Total Energy Study:

Report to the Vermont General Assembly on Progress Toward a Total Energy Approach to Meeting the State's Greenhouse Gas and Renewable Energy Goals

December 15, 2013

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Executive Summary

The purpose of this report is to inform the Legislature and the public of progress to date in carrying out the Total Energy Study (TES). The goal of the TES is to identify the most promising policy and technology pathways to employ in order to reach Vermont's energy and greenhouse gas goals. These goals are to: 1) meet 90% of Vermont's overall energy needs from renewable sources by 2050 and 2) reduce Vermont's greenhouse gas (GHG) emissions by 50% from the 1990 baseline level by 2028 and 75% from the 1990 level by 2050. Vermont's greenhouse gas emissions in 2011 were almost unchanged from the state's emissions in 1990. Vermont meets about 16% of its energy needs with renewable energy.

The Public Service Department expects to release, and submit to the Legislature, the Total Energy Study Final Report in the summer of 2014. While the Total Energy Study describes several policy and technology scenarios that are expected to achieve the State's goals, these reports are not intended to be or replace the Comprehensive Energy Plan. Neither this report nor the TES Final Report will articulate or recommend a definitive pathway forward.

The Department has structured its analysis around the development and evaluation of sets of policies and technology pathways. Technology pathways define different ways that the state could meet its objectives in terms of technology or 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 generally determine overall cost and economic impacts. Policy sets are the tools deployed by the State government (in concert with policies adopted at the National, regional, and local level) to shape deployment of technologies.

The TES analysis evaluates technology pathways on criteria including: ability to meet the state's GHG and renewable energy goals; total economic impacts; impact on capital flows; and risks such as technology performance risk. The TES analysis of policy sets evaluates them based on: impact (both scope and leverage); responsiveness to external changes; and independence from polices adopted by others. Combining policy sets with technologies pathways, analysis will indicate potential compatibility or incompatibility between policy and technology directions, as well as overall impacts on the pace of State goal achievement.

The effects of a particular policy/technology pathway with regard to most other state policies depend on the details of policy implementation. If energy policy is implemented poorly, it could conflict with other state policy goals. This report summarizes the areas of greatest interaction between comprehensive energy policies and non-energy policies in the areas of economic development, land use, transportation, forestry, agriculture, heath, and natural resources. The policy sets analyzed in this report have been formulated so as to minimize conflicts between energy policy and other state objectives. In many cases, there is the potential for mutually-reinforcing benefits between these policy areas.

Comprehensive and integrated energy policy sets should be constructed with recognition for the structure of the energy sector and energy markets. In particular, the energy sector is rife with market failures; policy structures that have been developed to address those failures. Market failures include prices that do not reflect costs, lack of information, lack of access to capital, and split incentives. Government action can use four leverage points (identified and discussed in the 2011 Comprehensive Energy Plan (CEP)) to shape the adoption of technologies: education and outreach; finance and funding; regulatory reform; and technology and innovation. Because the clean energy transition involves many cases in which upfront costs are increased while savings are accumulated over time through reduced operating costs, financing tools and access to capital will be essential.

This study has identified and constructed five policy sets that represent different comprehensive and integrated approaches to energy and greenhouse gas policy. These are:

- Total Renewable Energy and Efficiency Standard (TREES): Require all providers of energy in Vermont to meet a fraction of their sales with renewable energy or energy efficiency. The required clean energy fraction would be the same for all fuels, and would rise over time. Obligations would be met by "retiring" tradable certificates corresponding to a certain amount of renewable energy or efficiency.
- Carbon tax shift: Creation of an economy-wide carbon tax in the context of tax reform, maintaining at or near revenue neutrality for the State. In this option, other taxes are cut by an amount equal to or close to the amount of revenue raised by the carbon tax. This carbon tax has the effect of sending a price signal much closer to the societal cost of emissions incurred, addressing the market failure of the mismatch between prices and costs.
- Renewable targets with carbon revenue: Draws from the previous two policy sets; here, the state would set a target for the renewable energy content of all fuels, placing a non-binding obligation on energy suppliers. If the target were not met within a given sector, however, the obligation would become mandatory within that sector or that sector's carbon tax would be increased. This obligation structure would be paired with a small economy-wide carbon tax used to raise revenue applied to programs directed at making it easier for obligated parties to meet their target obligations.
- Sector-specific policies: Consists of sector-specific policies, each tailored to address a known challenge or market failure within a given portion of the state's energy economy. The policies within this set could work in an integrated and comprehensive manner to drive the clean energy transition, but there would be no single, overarching policy structure as in the previous three policy sets.
- New England regional policy focus: Policies adopted at the regional level or coordinated with our neighboring states may be more effective than policies adopted by a single state. This reflects understanding that the six New England states are served by an electric grid with a single regional operator and markets, and that biomass is commonly used in a state different from the state in which it is harvested. There is also a potential that the combined market power of New England or Northeast states (and potentially including neighboring Canadian provinces) can move markets and bring new technologies to scale in a way that no single state can do.

Each of these policy sets raises a number of questions regarding implementation and impacts. Ongoing analysis will identify aspects of each policy set that could be combined to a smaller number of policy sets for quantitative analysis to follow publication of this report. Readers are encouraged to address the open questions associated with each policy set in written comments.

Technology pathway analysis conducted for the TES has highlighted the potential and open questions regarding both energy demand and energy supply. Reduction in total energy demand has been reaffirmed as essential to meeting the state's energy targets 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.

The five renewable primary energy supply resources available to Vermont are solar, wind, hydropower, methane capture, and biomass. Each has strengths and weakness, 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. This report identifies several areas where non-renewable resources may most productively remain in use, making up the 10% of the state's total energy that is not renewable in 2050. These include flexible electric generators for grid stability; heavy duty transportation and machinery; and some industrial processes.

The Department, working closely with the staff of the Governor's Climate Cabinet, structured the TES process to facilitate significant stakeholder and public engagement that would inform development of a wide set of scenarios that might meet the State's goals, then narrow those scenarios down based on a set of qualitative criteria to result in a manageable number of potential scenarios for further quantitative analysis. To that end, the Department published and solicited comments on a Framing Report and held a number of stakeholder focus groups during the summer and fall of 2013. The Department also hosted a public meeting to share the status of our policy analysis at the State House and via webinar on November 14. The Department continues to welcome public input, and has opened a formal comment period extending until January 22, 2014. Please refer to the Total Energy Study webpage for more information.

1 Introduction

The Public Service Department (Department) is undertaking this "Total Energy Study" (TES) to identify the most promising policy and technology pathways to employ in order to reach Vermont's energy and greenhouse gas goals. Act 170 of 2012, modified by the General Assembly through Act 89 of 2013, initiated this study to address the State goals to 1) meet 90% of Vermont's overall energy needs from renewable sources by 2050 and 2) reduce Vermont's greenhouse gas emissions by 50% from the 1990 baseline level by 2028 and 75% from the 1990 level by 2050.

Vermont's greenhouse gas emissions in 2011 were almost unchanged from the state's emissions in 1990: approximately 8.11 million metric tons[1]. 46% of these emissions were due to transportation; 32% from residential, commercial, or industrial fuel use, and 5% from electricity consumption. The remaining 17% were due to non-energy sources, such as agriculture, industrial processes, and waste. Vermont meets about 16% of its energy needs with renewable energy. This includes approximately 5% of transportation energy, 25% of energy used in residential buildings, 23% of energy used in commercial buildings, and 19% of industrial energy use.

The State's energy and greenhouse gas goals are guided by the statutory foundation of the State's energy policy as stated in 30 V.S.A § 202a(1):

> To assure, to the greatest extent practicable, that Vermont can meet its energy service needs in a manner that is adequate, reliable, secure and sustainable; that assures affordability and encourages the state's economic vitality, the efficient use of energy resources and cost effective demand side management; and that is environmentally sound.

Vermont's renewable energy and greenhouse gas goals are articulated in the 2011 Comprehensive Energy Plan and 10 V.S.A. §578, respectively. These broad targets set the direction, however more detailed pathways to reach the targets have not been defined. The Total Energy Study seeks to provide a more detailed analysis of several policy and technology roadmaps that will move the state from our current renewable energy and greenhouse gas trajectory that falls short of the above goals to a course that achieves them. The study is not intended to provide a definitive pathway forward, but rather to:

- Focus state, legislative, stakeholder, and general public conversation on actions with a high probability of meeting State goals.
- Clearly identify policies that the State should or should not pursue.
- Identify areas where federal or multi-state policies may be required in order to meet State goals (or make desired outcomes more achievable).
- Identify high-level economic and societal impacts from analyzed policy and technology roadmaps.
- Identify challenges and opportunities associated with several possible implementation scenarios that would meet the State goals.

[1] http://www.anr.state.vt.us/anr/climatechange/Vermont_Emissions.html

1.1 Legislative charge

Vermont's greenhouse gas targets were articulated in 2006 through the enactment of [10 V.S.A. §578](a):

> General goal of greenhouse gas reduction. It is the goal of the state to reduce emissions of greenhouse gases from within the geographical boundaries of the state and those emissions outside the boundaries of the state that are caused by the use of energy in Vermont in order to make an appropriate contribution to achieving the regional goals of reducing emissions of greenhouse gases from the 1990 baseline by:
>
> (1) 25 percent by January 1, 2012;
>
> (2) 50 percent by January 1, 2028;
>
> (3) if practicable using reasonable efforts, 75 percent by January 1, 2050.

In 2011, Vermont adopted its first Comprehensive Energy Plan in over a decade. The Plan's intention is clearly articulated:

> [T]o set Vermont on a path to attain 90% of its energy from renewable sources by mid-century. . . . The goal is underpinned by this strategy: to virtually eliminate Vermont's reliance upon oil by mid-century by moving toward enhanced efficiency measures, greater use of clean, renewable sources for electricity, heating and transportation, and electric vehicle adoption, while increasing our use of natural gas and biofuel blends...

