly localized energy economy.

3.1 Interactions with other areas of state policy

The effects that a particular policy/technology pathway may have on other state policies depend on the details of policy implementation. The TES analysis confirms that well-implemented energy policy has the potential for mutually-reinforcing benefits with other policy areas. For example, the FACETS modeling indicates that woody biomass would heat an increasing fraction of Vermont's buildings under each policy scenario, but that the total amount of wood used is unlikely to increase significantly. Harvesting practices that support forest health and sustainability would be required in order to maintain this resource. This suggests compatibility between the energy policies studied here and other policy goals that prioritize air quality, forest health, and efficient use of our renewable resources. Modern wood heating systems installed in weatherized buildings can heat more buildings, more efficiently, while also resulting in better air quality due to improved combustion technology.

Similarly, policy goals related to land use and transportation choices, such as smart growth and transportation demand management ("TDM"), are highly compatible with the state's energy and GHG goals. However the qualitative nature of such broad changes places them beyond the ability of FACETS to accurately capture. Nonetheless, it can be conservatively assumed that smart growth and TDM policies have the potential to reduce GHGs from the transportation sector by 5-10% over the study period.[10] If these policies were implemented in parallel with the examined energy policies, they would have the result of lowering the net cost of the energy sector transition by mitigating the need to utilize the most expensive alternative measures.

The Comprehensive Economic Development Strategy recently completed by the Department of Economic Development[11] has identified renewable energy and energy efficiency as key areas of economic potential for Vermont. The recent Vermont Clean Energy Industry Report[12] identified that 4.3% of the state's workforce is in jobs related to renewable energy or energy efficiency, of which more than half of the employees spend all of their time on clean energy-related work. While the macroeconomic modeling of the FACETS results does not allow precise estimation of the impact of the energy transition on these or other industries, modeling does indicate that the state's energy transition would result in an increasingly local energy sector, with associated increases in local energy-related employment.

[10] Vermont Agency of Transportation modeling of diverse transportation energy futures using the pilot "Energy and Emissions Reduction Policy Analysis Tool" indicates results in this range.

[11] http://accd.vermont.gov/business/strategic_planning

[12] http://publicservice.vermont.gov/sites/psd/files/Topics/Renewable_Energy/CEDF/Vermont%20Clean%20Energy%20Industry%20Report%20FINAL.pdf

3.2 Technological pillars of the transformation

While each policy scenario and biofuel price assumption generates different modeled energy mixes, all cases revolve around three technological "pillars" upon which Vermont's energy transformation will be built: efficiency, fuel- and mode-switching, and renewable supply. Each of these pillars plays a critical role in supporting the large-scale carbon reductions and renewable energy increases necessary to meet Vermont's goals.

Reduction in total energy demand has been reaffirmed as essential to meeting the state's energy goals while maintaining compatibility with other state policy objectives. Energy demand can be managed through efficiency and conservation; demand shifting and load management; and fuel and mode switching. The discussion of fuel and mode switching, in particular, represents a new direction for analysis since the publication of the 2011 CEP.

3.2.1 Efficiency

Each policy scenario results in improved energy efficiency beyond the efficiency encouraged by already strong Vermont policy (which is itself reflected in the BAU case). Modeled policy options lead to greater efficiency via two primary means. The first is reduction in demand caused by higher energy prices that encourage conservation over time. The second is that increased fuel prices can encourage acquisition or installation of higher efficiency equipment that has lower life-cycle costs.

3.2.2 Fuel- and mode-switching

Modeling of all three policy options indicated that partial or complete fuel switching for both heating and transportation uses plays a critical role in meeting Vermont's energy goals. Depending on fuel price and availability, consumers are expected to shift from fossil fuels to solid or liquid biofuels or to electricity for heat and transport. If liquid biofuels are very expensive or unavailable, the shift to electricity happens much more quickly.

New electric technologies, such as cold climate heat pumps and electric vehicles, are significantly more efficient than the combustion-based incumbent technologies, so this fuel switch is also a type of efficiency improvement. Switching to liquid biofuel, such as distillate blended with biodiesel for heating oil, ethanol for light duty vehicles, or biodiesel for medium and heavy-duty transportation, requires less significant infrastructure change than would the adoption of electricity for any of those purposes. Heating and transportation demand for biofuels would be highly sensitive to the price of those fuels, which would largely have to be imported into Vermont.

While the quantitative modeling undertaken for this TES could not directly address mode switching in transportation (such as increased use of transit or carpools, or freight traveling by rail), such changes also have the potential to displace a portion of energy use while delivering the same energy service (mobility).