Following the release of the Comprehensive Energy Plan the General Assembly sought more detail on the policy and technology pathways that would allow Vermont to reach its goals. The Total Energy Study is required by Act 170 of 2012as modified in Act 89 of 2013:

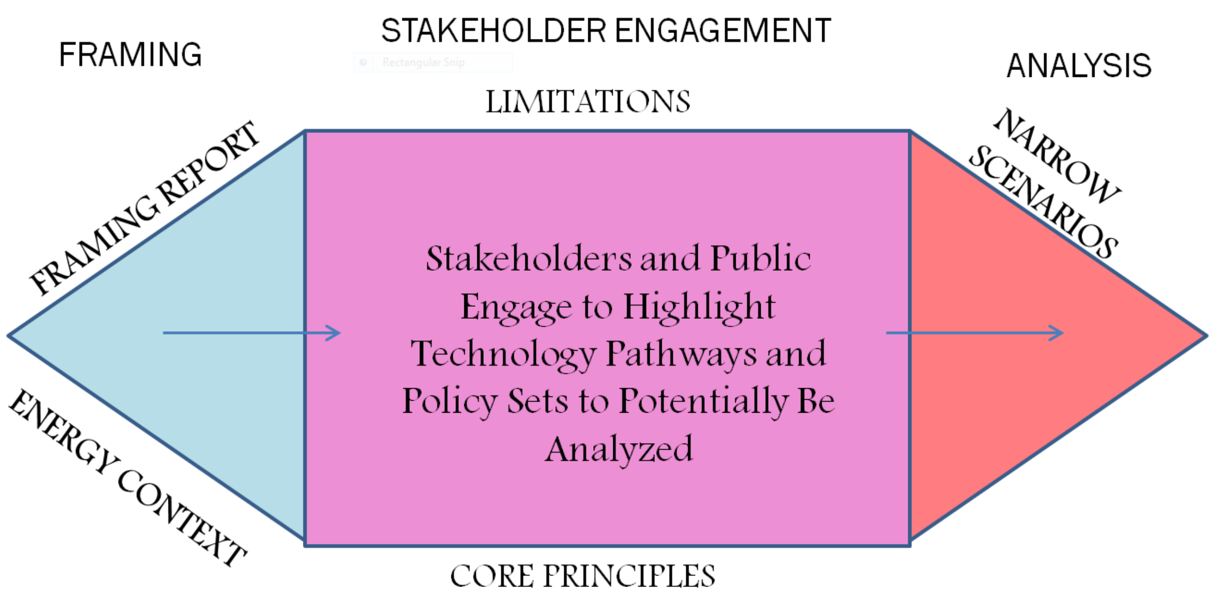
> (a) The General Assembly finds that, in the comprehensive energy plan issued in December 2011, the Department of Public Service recommends that Vermont achieve, by 2050, a goal that 90 percent of the energy consumed in the State be renewable energy. This goal would apply across all energy sectors in Vermont, including electricity consumption, thermal energy, and transportation (total energy).
>
> (b) The Commissioner of Public Service shall convene an interagency working group to study and report to the General Assembly on policies and funding mechanisms that would be designed to achieve the goal described in subsection (a) of this section and the goals of 10 V.S.A. § 578(a) (greenhouse gas emissions) in an integrated and comprehensive manner.
>
> > (1) The study and report shall include consideration of a total energy standard that would work with and complement the mechanisms enacted in Secs. 3 (SPEED; total renewables targets) and 4 (SPEED; standard offer program) of this act.
> >
> > (2) The group's study and report shall consider currently available information on the economic impacts to the state economy of implementing the policies and funding mechanisms described in this subsection.

(3) The group's report shall identify those policies and funding mechanisms described in this subsection that do and do not warrant serious consideration and any areas requiring further analysis and shall include any proposals for legislative action. The report shall be submitted to the General Assembly by December 15, 2013.

(c) Prior to submitting the report to the General Assembly, the group shall offer multiple opportunities to submit information and comment to affected and interested persons such as chambers of commerce or other groups representing business interests, consumer advocates, energy efficiency entities appointed under Title 30, energy and environmental advocates, fuel dealers, educational institutions, relevant state agencies, transportation-related organizations, and Vermont electric and gas utilities.

1.2 Process to date

The Department, working closely with the staff of the Governor's Climate Cabinet, structured the TES process to facilitate significant stakeholder and public engagement that would inform development of a wide set of scenarios that might meet the State's goals, then narrow those scenarios down based on a set of qualitative criteria to result in a manageable number of potential scenarios for further quantitative analysis. The Process generally follows the structure outlined in the following figure:



1.2.1 Framing report and initial public comments

The initial step in the Total Energy Study was to develop a Framing Report intended to facilitate public and stakeholder feedback and discussion. The Department commissioned the Regulatory Assistance Project to identify and provide an overview of the most promising technologies (e.g. electric vehicles, heat pumps, biomass heat, solar power, etc.) and policies (e.g. carbon based fees, renewable portfolio standards, smart growth policies, etc.) available to Vermont to meet its goals.

A request for public comment was issued on June 21, 2013 to receive feedback on the Framing Report and general comments regarding the Total Energy Study. The request solicited comments from the public and stakeholders regarding:

- Whether there are "key policies" or "key technologies" that should be considered that weren't identified by the Framing Report.
- What are the most promising policies and technologies, or combinations of policies and technologies available to the state.
- What are the most important considerations for determining which policies or technologies are worthy of further consideration and study.
- Whether the study should analyze potential pathways possible only with regional coordination or Federal action, or just what Vermont could implement alone.
- What principles should guide the development of the baseline case – i.e. the business-as-usual projection to which possible policy and technology pathways will be compared.

The Department received 19 sets of comments addressing some or all of the above questions. The comments are summarized in Appendix A.

1.2.2 Stakeholder focus groups

Following receipt and consideration of the initial public and stakeholder comments, the Department convened 11 stakeholder focus group meetings to solicit specific feedback on what participants thought were the most promising policies and technology pathways, what principles should guide the choice of policies and technologies, and limitations or constraints that would diminish their potential effectiveness. Participants were also asked to develop their own policy and technology scenarios.. The focus group topics ranged from being technology or sector specific (e.g. residential buildings, electric biomass) to explicitly cross-sectoral concerns (e.g. local/diversified infrastructure; costs and benefits across sectors).

One hundred and thirty-two people representing 79 organizations attended the focus group sessions. Focus group discussions included a wide range of participants from all varieties of businesses and their associations, local and national energy businesses and consulting firms, energy utilities, environmental and citizens advocacy groups, academics, financial institutions, philanthropists, transportation authorities, law firms, town energy committees, planners and other local, state, and federal governmental agencies. The participants are listed in Appendix B.

The Department structured the focus groups to encourage participants to freely express their opinions in frank and respectful discussion, without attribution, through the use of a modified Chatham House Rule[2]. These discussions informed the narrowing of the wide range of policies and technologies

[2] "When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed." (http://www.chathamhouse.org/about-us/chathamhouserule) In the TES case, we have revealed the names of the participants, but no attribution for any statement or idea may be revealed.

presented in the Framing Report to five policy sets and four technology pathways that might guide or inform decisions regarding the targeted energy transition. These policy sets and technology pathways are described in Sections 5 and 6 of this report. The focus group discussions also informed the development of the qualitative evaluation criteria (described in Section 2 of this report) that will be used to narrow 20 possible scenarios (five policy sets times four technology pathways) down to three promising scenarios for detailed, quantitative analysis taking place through mid-2014.

As required by Section 29 of Act 89 of 2013, the Department has coordinated with the Public Service Board in the Board's production of a report on the market for unregulated fuels and thermal building efficiency. Board staff attended the most relevant stakeholder focus group, and the Department has participated in the Board's process in developing its report. The TES and the Board's process drew upon the work already completed by the Thermal Efficiency Task Force, informed by subsequent developments in the sector.

1.2.3 Additional public meeting and comments

On November 14th, 2013 the Public Service Department held a public meeting and webinar at the Vermont State House. Twenty-five Vermonters attended the meeting in person and 26 connected via webinar. Between November 14 and December 2nd, the public and energy stakeholders submitted eleven sets of written comments in response to the meeting. The presentation for the public meeting can be viewed on the Total Energy Study webpage.

Appendix A summarizes all written comments received throughout the TES process to date, the focus group discussions, and the public meeting discussion.

1.3 Process in-progress and the future

Following a competitive solicitation, the Department hired Dunsky Energy Consulting (Dunsky) to assist with the analysis of technology pathways, policy sets, and scenarios combining them. Dunsky will also undertake detailed quantitative analysis of at least three unique scenarios to be defined in early 2014.

In the past months, the Department and Dunsky have defined technology and policy test scenarios, along with a baseline scenario to which each alternate scenario may be compared. The baseline scenario (known also as the business-as-usual case) is a quantitative description of the entire Vermont energy system up to 2050. The baseline scenario is being constructed with a various data sets and industry forecasts and takes account of existing State programs and policies.

At the time of this report, the Department and Dunsky are completing their qualitative analysis of the 20 test scenarios defined by the combinations of each of five policy sets and four technology pathways. This is being done using the evaluation criteria articulated in Section 2. The next step is to define three scenarios for continued quantitative analysis. These scenarios will likely be combinations of the most promising aspects of the 20 test scenarios. The Department expects to finalize the descriptions of these three scenarios in early 2014, following input from the Governor's Climate Cabinet, the public, and members of the Legislature as appropriate.

The modeling tool utilized by Dunsky and the Department is designed to optimize an energy system's resources for a given set of constraints, the most important of which are the renewable energy and greenhouse gas targets. Given the constraints defined, the model optimization identifies the least cost energy supply resources for each scenario. The model has the ability to account for complex interactions between the many variables representing the energy economy of Vermont and the New England region. The analysis will produce quantitative estimates of the pacing of each scenario through 2050 and describing their impacts on Vermont. The analysis includes predicting the economic impact of each scenario. Each scenario's quantitative output, including the economic impact (analyzed using a tool such as REMI PI+[3]), will be compared to the baseline scenario.

The Department and Dunsky expect to complete this quantitative analysis in the spring of 2014. Following its completion, the Department will publish the results and provide additional opportunities for public input, both in-person and in writing, to weigh in on and inform paths forward for state energy policy. The Total Energy Study Final Report is expected to be released in the early summer of 2014.

1.4 What this report is not

While the Total Energy Study describes several policy and technology scenarios that are expected to achieve the State's goals, these reports are not intended to be or replace the Comprehensive Energy Plan. Neither this report nor the TES Final Report will articulate or recommend a definitive pathway forward.

The Total Energy Study does not directly address non-energy greenhouse gas emissions (e.g. those from agriculture, waste, or chemicals). For energy greenhouse gas emissions, the Total Energy Study uses the same definitions used by the Agency of Natural Resources (ANR) in developing the State greenhouse gas emissions inventory, based on emissions at the point of combustion (including in electrical generation), not full life-cycle emissions.

This report does provide high level qualitative insights with regard to the economic and environmental impacts of choosing one scenario over another or relative to the baseline pathway. The report does not provide a detailed quantitative analysis of these impacts. Further quantitative analysis will be available in the TES Final Report to be published in the summer of 2014.

Along with subsequent analysis and work products through summer 2014, the TES Final Report will inform the next Comprehensive Energy Plan. Because these efforts address State policy goals with long timeframes (2028, 2050), an iterative energy planning process will continue to be necessary as technology, markets, and State policies evolve.

1.5 The structure of this report

Section 2 of this Report summarizes the Department's conclusions regarding appropriate criteria to use when evaluating future energy policy and technology scenarios. Section 3 discusses the overlap between policies designed to meet the state's energy and climate goals and policies designed to meet other state

[3] REMI PI+, a software product developed by Regional Economic Models, Inc., is the most commonly used tool for analysis of the economic impacts of policy choices in Vermont.

objectives in areas such as economic development, land use, transportation, forestry, agriculture, health, and natural resources. Section 4 outlines principles used in the design of energy policy sets, five of which are then defined and summarized in Section 5. Section 6 identifies technology pathways, including discussion of both energy demand and supply-side technologies, and the breadth of technology pathway choice available to the state while still achieving both renewable energy and climate change objectives. Section 7 concludes the report with a discussion of the ongoing study process.

Appendices to this report include a list of stakeholder focus group participants and a report summarizing all public comments received to this point in the TES process.

2 Criteria for the evaluation of policy and technology scenarios

In order to narrow the breadth of possible policy and technology scenarios and to choose a reasonable number of scenarios for detailed quantitative analysis, the Department and Dunsky developed qualitative evaluation criteria. The set of criteria developed was informed by the stakeholder focus groups and comments from the general public. These evaluation criteria are intended to support understanding of various advantages and trade-offs. Thus the criteria allow each scenario to be measured and compared against all other scenarios. The evaluation of policy and technology scenarios against these criteria is ongoing. Some initial results are reflected in the discussion contained in this Report; a more complete and quantitative analysis will be available in 2014.

2.1 Evaluating technology options

2.1.1 Ability to meet greenhouse gas and renewable energy goals

Each scenario that will be analyzed is constructed to meet the State’s 2028 and 2050 greenhouse gas targets, and the State’s 2050 renewable energy target. While there is likely to be some overlap among scenarios, reaching the climate and renewable energy goals does not necessarily require the same technologies in every case.

As described above, a baseline estimation of Vermont’s energy system, which falls short of the State’s targets, is being developed to compare with the test scenarios. In addition, for the initial narrowing of test scenarios the technology options will be qualitatively evaluated against a scenario developed using the software model. This initial quantified scenario will be constructed to identify the one set of energy supply technologies, and their pacing, to meet the renewable energy and climate goals at low overall estimated energy cost. Each test scenario will be evaluated against this initial scenario to determine how likely the test scenario is to achieve the State’s targets at reasonable cost.

The Department recognizes there is diversity of opinion on how to define the “optimum” technology pathway. The initial quantified scenario will be based on optimizing a simple net-present-value of overall energy costs. We are analyzing a diversity of technology pathways to capture the varying benefits and costs of different scenarios.

2.1.2 Total economic impact

Perhaps the next most obvious of evaluation criteria is to consider the overall impact of the policy and technology scenarios on the Vermont economy. The total net direct and indirect impacts to the Vermont economy will be measured in two ways, one of which places a value on reductions in greenhouse gas emissions, the other of which does not. The direct impacts will consider changes in actual expenditures on energy, while the indirect impacts will additionally consider how those changes flow through the Vermont economy. For example, energy efficiency savings were recently shown to have a "multiplier" effect, as the customer savings on fuel costs were re-spent in the Vermont economy, leading to an increased benefit[4]. Other harder-to-quantify costs and benefits, such as impacts on public health, will be considered to the extent possible.

Analysis of economic impact to be conducted in 2014 should provide information about consequences for costs, prices, and manufacturing competitiveness in Vermont. The quantitative analysis will be completed in a format that facilitates input into state economic models such as REMI PI+.

2.1.3 Capital flows

Dunsky and the Department will also identify the capital flows associated with each scenario in order to determine the extent that the benefits and costs of the scenarios remain in-state or are exported out-of-state. The initial qualitative analysis will provide a high level indication of the direction and magnitude of these flows. The detailed quantitative analysis of three scenarios will provide more detail and, to the extent possible, will identify cash flows between individual sectors within the economy so that impacts can be analyzed across different socioeconomic groups, geographic areas, and/or economic sectors.

2.1.4 Risk

The pace, timing, and impact of technological change is nearly impossible to predict. Thus, the ongoing TES will qualitatively evaluate technology options with regard to the impacts of potential variances in initial projections, such as technology implementation cost, availability, and acceptability. This criterion will consider the flexibility of each technology option with regard to the diversity of energy supply technologies.

2.2 Evaluating policy options

2.2.1 Responsiveness

Similar to the diversity of energy supply resources discussed under the "risk" technology criterion, this criterion considers the ability of a policy to take advantage of new opportunities and meet new challenges. For example, if the availability of a technology changes (e.g. due to changes in performance or cost), then the policy may or may not be able to take advantage of those changes. This criterion evaluates a policy's responsiveness and/or vulnerability to change.

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[4] See, for example, Appendix 5 of the 2011 Comprehensive Energy Plan, available from http://publicservice.vermont.gov/sites/psd/files/Pubs_Plans_Reports/State_Plans/Comp_Energy_Plan/2011/2011%20CEP_Appendixes%5B1%5D.pdf.

2.2.2 Independence

As discussed in Section 4, Vermont is a small state that is impacted by changes in markets and by policies set in other jurisdictions. The "independence" criterion considers the extent to which a policy is dependent on other jurisdictions' energy policies. There is real value in having Vermont policies compatible with those in neighboring states; indeed the economic impacts (either positive or negative) or even the ability of a policy scenario to facilitate meeting Vermont's energy goals may crucially depend on how other jurisdictions act.

2.2.3 Impact

A policy choice could score well against the above criteria, but only apply to a limited portion of Vermont's energy system. Thus, it is important to consider the overall impact of a policy choice. This will be done in two ways. First, the scope of energy sources and emissions addressed by the policy choice will be evaluated. Second, the possible leverage of the policy to ensure the desired outcome will be considered, taking into account whether a policy is voluntary, prescriptive, or mandatory.

2.2.4 Complementarity

Finally, it is imperative that the policy and technology pathways not undermine other efforts and goals of the state; instead they must work in coordination. Thus, each scenario was also constructed to be complimentary to the State's other energy and non-energy policies. A description of the state policies with which the Total Energy Study must coordinate can be found in Section 3.

2.3 Evaluating technology plus policy scenarios

In addition to the analysis of each technology pathways and policy set against the criteria above, each combination scenario will be evaluated. Evaluation will weigh whether implementation of a policy set is particularly compatible or incompatible with the technology pathway under analysis. It is important to note that Vermont's greenhouse gas and renewable energy goals may be reached at different times under different combinations of policies and technologies. The Study will seek to the extent possible to analyze the pacing of how quickly we will meet our goals under each combination. In addition, analysis may identify the optimal sequence for deployment of technologies or policies within each combined scenario.

3 Coordination with other state policies

Most activities in the Vermont economy have implications for the state's energy use and result in some greenhouse gas emissions. As a result, Vermont's energy and greenhouse gas policies are intimately linked with the state's policies in other areas. The state has developed polices that reflect Vermonters' priorities and expectations across the economy, and the energy policies and technology pathways studied here must be evaluated based on how well or poorly they interact with other state policies.

Through this study process, it has become clear to the Department that because the proposed scenarios are general in nature, the effects of a particular policy/technology pathway with regard to most other state policies depend on the details of policy implementation. If energy policy is implemented poorly, it could conflict with other state policy goals. The Department has attempted to design the scenarios such that neither policy design nor its thoughtful implementation would directly conflict with other state policies.

However, it is important to maintain awareness of the key policy areas where poor energy policy implementation could have a negative effect on other state policy goals. This section addresses areas of policy interaction and how energy policy and technology might be shaped by consideration of each policy area.

3.1 Economic development and equity

One of the key messages the Department heard from stakeholders during this study process was the importance of energy to the state's economic vitality. To that end, the Department has participated in the Agency of Commerce and Community Development's (ACCD) ongoing development of a Comprehensive Economic Development Strategy (CEDS), and ACCD staff have participated in the interagency and stakeholder TES working and focus groups.

There are two primary ways in which energy policy impacts the state's economic development: the cost of energy and the development and growth of Vermont's "clean energy" economy. Regarding the cost of energy, energy policies must be aware of both the marginal cost of a unit of energy, delivered via various fuels, and a customer's total expenditure on energy. (In the electric context, for example, that means both rates and bills.) Both of these have impact on the cost of living and the cost of doing business in Vermont, with implications for regional, national, and global competitiveness. Policy analysis and design should be concerned with inter-sector equity (favoring policies which distribute benefits to the same sector which directly bears the policy's cost), and aware of the implications for shifting economic activity from emissions-intense to less-emissions-intense activities. Further, policy analysis and design should also be aware of the timing of any imposed costs or secured benefits.