3.2.3 Renewable supply

The five renewable primary energy supply resources available to Vermont are solar, wind, hydropower, methane capture, and solid and liquid biomass. Each has strengths and weaknesses, described in detail in the 2011 CEP. Assessment of the use of each of these resources depends on their efficiency of utilization (especially for combustible resources) and the scale and location of energy generation infrastructure.

The TREES scenarios have a stronger influence on the growth of renewable power generation (both in state and out-of-state) than does the Carbon Tax Shift in the low biofuel price case, particularly in the latter half of the study period. In the near to mid-term, growth in renewable energy supply at scale can be secured at lower cost to the energy system through large scale/centralized resources, whether in or out of Vermont. In the longer term, in-state renewable resources of all scales play a more significant role as costs and risks are expected to decrease over time.

3.3 Complimentary policies

The three policy scenarios examined in detail for this Total Energy Study were chosen as illustrative overarching pathways to achieve Vermont's energy goals. Policy implementation outside the idealized world of modeling could require additional policies or programs designed to complement these overarching market-based structures. The Department has identified three general types of these complimentary policies: information and access, strategic investment, and codes and standards.[13]

Information and access policies address real-world shortcomings of a price-based policy instrument such as a Carbon Tax Shift or TREES. These policies enhance markets by providing information, technical assistance, or access to capital, as well as addressing market failures such as the misaligned incentives present between landlords and tenants. They are aimed at ensuring efficient markets where consumers can identify and act upon least cost options.

The technological directions identified in the FACETS modeling could result from adoption of the policies modeled, however strategic investment may be required to spur and shape the early adoption of new technologies and their markets. Research and development may produce examples to build upon to and energy supply or demand reduction options. Policies can build markets for nascent technologies, such as Vermont programs supporting development of farm methane digesters, small-scale solar PV deployment, and bulk wood pellet infrastructure through the Clean Energy Development Fund, or multi-state efforts to advance electric vehicles through the Zero Emission Vehicle Action Plan.[14] Strategic investment that is directed at the highest-cost necessary technologies for achieving Vermont's goals (those used toward the upper right of Exhibit 4) can reduce those costs, or achieve those emission reductions through mechanisms other than price alone. This allows price-based policies to drive optimization without unreasonable direct price impacts.

Codes and standards, such as building energy codes, appliance efficiency standards, vehicle fuel economy rules, and land use plans, serve to avoid lost efficiency opportunities in long-lived products and infrastructure using established technology. Such rules commonly require actions that are demonstrated

[13] This structural formulation is inspired by Grubb, Hourcade, and Neuhoff, *Planetary Economics: Energy, Climate Change, and the Three Domains of Sustainable Development* (Routledge, 2014).
[14] http://www.nescaum.org/documents/multi-state-zev-action-plan.pdf

to have a positive lifecycle economic benefit and lock in economic savings for consumers. Enforcement of these policies ensures that savings occur.

4 Key questions

The following short sections identify a number of questions and issues that have come to the surface as a result of the TES process. The Department expects to engage with each of these points during the upcoming 2015 Comprehensive Energy Planning update process, through both further analysis and stakeholder and public comment.

4.1 Liquid biofuels

The price, availability, and climate implications of liquid biofuels are a primary source of uncertainty in the TES energy sector modeling. The energy modeling conducted for the TES assumed that next-generation liquid biofuels could result in significantly lower GHG emissions than their fossil equivalents (including on a full life-cycle basis). Liquid biofuels considered included corn ethanol, cellulosic ethanol, biodiesel, and bioheat, and did not include biogases (such as from anaerobic digesters or landfills). If liquid biofuels 1) can be used as “drop-in” replacements, particularly in heavy-duty transportation and heating uses (such as replacing diesel fuel or distillate heating oil), 2) are available at Vermont scale and reasonable prices, and 3) are considered to be renewable low-carbon resources, then the least expensive path to meet Vermont’s renewable energy and GHG goals would use them heavily. If, however, these various conditions are not met (biofuels are not available at scale, are very expensive, or are not low-carbon), then Vermont’s least cost path is more expensive, and liquid biofuels play less of a role even though energy and GHG goals are still achievable. Vermont’s risk, however, is that these conditions are largely beyond our control because national policies, markets, and technological development will determine them. This leads to questions of how to mitigate this risk. Should Vermont avoid these technologies as too risky, opting to face a potentially more expensive path? Use them as a bridge to other fuels? Invest heavily in them in hopes of encouraging scale economies, perhaps in concert with regional collaborators?