Procuring a growing fraction of the state's clean energy resources in the state (both supply- and demand-side resources) serves to bolster local firms delivering those resources, and also provides a platform from which firms can develop products and services offered in global markets. Vermont policies can foster innovation in both business models and technologies.

The cost of energy is borne unequally across Vermont consumers, both commercial/industrial and residential. Therefore, polices that change the costs of energy, or the relative costs of different fuel choices, will have uneven effects. For example, rural Vermonters are more sensitive to the cost of transportation fuels. Energy is also a larger fraction of household expenditures for low-income Vermonters than for higher-income, so policies which increase the cost of energy relative to other goods and services should also be designed with compensating features that ensure that benefits flow back to those bearing greater relative costs, particularly to the state's low- and middle-income residents.

3.2 Land use

The built environment, including both buildings and roads, both shapes and is shaped by energy and climate policies. The state's long-term commitment to compact settlement patterns is highly compatible with efforts to reduce energy use and increase the efficiency of the transportation sector because it increases the ability for Vermonters to live close to where they work and play and makes alternative modes of transportation viable alternatives to single occupancy vehicles. The energy polices considered here, then, should respect and complement the state's progress on implementing smart growth principles. While historic preservation is a key component of maintaining this settlement pattern, energy policy implementation should also respect the need to balance the desire to improve the efficiency of buildings, and to develop or maintain energy resources such as hydroelectric resources, with such preservation.

Energy infrastructure, such as electric generators, transmission lines, district heating systems, and pipelines, also has significant land use impacts. The recommendations of the Vermont Energy Generation Siting Policy Commission directly address potential improvements to the siting process that can increase the potential for compatibility between land use aims and clean energy implementation. One key take-away from that process is the importance of planning, for both energy and land use, and the need for these two kinds of plans to inform each other.

Even as Vermont makes progress on reducing greenhouse gas emissions, previous emissions and emissions from other jurisdictions continue to change the global climate. To this end, technology and infrastructure deployment, including buildings, road, and energy infrastructure, should be pursued in a way that increases resilience in the face of extreme weather, while avoiding undue impact on the state's natural resources, which will likely face increased stresses as well. A dynamic and resilient energy system, fostered by appropriate policies, can lessen the negative impacts on the state from such events.

3.3 Transportation

More than one third of the state's energy consumption, and nearly half of its greenhouse gas emissions, are tied to the transportation sector. Transportation infrastructure choices are also in many cases land use choices, involving them with energy through the mechanisms discussed above regarding land use. Broad energy policies, such as those focused on modal choice or the cost of competing fuels, can also impact how transportation infrastructure is used, and which infrastructure is required. For example, a shift of heavy-duty transportation away from trucks and toward rail has implications for the necessary rail infrastructure; the cost of gasoline has a direct impact on utilization of transit services. Coordination of policies and planning between these two economic foundations – energy and mobility – can advance state goals in both arenas. In addition, a significant fraction of the state's revenue for transportation infrastructure and programs is raised via taxes on energy products (gasoline and diesel). Thus, policies which address either side of this coin impact the other. The state and our regional neighbors have a compelling long-term need for sustainable funding for transportation infrastructure, so long-term energy policy planning must take this need into account.

3.4 Forestry

Vermont has a limited biomass resource that can be harnessed sustainably for energy purposes. Policies which increase or decrease the use of different kinds of woody biomass for energy will impact the state's forests. The Department's analysis of the availability and utilization of biomass for energy is informed by the amount of biomass that can be harvested sustainably and in a way that maintains or improves the health of the state's forest resource. This effectively serves to put a cap on the amount of biomass energy that the state's policies should count on using for energy purposes.

There is also a potential for synergy between forest health, the forest products industry, and meeting the state's energy goals. Sustainably harvested low-grade wood for energy purposes provides an economic driver for maintaining forested land in wood production, and can increase the quality of the forest resource over time. This results in less low-grade wood available for energy uses, but a greater state resource for other, higher-value wood products, and a potential positive impact to the forest products industry. Maintaining forested land as forest also can be compatible with the compact settlement patterns discussed above, and with maintaining habitat connectivity, carbon sequestration, and other environmental services.

3.5 Agriculture

Similar to in the forestry discussion above, energy has potential to be a co-product from Vermont's agricultural sector. As a co-product, it can improve the economics of the state's farms (through monetizing what might otherwise be waste) and also advance natural resource objectives. Anaerobic digester technologies, such as those deployed at a number of Vermont dairy farms, can contribute to addressing the organic-waste-disposal needs created by Act 148. Processing wastes explicitly through digestion can also increase the ability to capture potential water pollutants and nutrients for appropriate disposal or reuse.

Agricultural land can be an appropriate place to site energy infrastructure, including electric generation by various technologies. However, energy facility siting can also have implications for the use of the state's prime agricultural soils, so deployment plans for different types of renewable energy generators should be designed to respect this state resource.

3.6 Health & natural resources

In addition to the forest and farm resources discussed above, energy polices have implications for the state's air and water quality and the vitality of other natural resources. Energy policy structures under consideration should be compatible with policies that promote the maintenance or improvement of natural resources.

Greenhouse gases are global air pollutants whose reduction is inherent in the policies considered in this study. Other air pollutants, however, such as those resulting from combustion of fossil or biomass fuels, can have local and regional impacts on human health (e.g. cardiovascular and respiratory diseases and illnesses, cancer, etc.). Energy policies that reduce combustion for electricity generation, transportation, or heating also reduce such emissions. In addition, policies should reflect the differing ability of different combustion technologies to reduce emissions and the potential (or lack thereof) for "scrubbers" or other technologies to remove pollutants from flue gases.

Energy-related impacts on Vermont's water quality include impacts from dams and hydroelectric generators, introduction of various waste streams (e.g. via run-off), and deposition of air pollutants into water (e.g., via acid rain). Clean energy pathways that the state might pursue are generally consistent with polices to improve water quality by addressing such concerns; one area of potential greater conflict is in Clean Water Act compliance and the use of hydroelectric generators in run-of-river vs. more controlled operation, as well as the expansion of hydroelectric generation to existing dams (rather than the dams' removal).

Siting and construction of energy facilities can have impacts on wildlife habitat and the state's other natural resources, as well as water and air quality. Public and regulatory acceptability of clean energy technology deployment depends on the ability of such developments to mitigate impacts on the state's natural resources, and ideally to improve them.

Policies that advance clean energy can also have direct impacts on human health. For example, land use policies and transportation infrastructure that support compact settlement patterns, with resulting energy savings, also provide a context for walking and biking, with resulting improvements in fitness. Climate change will also have increasing impacts on Vermonters' health, such as through extreme heat events, flooding events, or introduction of diseases or pests. The built environment can directly impact the ability of Vermonters to weather such changes. For example, more efficient buildings can be better able to maintain heat (in winter) and cold (in summer), increasing human comfort and health.

4 Developing "comprehensive and integrated" energy policy sets for analysis

4.1 Market structure and failures

Global, national, state and local energy markets are not free markets – they are strongly shaped by utility regulation, tax policies, incentives, and environmental regulation. Many of the policy sets described in Section 5 address known and identified market failures (such as utility regulation in the context of natural monopolies); others exacerbate such failures. In developing and analyzing energy policy options for Vermont, the Department has identified several market failures that could be addressed in order to increase the alignment between market forces and the public interest.

The market failures identified here exist to different degrees and in different guises in different parts of the energy economy. For example, the natural monopoly world of electricity and pipeline natural gas is shaped by utility regulation and rate-setting, while delivered fuels are subject to competition between suppliers. At the wholesale level, however, electricity and natural gas are traded commodities, similar to oil, gasoline, or propane, operating under a different set of market forces. Public policies (or other forces) that result in a shift of demand to or from price-regulated fuels will have impacts throughout the energy economy, changing the characteristics of different parts of relevant markets.

Market failures identified in the Department's research and raised by stakeholders include:

- **Prices that do not reflect costs:** In order for consumers to make economically efficient decisions that also reflect the public interest, the prices paid for goods and services should reflect the full cost of those goods. For example, the market prices of fossil fuels do not reflect the full environmental cost (both present and future) of the production and combustion of those fuels;

similarly the price of electricity generated by a renewable facility may not reflect the full societal cost of the construction and operation of the facility. Costs borne by someone other than the person paying the final price are called “externalities.”

- **Lack of information:** If a consumer lacks complete information her purchasing decisions may fail to serve either her own personal interest or the public interest. For example, the lifetime cost of an appliance or automobile is a combination of the upfront cost and ongoing fuel and maintenance costs (among others). A more efficient appliance may cost more up front but save money in the long term. However, without complete information, the consumer may unintentionally choose the product with a higher overall cost, a phenomenon known as adverse selection.
- **Lack of access to capital:** The more economical long-term energy choice may require greater upfront expense, and if a consumer lacks access to the capital necessary to make that investment, she may not be able to make the choice she would like to optimize her well-being.
- **Split incentives:** In many cases, such as in a landlord-tenant relationship, the parties who make purchasing decisions are not those who pay for operating costs associated with those decisions. This situation is considered a principal-agent problem, a problem commonly observed within organizations where capital and operating costs are treated separately. The nature of a principal-agent problem is that the best collective choice (for the landlord and tenant together, or for the organization as a whole) is not in the best interest of the persons making the decision (the agent).

The policy sets the Department has developed for analysis, described in Section 5, address these market failures in a variety of ways. One way to think about each policy set, however, is that it uses some policy tools to encourage prices to approach the correct societal costs, and other complementary policy tools to reduce other market failures and allow these price signals to be more effective or otherwise shape consumer or producer behavior to address market failures.

4.2 What are the leverage points, and who can wield the levers?

As discussed in the 2011 Comprehensive Energy Plan, attempts by government and others to shape the energy sector or reduce greenhouse gas emissions can be categorized into four leverage points:

- education and outreach,
- finance and funding,
- regulatory reform, and
- technology and innovation.

These leverage points can address the market failures discussed in the previous section, although they also have other roles in meeting the state’s energy and climate change goals. For example, education and outreach can address the lack of information; finance tools can address the lack of capital, and regulatory reform can address alignment of prices with costs. These leverage points must work in concert, however, in order to be truly effective.

Different levers, or different aspects of each lever, may also be best operated by different kinds of entities. Potential actors in Vermont include state agencies, political leaders, community leaders, educators, financial institutions, businesses, researchers, and non-profit organizations. Coordination among these different kinds of actors, each wielding the levers they can, can increase effectiveness of each contributor's actions. The state has long recognized this, and it is implicit in the logic behind the development of a regularly-updated Comprehensive Energy Plan and the generally collaborative nature of the energy policy process in the state. The policy sets described here are each constructed with the intent to provide an overall policy framework to facilitate a common understanding of the tradeoffs between the costs and benefits of various policy choices, with which Vermont's broad cast of actors can engage in meaningful debate.

An example, based on one of the underlying shifts the Department has identified as key to the clean energy transition, may be illustrative. Across almost all sectors and energy uses, both efficiency and renewable energy technologies have a greater up-front cost but lower ongoing or operating costs than is the case for existing technologies they might displace. For example:

- Home weatherization increases the capital invested in the building while reducing the home's operating costs.
- Pellet boiler systems are more expensive than fuel oil boilers, but pellet fuel is less expensive than fuel oil.
- Solar PV, wind, and hydroelectric generators incur almost all of their lifetime costs at their time of installation, with no cost for the sun, wind, or water used to generate energy. Fossil fuel generators are relatively inexpensive to construct, but retain significant fuel costs throughout their operation.
- Electric vehicles are generally more expensive than an equivalent gasoline-powered vehicle, but have significantly lower cost per mile of operation.
- Transit vehicles and infrastructure have significant upfront capital cost, but reduce the cost of mobility for their riders as they have lower operating costs than the total costs of all the single-occupancy vehicles they displace.

Given this aspect of the clean energy transition, how can different actors use their leverage in a coordinated fashion to accelerate change and overcome time preferences biased toward the present?

Financial levers, generally wielded by the private financial sector, have a lead role to play in this circumstance because of the ability of financial tools to amortize high upfront costs over time. For cost-effective investments, lower operating costs combined with repayment over time can result in reduced overall recurring costs. This allows the customer to see immediate and ongoing benefit from making a clean energy investment. Where investments are not yet cost-effective, or where financial tools do not yet correctly reflect the risk profile of the investment, funding tools, generally wielded by or under the direction of government agencies, can step in to help bring down the cost of new technologies through market growth or to enable demonstrations that develop data to document risk.

Even with cash-flow-positive financial structures, however, energy consumers need access to good information and encouragement – shared by political and community leaders, educators, non-profit organizations, and businesses – to develop the confidence to proceed in a clean energy investment. State agencies and financial and other regulated firms may need to work together to develop new regulatory structures that encourage cost-effective clean energy investments, rather than present barriers. And technology and business model innovators can develop new technologies, and businesses to deploy them, lowering overall costs while improving quality of life.

Coordination in this context requires, for example, that as new technologies are developed, the private financial sector, technology innovators, and government funders coordinate to provide necessary but not excessive support while demonstrating technical and economic performance, lowering risk, and enabling lower financing costs. In a capital-intensive clean energy context, "green" jobs are likely to be more in installation, rather than operations.[5] This highlights the benefits of coordination between technology innovators, business model innovators, and educators, as well as political and community leaders who can spread the word about these opportunities. The pace of clean energy infrastructure investments shapes the size and scope of the clean energy industry.

4.3 Recognizing the role of the State vs. private sector and other governments

When developing policy sets for analysis, the Department considered the question of the correct role for state government *vis a vis* both other governments (federal and other states) and the private sector. Energy demand, supply, and distribution are shaped by Federal and state government policies but are fundamentally functions of the private sector. The Department's consideration includes an understanding of Vermont's role in the national and global energy sector and economy, and in the context of global climate change.

Vermont is a small state. Vermonters could eliminate our greenhouse gas emissions, or double them, with only marginal direct impact on the climate. Similarly, our actions have only marginal effect on the price of global energy commodities, appliances, vehicles, or infrastructure. At the same time, however, the global climate and the regional, national, and global energy markets have profound impacts in Vermont. In this context, it is in the state's interest to impact the decisions of others, whose collective actions can materially impact the global climate and energy sector. Vermont can demonstrate a successful path forward and inspire broader action by recognizing the imperative to act on climate change and by developing policies that work for Vermont and advance the state's energy, economic, and environmental goals.[6]

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[5] This shift is not absolute, of course. For example, a growth in transit will result in more transit operators; they are displacing the unpaid role of "single occupancy vehicle driver" that might otherwise have been played by each of their passengers.

[6] An example: Vermont was an early leader in electric energy efficiency. While our average and overall electricity consumption was already low relative to the rest of New England, our commitment to energy efficiency and success delivering programs paved the way for most of our neighboring states to embrace electric energy efficiency. Vermont's investment in energy efficiency is small (in absolute terms) relative to other states, but the

One tension that the Department identified in analyzing the state's role is the potential tension between policies that may be easily generalized and exportable, but perhaps not well suited to Vermont, and polices that are designed to reflect Vermont's uniqueness, but are necessarily less immediately exportable. Our conversations with stakeholders convinced the Department that the latter path is preferable. We should not accept sub-optimal policies for Vermont that risk incurring unnecessary costs in achieving other state goals, including robust economic progress, in order to make our policies more easily exportable. As a rural northeastern state, the technology pathways available to Vermont are not necessarily those available to many other states or nations, and we also face unique challenges. By demonstrating the success of correctly-designed policies, we will inspire others to design the policies that achieve comparable energy and climate impacts elsewhere. Aspects of our policy solutions may be adapted to other jurisdictions facing similar challenges or with similar opportunities, and Vermont should share what we have learned.

Regional collaborations, with both our neighboring states and Canadian provinces, can carry weight beyond what Vermont alone can do. The Regional Greenhouse Gas Initiative (RGGI), for example, is reducing the greenhouse gas emissions from the electric power sector across 9 states. This reduces the GHG emissions of Vermont's electricity portfolio through regulation of power plants in other states. Energy-related infrastructures (such as road, rail, pipeline, and electric grid networks) are commonly addressed at the regional level, so polices that directly impact these networks may particularly benefit from regional consistency. The northeast is also a large enough potential energy market to exercise some "demand pull" if the region's states collectively act to shape markets (such as encouraging the availability of new products such as electric vehicles). Vermont has also played a role as a bridge between New England and Quebec in the flow of energy, goods, and services.

As Vermont looks to lead on energy and greenhouse gas emissions, we must be cognizant of current and emerging regional markets, trends, and policy structures. In particular a Vermont decision to rely on more constrained renewable resources like biomass and hydroelectricity could interfere or interact with choices made by other states or provinces.

The Federal government can take a wide range of actions that are unavailable to Vermont, for example, because Vermont may be preempted from acting in areas of Federal jurisdiction, or more simply due to scale of potential investment. More specifically, Vermont may be too small to sustain large-scale state-funded research and development activities given the potential for the fruits of those investments to flow to other states; the federal government has less concern than any state might about such interstate benefit flows. Vermont may, however, identify technologies particularly well suited to Vermont needs and focus our efforts there (as we have done historically, for example, with anaerobic digesters). Due to preemption, Federal policy-making could (in theory) upend most any policy structures Vermont might establish; in practice state policy innovation has also provided examples that the Federal government can adopt.

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state benefits from reduced market prices, transmission needs, and emissions saved by other states. Another example has to do with RGGI. Vermont was the first state to Vermont was the first state to call for auctions of the allowances and to dedicate 100% of the auction proceeds to clean energy investments, which have had the effect of lowering demand for, and therefore the price of, the allowances.

Within the state government, different kinds of actors can be most effective with different roles. For example, regulatory programs are the natural purview of long-standing (and stable) agency bureaucracies due to the importance of consistency and subject matter expertise. Technical assistance and funding or finance programs benefit from being more nimble and responsive to market changes and contain the flexibility to develop public-private partnerships. Political leaders more closely reflect the concerns and hopes of their constituents, and serve to both reflect those opinions into policy-making and exercise political leadership by shaping public opinion. There is a feedback loop between state policy-setting, political acceptability, and changes in the public understanding of and opinions toward the clean energy transition.

State actions and policies can also send signals to the marketplace and to citizens regarding the importance or impacts of the clean energy transition. (These signals can be discouraging or encouraging.) For example, state support for installation of electric vehicle charging equipment (EVCE) could have the combined results of increased range confidence among drivers of electric vehicles, increased visibility of electric vehicles as an option, and identification of Vermont as a state on the leading edge of new technology. State operational "lead by example" initiatives have the potential to shape public understanding and opinions by demonstrating, through the operations of government itself, the benefits of a clean energy economy. Political leaders can also use their opportunity to be heard in order to "lead by example" on changes in opinion and culture. State policy leadership itself enhances the Vermont brand and sends a "welcome" signal to clean energy investment and entrepreneurs.

5 Trial policy sets

The Department developed the five integrated and comprehensive sets of potential energy and greenhouse gas policies described in this section in order to evaluate the strengths and weaknesses of each in meeting the State's energy and greenhouse gas goals. The first sub-section describes the baseline of state policies, principles, and tools that will be incorporated into all scenarios being modeled and analyzed. Each of the following subsections describes one set of potential policies identified for further analysis and consideration.

5.1 Common policies across all scenarios

As discussed in Section 3, there are numerous interactions between the course that Vermont takes toward its clean energy goals and state policies and objectives not directly associated with energy. For the purposes of its analysis, the Department has assumed that the non-energy policies, programs, and objectives are maintained to the degree possible while pursuing each of the five policy sets described in greater detail in the remainder of Section 5. Policy sets may include strengthening existing non-energy policies or objectives (for example, land-use policies directed at creating compact development patterns).