One option could be to identify some sectors where liquid biofuels are appropriate, and where policies could lean on them for success, but avoid them in other cases. For example, Vermont could pursue different options for industrial process heating applications and heavy duty and on-farm transportation than we pursue for generic residential and commercial building heat. Additional considerations include the economic implications of liquid biofuels, which would generally replace an imported fossil fuel with an imported biofuel.

4.2 Natural gas

One of the larger uncertainties highlighted by the FACETS modeling is the future of natural gas as a significant portion of Vermont’s total energy supply. While in all policy cases the use of natural gas is lower than in the BAU case (where GHG and renewable energy goals are not met), the low-biofuel price Carbon Tax Shift scenario retains significant natural gas consumption through 2050. The low-biofuel price TREES policy reduces natural gas consumption as the last fossil fuel to switch to renewable energy, in the model year 2050. This correlates to the marginal cost in the carbon emission reduction cost curve for that scenario, seen in Exhibit 2, which shows that the final 10% of carbon reductions costs $300-$450 per ton of CO_2e emission reduction. The high-biofuel price scenarios reduce the portion of natural gas from Vermont's energy mix somewhat sooner. All policy cases retain natural gas use equivalent to current levels at least through 2028. These FACETS model outcomes are a result natural gas's smaller burner tip combustion emissions of carbon dioxide and lower cost relative to petroleum-based fuels. This suggests that natural gas could have an important role as a fuel that helps to reduce the state's emissions while mitigating upward pressures (if any) on energy costs.

These results highlight several choices that were made in modeling the state's energy future. Natural gas was modeled as relatively unconstrained by infrastructure over the extended model period, recognizing that economic or policy forces could result in significant expansion of pipeline infrastructure and/or expansion of compressed or liquefied natural gas. The model did not explicitly consider the cost of natural gas infrastructure, but natural gas is expected to remain less expensive than other fossil fuels after accounting for the cost of infrastructure, so such inclusion would have been unlikely to change the general path resulting under each scenario. Finally, a renewable component of natural gas supply was not modeled due to data limitations and uncertainty with regard to its potential magnitude.

4.3 Timing and pace

The FACETS energy system modeling projects significant technological change over time, but it lacks resolution regarding the early stages of market transformation needed to create the potential for those technologies. As a model of rational economic actors, when a new option becomes less expensive, on a life-cycle basis, the model enacts a large-scale switch in a very short period. In fact, new technologies are likely to require early adopters and those with specialized needs to lead the way. There is a transition time, therefore, between a technology's introduction and the point when it becomes ubiquitous among products for sale. Statewide vehicle fleets and building stocks have long lifetimes—10 or more years for vehicles; decades to centuries for buildings—so even if all new cars and buildings embody a new technology, it will take time for the stock to reflect the shift.

There may also be significant synergies (or conflicts) that could arise when fuels are used across sectors. For example, if biodiesel fuel supply is constrained, it may make sense to focus on its use in some sectors prior to others. Electricity requires constant matching between supply and demand, so there may be merit in incorporating technologies with controllable loads at a pace comparable to the introduction of intermittent generation from renewable sources. Matching seasonal generation to appropriate loads may also be desirable.

4.4 Prioritization of goals

When comparing the Carbon Tax Shift to the TREES and TREES Local policy sets, one of the primary points of difference is whether the policy is built upon GHG emissions reductions or renewable energy promotion. Each policy advances both GHG emissions and renewable energy goals. However, the Carbon Tax Shift alone does not meet the goal of 90% renewable energy by 2050, while the TREES policies exceed the 2050 GHG reduction goal, but would need to be accelerated (at a likely additional cost) beyond what was modeled in order to achieve the 2028 GHG reduction goal. This raises the question of the prioritization of goals. If the statutory GHG goals are primary, and renewable energy is pursued simply as a means to achieve GHG emission reductions, then it may be preferable to use a GHG-based policy instrument such as a Carbon Tax Shift. This would also avoid what would then be excess, high-cost GHG emission reductions in the later parts of the period as occur with the TREES policies set to reach 90% renewable by 2050. However, if increased use of renewable energy (as a fraction of the total) is pursued for its own purposes, such as increased locality of energy supply, energy security, and the avoidance of other externalities (such as those related to nuclear power or natural gas extraction), then it may be preferable to use a TREES-like policy set.