Turning to policies or programs directly related to energy, the Department assumes that the general energy policy of the state, embodied in 30 V.S.A. §202a, is maintained:

(1) To assure, to the greatest extent practicable, that Vermont can meet its energy service needs in a manner that is adequate, reliable, secure and sustainable; that assures affordability and encourages the state's economic vitality, the efficient use of energy resources and cost effective demand side management; and that is environmentally sound.

(2) To identify and evaluate on an ongoing basis, resources that will meet Vermont's energy service needs in accordance with the principles of least cost integrated planning; including efficiency, conservation and load management alternatives, wise use of renewable resources and environmentally sound energy supply.

The similarity between the principles contained in §202a and the policy evaluation criteria used in this report is intentional. Section 202a(2) provides grounding for the assumption that cost-effective efficiency, conservation, and load management are to be the first resources utilized, consistent with the principles of least cost integrated planning, under all evaluated scenarios.

Consistent with this policy, the Department assumed continued use of policy levers aimed at addressing market failures due to lack of information and lack of access to capital. In particular, this includes robust and consistent education and outreach regarding clean energy opportunities. Similarly, the state is assumed to have a continuing interest in development and promotion of financial tools that allow Vermonters access to capital to make cost-effective clean energy investments.

5.2 Total Renewable Energy and Efficiency Standard (TREES)[7]

The first policy set the Department identified for analysis requires all providers of energy in Vermont to meet a fraction of their sales with renewable energy or energy efficiency. (A version of this policy was first proposed in the 2011 Comprehensive Energy Plan, under the title of a "Total Energy Standard." The Legislative charge for this study requires consideration of this policy option.) The required clean energy fraction would be the same for all fuels, and would rise over time (for example, to 90% by 2050). Obligations would be met by "retiring" certificates corresponding to a certain amount of renewable energy or efficiency. These certificates could be traded commodities, called "TREE certificates" or "TREE credits." For example, a weatherization contractor could sell TREE credits for home weatherization to an electric utility, or a solar PV developer could sell credits for PV generation to a heating fuel distributor. This is the economy-wide equivalent of a renewable portfolio standard (RPS; a policy tool used in 30 states to regulate electric energy supplies), with incorporated energy efficiency. For the electric supply sector, TREE certificates would be essentially identical to Renewable Energy Certificates (RECs).

Practical implications and open questions in the design and implementation of this policy set include:

- At current, it is much more obvious how to achieve validated credits for some activities than others. For example, the verified savings from Efficiency Vermont or the Renewable Energy Credits generated by a small hydroelectric plant are well established. In contrast, at low levels of blending the biofuel content of heating oil is difficult to track, and there are no established

[7] The Department welcomes comments regarding alternate names for this policy structure.

protocols for measuring and verifying efficiency savings from efforts such as the development of a new transit service.

- Should credits be awarded for generation or savings in the year of obligation or awarded at the time of implementation for an expected project lifetime? Renewable energy credits generally use the latter formulation; “white certificates” in European energy efficiency obligation programs generally use the former. Would the policy work well with both of these kinds of credits?
- If energy efficiency measures are awarded lifetime credits, it could mean that the overall obligation could rise above 100% (e.g. achieved through 30% lifetime efficiency – saving 2% annually for 15 years – and 75% renewable supply). The Department observes that energy efficiency is relatively less expensive than renewable energy supply across most energy sectors, so achievable energy efficiency would generally be obtained first; by the later years when obligations are high, most achievable waste may have been captured.
- Trade, marketing, and advertising guidelines have been developed over the past decade or so that describe green claims, renewable energy claims, etc. (For example, if a utility owns the energy, but not the RECs, from a generator, they can’t claim to be providing renewable energy from that generator to their customers without running afoul of fraud guidelines.) In the TREES context, Vermont would need to develop ways to correctly characterize the attributes of delivered energy services that have been sold as a credit and retired to meet an energy provider’s obligation.
- The TREES could be designed with carve-outs or other sub-obligations to help meet other policy goals. For example, a requirement on electric utilities that some fraction of their credits correspond to small-scale generation distributed across the electric grid could support grid resilience and control transmission and distribution costs, while reducing line losses. There could also be limits on the amount of energy efficiency able to be used in meeting obligations in order to ensure a minimal amount of renewable energy.

One possible structure that would address the uncertainty regarding the creation of TREE credits for sectors and activities without well-established accounting mechanisms is as follows: Begin the TREES program with requirements placed only on suppliers of energy in some sectors or fuels. For example, the policy could begin with just the electric utilities and heating fuel (regulated and unregulated) sales to residential customers. These are sectors in which at least some renewable supply is well characterized and countable, via RECs in the case of electric supply and bioheat, biogas, and pellets in the case of residential heating. Similarly, learning from the regulated energy efficiency structure, there are established ways to quantify credits for energy efficiency in these sectors.

To expand the TREES beyond its initial participants and obligated parties, the first step would be to accept credits from other sectors or fuels. For example, credits earned through industrial process improvements that reduce the use of process fuels could be sold to an electric utility. This would encourage experimentation and the establishment of protocols for the creation of credits in these other sectors. In order to ensure continued progress in the covered sectors, the TREES could include limits on the number of credits from “uncovered” sectors that could be used. This is compatible with expanding obligations to other sectors over time. Knowing that obligations will come, firms will develop ways to earn and quantify TREE credits in those sectors; this in turn eases the expansion of the TREES into those and other sectors.

5.3 Carbon tax shift

The second policy set the Department identified for analysis creates an economy-wide carbon tax as one leg of a tax reform package that maintains or comes close to maintaining revenue neutrality for the State. The Department's modeling simulations will assume that such a carbon tax would have the effect of aligning price signals with the external costs of emissions. A similar policy has been adopted in British Columbia, where a carbon tax on fossil fuel combustion has been in place since 2008. British Columbia maintained revenue neutrality by reducing personal income and business taxes, and by providing property tax relief to "rural and northern homeowners." The tax was ramped up over four years to $30/metric ton. A 2012 evaluation resulted in the continuing of the policy.[8]

Practical implications and open questions in the design and implementation of this policy set include:

- Determining the correct amount for the tax, and updating it over time. The economically efficient price to assign is the price that equals the social cost of carbon emissions. However, there is no state, national, or global consensus on that value. Some potential values include the values used for Federal rulemaking (expressed as a range between $12 and $116 per metric ton, and rising over time[9]) and the value derived to estimate the cost of carbon abatement, used by some energy efficiency program administrators across New England, including Vermont ($100/short ton[10]). Once set, the value of the tax serves two purposes: maintaining state revenues (which would fall if the tax is successful at reducing emissions) and causing decision-makers in the state to make choices that result in lower emissions. There is no inherent guarantee that the correct value for the purposes of state revenue and the correct value for the purposes of hitting state GHG emission targets are the same value, and both may change over time.
- Tax reform may benefit from being phased in over time. For example, the tax could be ramped up at a rate of $10/ton per year until the final value is achieved.
- There is no guarantee that a price on carbon will encourage greater usage of renewable energy, as opposed to switching between fossil fuel sources or using nuclear-generated electricity.

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[8] "After a review last year, B.C. confirmed it will keep its revenue-neutral carbon tax, the current carbon tax rates and tax base will be maintained, and revenues will continue to be returned through tax reductions…The review covered all aspects of the carbon tax, including revenue neutrality, and considered the impact on the competitiveness of B.C. businesses such as those in the agriculture sector, and in particular, B.C.'s food producers." http://www.fin.gov.bc.ca/tbs/tp/climate/carbon_tax.htm accessed November 19, 2013.

[9] http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

[10] See chapter 4 of http://publicservice.vermont.gov/sites/psd/files/Topics/Energy_Efficiency/AESC%20Report%20-%20With%20Appendices%20Attached.pdf

Supplementary policies may be necessary to encourage enough use of renewable energy to achieve the 90% renewable energy goal and simultaneously cut emissions[11].

- What reduction in other taxes or fees is necessary and appropriate in order to remain revenue neutral? Adoption of a carbon tax of this sort invites a larger discussion about tax reform and provides an opportunity to better align costs with prices throughout the economy. It may be appropriate to reduce other taxes on the same fuels that are charged a carbon tax in order to mitigate net price effects and maintain equity among fuels on a carbon basis. Fuels for which there is already a small carbon payment (such as electricity via the RGGI cap and trade system), could have a reduced payment to avoid double-payment. The energy efficiency utilities (EEUs) exist to meet the obligation of the state's regulated energy providers to provide least cost service, so this policy would not immediately impact these programs, nor would the tax revenue obviate the energy efficiency charge levied to pay for these programs.
- Where are the most appropriate and implementable points to measure greenhouse gas emissions? Measuring fuel use at the point of import into Vermont may be the most straightforward to implement. (There are relatively few energy importers, so relatively few taxpayers, compared with energy consumers.) However, measuring at the state line neglects upstream emissions from fuel refining, drilling, extraction, transportation, etc. Electric utilities can track their emissions through the NEPOOL Generator Information System, which allows the calculation of emissions due to electric generation at facilities throughout New England, but again this does not include upstream emissions. Life-cycle emissions for biomass (woody biomass in particular) also depend on harvesting and replanting rates.

One concern raised by this policy set is that simply setting the "correct" price is unlikely to be sufficient to cause the necessary change in behavior, given other market failures. Therefore, it may be necessary to develop complementary programs, which will have associated costs, in order for the revenue neutral carbon tax to work effectively. These programs would change over time, but would likely include purchase incentives, financing tools including credit enhancements, technical assistance programs, and programs designed to mitigate the impacts of increased energy costs on low- and middle-income Vermonters. There are two primary options for revenue to support such programs. The first is to make the carbon tax not quite revenue neutral – that is, to offset the carbon tax by reduction in other taxes and fees that do not quite cancel the net revenue impact, thereby generating net revenue. The second is to capture some or all of the increase in state revenue that could come with increased economic activity associated with a more economically efficient tax structure. The former of these is more certain and is available immediately; the latter avoids increases in overall tax rates but is uncertain and takes time to develop.

A second concern to be addressed is the tax's impact on energy-intensive commercial and industrial activity. During a period in which Vermont levies a carbon price but other jurisdictions do not, Vermont firms may be at a disadvantage. The extent of this disadvantage depends on the taxes cut to balance the

[11] A recent report from the International Energy Agency, available at http://www.iea.org/publications/insights/insightpublications/name,43825,en.html, describes a framework for analyzing the interaction between carbon pricing and energy policies.

carbon tax, however particularly emission-intense firms are likely to see a net tax increase. One option to address this concern, developed based on stakeholder input, would be to exempt firms from the carbon tax if they make particular progress to increase their productivity per unit of emissions. Increases in productivity that would redound to Vermont's benefit could be measured in units such as the firm's payroll or state tax burden. So, for example, a firm could be exempted from all or part of the carbon tax if its payroll per ton of emissions increases at a certain rate, evaluated on an annual basis. Designing this tax incentive program would require a careful balance between state goals regarding economic development and state greenhouse gas reduction goals.

5.4 Renewable targets with carbon revenue

The third policy set the Department identified for analysis combines aspects of the previous two policy sets, while taking a somewhat different approach: In this policy set, the state would set a target for the renewable energy content of all fuels, placing a non-binding obligation on energy suppliers. If the target were not met within a given sector, however, the obligation would become mandatory within that sector. This obligation structure would be paired with a small economy-wide carbon tax, used to raise revenue applied to programs directed at making it easier for obligated parties to meet their target obligations. As an alternative to making the obligations mandatory in the case of failure to meet renewable energy targets, the carbon tax could be increased in such sectors.

Revenue raised with the carbon tax would be paired with regulatory reform to increase the pace of business model innovation throughout the clean energy economy. For example, funds or regulatory changes could be used to increase the pace of adoption of electric vehicles or alternative modes of transportation; adapt regulated utility business models to allow or incent them to make investments or utilize financing tools to make adoption of efficiency or renewable energy easier; or establish funding or financing programs that support fuel dealers expanding their business into becoming energy service providers, more broadly defined.

Practical implications and open questions in the design and implementation of this policy set include:

- How to structure the voluntary targets and trigger mechanism to provide the right amount of incentive to market actors while also achieving the state greenhouse gas and renewable energy goals.
- Voluntary carve-outs could be established with or across sectors, similar to the TREES structure. Whether failure to meet a carve-out target would force the trigger provisions is an open question.
- Allocation of limited carbon tax revenue to the correct programs to best address market challenges would require a flexible and informed priority-setting process that also respects the value of program stability and predictability.
- In the event that the targets are not met, many of the questions or implications of the TREES policy set could apply in the relevant sector.

5.5 Sector-specific policies

The fourth policy set the Department identified for analysis consists of sector-specific policies, each tailored to address a known challenge or market failure within a given portion of the state's energy economy. The policies within this set could work in an integrated and comprehensive manner to drive the clean energy transition, but there would be no single, overarching policy structure as in the previous three policy sets. This reflects the opinion, expressed by some stakeholders, that each sector is unique and may best be addressed by tailored policies. These policies might also be identified as complements to the three policy sets described above to address market failures not addressed by those overarching policy structures.

The set of polices the Department selected for analysis includes:

- Electric supply governed by a Renewable Portfolio Standard (or potentially by renewable energy planning targets of the sort currently established in 30 V.S.A. §8005).
- Continue energy efficiency utility structure for currently regulated fuels.
- Innovation in regulated utility revenue and rate making models to allow and incent utilities to invest in promotion of fuel switching, distributed generation, and development of financing tools.
- Establish energy efficiency obligations on all heating fuel suppliers, for which dealers could procure efficiency (in a manner similar to the TREES discussed above) or pay an alternative compliance payment. The compliance payment would be used to fund thermal efficiency programs. An open question is whether demonstrated use of renewable fuels could be used as a method of compliance (in which case this is a clean energy obligation, rather than an energy efficiency obligation).
- Transportation funding based on vehicle miles travelled (VMT) and vehicle weight, with increased funding support for modes other than single-occupancy motor vehicles in the light-duty market and other than trucks in the heavy-duty market. This funding mechanism preserves an incentive to drive less even in the face of the reduced marginal cost of driving that comes from the adoption of more efficient and electric vehicles. A "utility" model of transportation infrastructure funding, in which per-mile rates are set to meet known revenue requirements, could be deployed here.
- Shape the vehicle purchase decision through use of a "feebate" purchase and use tax structure that requires payment of more tax on less efficient vehicles; and serves as a rebate for purchase of more fuel efficient vehicles Alternatively, or in addition, adjust the gasoline and diesel tax structure to lower the relative price of liquid biofuels for transportation, compared with fossil fuels.
- Strengthen land use policy to drive growth in designated areas and restrict it elsewhere.

Practical implications and open questions in the design and implementation of this policy set include:

- Is the Vermont market of unregulated fuel dealers large and sophisticated enough to support the regulatory infrastructure surrounding energy efficiency obligations? If all firms would choose to pay the alternative compliance payment, it may be more straightforward to raise funds via an excise tax and directly fund independent efficiency programs.

- The Framing Report (pages 71-72) identifies a number of questions regarding the design of a renewable portfolio standard; each would need to be answered before such a policy was adopted.
- One additional idea raised by stakeholders was to cover only portions of the electric utility sales with an RPS (such as requiring that the electricity used for transportation be 100% renewable, or requiring only sales to particular end-use classes to meet the renewable percentage requirements). The benefits (price stability) and costs (potential increased energy costs) should flow through to the affected sectors.
- VMT-based transportation funding may be better adopted at a regional or national level than in a Vermont-only context, due to the large number of Vermonters who drive in other states (and pay those state's gas taxes), and the large number of out-of-state cars and trucks on Vermont roads.

5.6 New England regional focus

The fifth policy set the Department identified for analysis takes as its starting point the notion that policies adopted at the regional level or coordinated with our neighboring states may be more effective than policies adopted by a single state. It also reflects understanding that the six New England states are served by an electric grid with a single regional operator and markets, and that biomass is commonly used in a state different from the state in which it is harvested. There is also a potential that the combined market power of New England or Northeast states (and potentially including neighboring Canadian provinces) can move markets and bring new technologies to scale, in a way that no single state can do. Common policies across state lines would also level the playing field for many firms that compete in the regional market.

The set of polices the Department selected for analysis in this set includes:

- An electric supply renewable portfolio standard designed to match and pace with the rest of the region. Establish common regional definitions for eligibility of different kinds of renewable resources, including biomass.
- States have common and synchronous adoption of VMT-based transportation funding that encourages more efficient vehicle purchase and raises revenues for alternative modes.
- Establish and maintain synchronized regional standards for liquid biofuels/bioheat, as well as common programmatic promotion of pellets and/or heat pumps.
- Establish regional biomass harvesting and procurement standards, as well as pellet standards.
- Each state continues adoption of the California low-motor vehicle emission standards.
- Common vehicle purchase incentive structures, such as for electric light duty vehicles or natural gas heavy duty fleet vehicles.
- Establish a regional low carbon fuels standard, requiring increased availability and utilization of advanced biofuels, natural gas, and electricity for transportation.

- Plan and coordinate regional infrastructure for EVs (such as travel corridors and shared payment methods like EZ Pass), as well as for rail service and freight movement.
- Programmatic funding from a common regional tax or fee structure, such as through expansion of the Regional Greenhouse Gas Initiative (RGGI) to cover fossil fuel use outside of the electricity sector, and the associated revenue.

Practical implications and open questions in the design and implementation of this policy set include:

- How to establish and maintain a common regional framework and emission/renewable energy goals across multiple sectors in the face of political pressures that may vary over time and between states.
- Whether the policies adopted region-wide would be sufficient to reduce Vermont's emissions, and increase the use of renewable energy in Vermont, at the pace necessary to meet the State's goals.

6 Technology pathways

Technologies deployed as the state achieves its greenhouse gas and renewable energy goals can be broadly described as falling into demand-side and supply-side technologies. The electric grid serves as an intermediary between demand and supply and has its own potential for technological innovations; it is incorporated into both the demand and supply discussions below. This section describes the understanding of many of these technologies that the Department has constructed during the Total Energy Study process. It concludes with a short discussion of the analysis the Department is conducting to understand the breadth of the range of energy options (particularly energy supply options) available to the state that also allow the state to meet its targets.

The 2011 Comprehensive Energy Plan describes the context and opportunities in energy demand and supply in much greater depth than is included here. The reader is asked to refer back to that plan; this report tells only a small portion of the story, and focuses on new insights gleaned during this study process.

6.1 Energy demand

Reducing the state's total energy demand will be an essential component of all technology pathways that achieve the State's greenhouse gas and renewable energy goals. The Department assumes that Vermont will maintain its commitment, established in 30 V.S.A. §202a(2), to the principles of least-cost integrated planning, applied across the energy sector. Pursing least cost service requires ambitious and extensive efforts on reducing and controlling energy demand, as well as in capturing the potential to meet needs with new modes or fuels.

6.1.1 Efficiency & conservation

Energy efficiency is defined as actions taken to reduce the energy used to deliver a set amount of energy service. For example, an LED light bulb delivers the same service (light) at a fraction of the energy demand of an incandescent bulb. Energy conservation, on the other hand, denotes reductions in energy use that are related to reductions in the energy service provided. For example, turning down the thermostat in the winter saves energy but also reduces the service provided (in this case, comfort). Assigning any given action to be either 100% efficiency or 100% conservation, however, is often not possible. For example, using a bus to get to work instead of a personal vehicle uses less energy, but may also provide less service (in that the trip cannot be undertaken at the exact time of the rider's choosing, and may take a different amount of time). Reconceiving energy services can result in even greater savings – teleworking, for example, might eliminate the need for the trip to work at all.

The preliminary quantitative analysis conducted by the Department has shown that reducing the total amount energy consumed in Vermont (or in electric generators serving Vermont) will be key to achieving the State's goals. The more complete to be completed in the spring of 2014 will likely confirm this, and is expected to reveal a need to reduce the state's total energy use by factor of two or more by 2050. This would imply a dramatic increase in the energy productivity of the state's economy.