4.5 Policy flexibility and control

Related to the question of prioritization addressed above are the questions of certainty and flexibility. The TREES policy sets offer a certain quantity of renewable energy and energy efficiency, and more assurance of emission reductions, but without price certainty (either overall or per ton of emission reductions). In contrast, the Carbon Tax Shift policy offers guidance regarding the value of emissions reductions, which may promote greater investment certainty and lower cost of capital, but provides no certainty regarding the amount of emission reductions achieved.

For example, a TREES policy would achieve renewable energy and GHG emission reduction goals regardless of the price and availability of liquid biofuels. It would cost more in the case where such fuels are not utilized, but the policy would not need to be amended. In the Carbon Tax Shift case, on the other hand, if the tax were set to rise on a path to $450/ton in 2050 assuming access to plentiful and low-carbon liquid biofuels, but those fuels turned out not to be available, the tax trajectory would need to be amended significantly in order to meet the state's GHG emissions goals.

The Carbon Tax Shift policy offers greater policy implementation flexibility to the state government than do the TREES policies. TREES policies have flexibility in policy design (such as determining the parameters of comparability between different kinds of TREES compliance), but are based on the creation of a new and relatively independent market and lack the flexibility to direct significant sums of revenue.

A carbon tax would raise significant amounts of revenue, with the intention that those dollars be returned to Vermonters. The flexibility of a carbon tax lies in how to return that money and maintain revenue neutrality. The potential sums are comparable to or greater than the amounts raised by some of the state's core taxes, including the sales, income, fuel, and property taxes. Some or all of these taxes could be cut significantly in order to balance the carbon tax revenue. Alternatively, the state could issue dividend payments on a regular basis. Commercial and industrial customers are a particular challenge for this aspect of policy design, as they (in aggregate) currently pay less in state taxes than they might pay under a carbon tax scenario; merely offsetting tax reductions would then not be sufficient for revenue neutrality. A dividend option is therefore a possibility, but how would the state decide on the size of dividend for each firm? This policy offers great flexibility, which is associated with the need to make a number of decisions. The effect of regional choices increases the complexity of these decisions.

4.6 Regional and national markets and policy consistency

The FACETS and REMI modeling conducted for this study focused on policy action that impacts Vermont energy supply and demand. REMI modeling supports a conclusion that similar policy action in other jurisdictions is in Vermont's economic interest. Policy and technology choices made in Vermont should be compatible with the choices made elsewhere, or at least recognize and account for them. Vermont has experienced the impacts of being regionally out of sync with respect to renewable portfolio standard policies.

There are three main aspects in which Vermont's policy and technology choices depend on uncertain outcomes of regional or national processes. The first is the potential impact on Vermont's economy of the relative cost of doing business here when compared with other jurisdictions. Vermont policymakers typically choose a path of leadership, to capture early-mover advantage in new markets, while simultaneously working to inspire other jurisdictions to action. This creates markets for Vermont's clean energy firms while also creating an uncertain economic impact if other states do not follow. The second is the area of liquid biofuels, where the national choice made by the heavy-duty vehicle sector between compressed natural gas and biofuels will have an impact on how Vermont adapts.

Third, and more generally, is the question of policy compatibility in the face of regional markets. Where Vermont firms export or import goods, including energy, the policies in other states can have a direct impact on Vermont firms. This exposes Vermonters to a policy risk from changes in other jurisdictions. Similarly, regional and national markets and policies significantly affect the availability and price of renewable or low carbon fuel technologies. For example, if all of New England and New York support similar policies to promote electric vehicles and infrastructure, this may significantly reduce manufacturer costs (passed on to consumers) associated with meeting this broad regional demand. This demand could, in turn, move the national market, further reducing costs. On the other hand, if Vermont acts alone to promote electric vehicles, then the cost to manufacturers (passed on to consumers) may be much higher. To that end, reasonably compatible policy structures reduce risk for all regional states, and have the potential to reduce costs as well.

Vermont cannot make the energy transition modeled in this study on its own, just as it cannot sustain the business as usual path on its own. At the same time, Vermont can also be a policy and technology leader. Based on other experiences, the state's small scale allows faster transitions and more coordinated actions across sectors than is generally possible in other states. Demonstrating policy leadership can set examples for other states or nations. Leadership in clean energy innovation enhances the Vermont brand, with the potential to bring additional firms to Vermont and assist those here and growing.

4.7 Potential in the industrial sector

FACETS modeled Vermont's manufacturing and industrial sector simply as reactive to fuel prices, due to a lack of Vermont-specific industrial energy use data. Thus, technological or fuel shifts that might have been less expensive than the fuels chosen for the sector in the model were not considered. As a result, in this respect FACETS likely overestimated the costs of meeting state policy goals.

These issues identify clear future data and analytic needs for policy design. For example, a more robust picture of the efficiency and fuel-switching opportunities in this sector is needed. While the sector is not modeled completely in this analysis, it will be imperative that state policies reflect the sector's important role in seizing opportunities associated with energy system transitions, increasing Vermont's energy productivity and reducing emissions.

4.8 Access to capital

One of the primary characteristics of the technologies deployed to achieve Vermont's goals is a shift toward energy technologies with greater up-front cost and lower (or no) operating cost (energy efficiency is the clearest example, but also solar, wind, and hydroelectric generators, biomass heating systems, and electric vehicles). This raises the importance of access to capital and financing. To avoid creating barriers to technology deployment, such capital must be straightforward to access, available at Vermont scale, and at rates of interest comparable to risk. While this analysis did identify the capital needed to invest in these technologies over the 36 years ahead to 2050, the TES did not examine the financial structures necessary to access that capital. This question was examined at a pair of Clean Energy Finance Summits in 2012 and 2013 co-organized by the Department, and continues to be an area for the Department to explore in collaboration with other state finance entities and stakeholders.

4.9 Carbon accounting

10 V.S.A. §578 articulates the goal of the state to reduce greenhouse gas emissions from "within the geographical boundaries of the state and those emissions outside the boundaries of the state" caused by Vermont's energy use. As noted above, the greenhouse gas impacts described in the TES are from a "burner tip" perspective; they represent the amount of fossil fuel emissions emitted at the point of end use, or in the case of electricity, biomass, or biofuels at the point of production. This treatment is comparable to that currently used by the State to calculate GHG emissions. However, GHG emissions resulting from Vermont energy use include the impacts associated with that energy throughout all stages of its life-cycle, from fuel extraction, processing and production—through transportation, delivery and end use combustion. It is unclear how modeling results would change if carbon were measured in this manner, or if the assumptions made for this analysis regarding biomass and biofuel net carbon impacts were higher or lower. For example, in the Carbon Tax-shift policies, would nuclear energy remain part of the electricity portfolio if lifecycle emissions were included? Carbon-emission based policies are likely to be more sensitive to the results of emissions calculations than are renewable-based policies. Consensus values for life-cycle emissions for all types of fuels are not currently available. While incomplete, "burner tip" analyses offer clear comparisons to historical data, and are generally more straightforward calculations. Alternative options would require addressing the question of whether the state should prioritize emissions reductions from energy used solely within the state, or also emissions reductions elsewhere that could have an impact on Vermont's lifecycle emissions. This question also highlights the need for clearly articulating lifecycle analysis methodology and data.

5 Next steps

This report concludes the Department's formal efforts of the Total Energy Study, required by Act 170 of 2013 and Act 89 of 2013. The results identified in this report and its appendices contribute to the substantial body of analysis that the Department has at its disposal as it prepares to produce the 2015 Comprehensive Energy Plan update. The Department anticipates a multi-faceted effort to produce that Plan, including both additional quantitative and qualitative analysis, conducted by in-house and outside experts under contract as well as by interested members of the public and outside organizations. During the late fall and winter of 2014-2015, the Department plans to engage with members of the public and the Legislature regarding the results of this Total Energy Study. The formal public process for the 2015 CEP will take place beginning in early 2015 and will include multiple rounds of public engagement via written comments, public meetings, and presentations to and solicitations of input from stakeholder groups, extending throughout 2015. The Department welcomes engagement on any and all aspects of the Comprehensive Energy Plan.

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Appendices

A. "Policy Options for Achieving Vermont's Renewable Energy and Carbon Targets." Prepared by the Regulatory Assistance Project for the Vermont Public Service Department. 2013.
B. "Total Energy Study: Progress Toward a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals." Public Service Department. Report to Vermont Legislature, Dec. 15, 2013.
C. "Energy Policy Options for Vermont: Technologies and Policies to Achieve Vermont's Greenhouse Gas and Renewable Energy Goals." Prepared by Dunsky Energy Consulting for the Vermont Public Service Department. 2014.
D. "Economic Modeling Analysis of Total Energy Policies." Public Service Department, Dec. 5, 2014.
E. "Total Energy Study: Public and Stakeholder Engagement Appendix." Public Service Department. 2014.