In this context, there is great potential to deploy a range of "technologies," very broadly defined, that can reduce energy use while maintaining or increasing quality of life. These technologies include those mentioned above, and also:

- Compact development of towns and growth centers
- Infrastructure for alternative transportation modes, including transit, walking, and biking
- Building weatherization, especially air sealing and insulation
- Development or adoption of new industrial processes that produce the same or increased output for a given amount of energy input

This list is by no means exhaustive; its intention is to incorporate disparate deployment decisions into the rubric of energy efficiency and conservation, so they contribute to the development of comprehensive and integrated solutions.

6.1.2 Load shifting and demand response

Energy flow and consumption depends on a number of shared infrastructures, including the electric grid, fuel pipelines, road and rail transportation networks, and many of the state's buildings themselves. Increasing the productivity of energy use can be accomplished in part by using these shared infrastructures more effectively and completely. Greater integration of data and information technology into the management and use of these infrastructures is a promising tool to create this increase in productivity, when accompanied by the technologies that allow utilization of data and control systems.

Grid modernization (the so-called "smart grid") provides a key example of the potential of this approach. The electric grid is designed to be able to provide a peak level of service for only a few hours per year, at times of greatest load. By better understanding the flows of energy on the grid, and then shifting and shaping those flows (even without using less energy), we can: put more energy through existing wires and transformers; avoid the need to pay for upgrades to the grid; and better integrate variable electric generators into the grid. Better control over electricity use will allow such use to be more elastic, in the economic sense – better able to respond to price signals. This, in turn, makes price signals (like those discussed in the context of market failures) more effective at shaping market decisions and driving societally-beneficial outcomes.

Regulatory flexibility and innovation will be necessary to harnessing and appropriately shaping these technological developments. Privacy concerns regarding energy use data and security concerns regarding control systems will need to be carefully and completely addressed. Where shared infrastructures result in rate-regulated monopolies, rate design will be a primary tool.

This same model of harnessing information technology could be expanded to the use of other shared infrastructure, or enable the sharing of current unshared infrastructure. This extends from telework enabling each of several firms to use the same physical office space, to car sharing networks, and pop-up stores.

6.1.3 Fuel and mode switching

One way to reduce energy use overall is to find new ways, potentially using different fuels, to provide similar energy services. These switches may not provide the same service, and so they are prime examples of the kind of actions that are neither perfectly described as efficiency or as conservation (such as the bus ridership discussed previously). The most common examples are:

- Use of alternative modes of transportation,
- Switching fuels for vehicles (e.g. to biofuels or electricity), and
- Switching fuels for heat (e.g. to electric heat pumps or wood pellets).

Transitions between modes and between fuels have historically been driven by changes in technology, by market prices, and by public policy. These three forces will also shape how these transitions are adopted to help Vermont meet its goals. Public policy innovation and flexibility will be required to adapt existing structures, including regulatory and tax structures, to new modes or fuels. Each of these transitions involves a broad array of interests. Transportation, in particular, involves an array of interests that have not historically been at the table regarding energy use. In contrast to the structure of the 2011 Comprehensive Energy Plan, in the future it will not make sense to think of “electric,” “thermal,” and “transportation” as three distinct fields.

The fuel transitions garnering the most attention in Vermont now are driven by advances in technology: cold-climate air-to-air heat pumps and electric vehicles. These technologies have the potential to dramatically lower the energy required to heat Vermont homes and move Vermonters around the state. Both are new technologies, rapidly evolving, and causing disruption in the marketplace. They offer the potential for dramatic reductions in the cost of heat and transportation without changes in the cost of the underlying fuel. If these two technologies are adopted at scale (tens to thousands to hundreds of thousands of units in the state), they will have impacts on the way the grid is operated and built. We do, however, have time to study and examine these technologies as their performance is proven and they are adopted at greater scale before they have large impacts on the grid (or, in the case of electric vehicles, on transportation funding). If either or both of these technologies deliver on their promise, Vermont will see a significant economic benefit due to reductions in expenditures on fuel, and environmental benefit due to the displacement of fossil fuel combustion with electricity (provided the electricity is supplied by predominantly renewable sources). At this time, public policy should be aware and supportive of these technologies, given their potential, however the extent of their current and potential impacts needs to be better understood. The example of these technologies is one of the reasons that the Department selected responsiveness to technology change as one of the criteria for policy evaluation.

The Department examined the extent of overall increased electric use if heat pumps and electric vehicles were adopted universally between now and 2050, and the resulting impacts on infrastructure. The approximate range of gross electric use increases in the context of these new end uses is between 20% and 50%. That is, the state is unlikely to use more than 50% more electricity in 2050 than we do today; a more likely figure would be an increase of 30%, even if the state's path forward skews heavily in the direction of electrification rather than utilization of biomass-derived fuels. The extent of increased electric use relative to current totals depends on several factors: the extent of electric efficiency implemented in other currently-electric end-uses; the extent of weatherization applied to buildings at the time of or following installation of heat pumps; and whether the low marginal cost of driving electric or other highly efficient vehicles hampers efforts to reduce VMT.

Given the state's current load shape and grid capacity utilization, and assuming that demand does not become elastic enough to entirely flatten the state's load profile, this would result in some moderate increase in the state's peak electric demand. It is likely, however, that the peak would increase by significantly less than the energy increase (that is, significantly less than 30%). That is because electric vehicles are likely to be a relatively elastic demand, predominantly charged late at night. It may mean, however, that Vermont returns to being a winter-peaking state, with heating load coinciding with the current winter peak. The same infrastructure can support a higher winter peak than summer (due to thermal load constraints), but it is likely that mass deployment of these two technologies would result in need for some new grid infrastructure -- not for a dramatic overhaul of the grid. Given the multi-decadal nature of this shift, careful planning could control this cost.

One additional kind of fuel or mode switch for discussion is the use of combined heat and power (CHP). (This technology also serves as a bridge between demand and supply.) In this case, what would have been a waste product (excess heat) is captured and utilized, increasing overall energy efficiency. In heat-led CHP, electricity is a by-product generated using the excess high-quality heat from a process that uses most of the energy as heat. In electric-led CHP, the waste heat from an electric generator is captured and utilized. Heat-led CHP is significantly more efficient than electric-led CHP, but it is harder to find 12-month-per-year heat-led applications in Vermont.

Combined heat and power could be implemented in concert with district heating systems, although the seasonality of building heat requirements may make the integration of electric generation impractical or uneconomic. Even without electric generation, however, district heat is another kind of mode switch for energy use. Rather than have each building in a downtown or campus provide its own heat, a centralized facility, taking advantage of economies of scale, can provide heat for the district. Biomass and biogas heat, which benefit from scale and centralized fuel handling, are particularly amenable to this mode/fuel switch.

6.2 Energy supply

Vermont's aspires to meet 90% of its energy demand in 2050 using renewable resources. This section addresses the potential sources of that energy, and includes some discussion of the likely composition of the 10% of energy use that is not renewable (and the 25% of 1990-level greenhouse gas emissions remaining).

The five renewable primary resources available to Vermont are solar, wind, hydropower, methane capture, and biomass. Each of these can be used to generate electricity; solar is also used for heat and light, while biomass and methane capture are also used to produce fuels for heat and/or transportation. These fuels are discussed in great detail in the 2011 Comprehensive Energy Plan.

Vermont's biomass resource is extensive, but also limited. Sustainably harvested low-grade wood for energy use has the potential to both improve the quality of the state's forests (thus increasing the forest resource for non-energy applications), and improve the economy. There is also significant, but less well understood, potential to harness the state's agricultural resources for energy crops (such as perennial grasses) or use agricultural wastes (such as manure) on a more extensive scale for both electricity and heat. Food and other organic wastes could also have energy implications in the context of Act 148's coming restrictions on organic materials in landfills.

When considering combustion of biological fuels in particular (but also fossil fuels), the efficiency of combustion and utilization is a key consideration. Greater efficiency is essential to make limited resources stretch to meet the state's needs (in the case of biomass); for fossil fuels greater efficiency minimizes the greenhouse gas emissions per unit of energy service delivered. Different types of application have different efficiency, and the state should prioritize use of combustible fuels in this order: heat-led combined heat and power (CHP); heating only; transportation; electricity-led CHP; and electricity only.

In considering future electric supply portfolios, in the context of meeting most of the state's non-electric energy use with biologically derived resources, the Department examined the question of the scale of resources appropriate to meet the need. Future electric portfolios will depend on extensive build-out of one or more types of resources, including likely increases in each of the kinds of renewable electric generation that currently serve Vermont. Given Vermont's resources, accessing necessary resources will require either import (especially if the state were to pursue extensive hydroelectric power) or the construction of some generation resources at what is commonly referred to as "utility scale" (generation in the tens of MW or larger per facility).

When Vermont achieves its goal of 90% renewable energy across all sectors, it will still get 10% of its energy from fossil fuel and/or nuclear sources. Stakeholders have assisted the Department in identifying areas for which renewable resources are more difficult to integrate. These are the most likely areas to draw upon this remaining portion.

- Natural gas or oil electric generators needed to maintain grid balance and stability on a moment-by-moment basis (as discussed above). The extent to which these generators are necessary depends on the extent to which biomass or hydroelectric resources can be controlled in a similar fashion, the availability of electric energy storage technologies, and the elasticity of electric demand.

- Heavy-duty transportation and machinery require energy densities beyond that available with existing battery energy storage technologies. Primary options beyond fossil diesel fuel are biodiesel and natural gas. Vermont does not have the market pull to direct this market toward one or the other of these options; at the moment it appears there is significant market interest in natural gas for long-distance trucking; natural gas is already in use by several heavy-duty fleets in Vermont.
- Liquid and solid biofuels require some amount of energy to produce. Some of this energy is likely to be fossil fuel energy, particularly for liquid fuels imported to Vermont from states that lag behind Vermont's renewable energy mix.
- Industrial process uses of natural gas (and other specialized fuels) can be substituted to some extent by biogas or renewable natural gas, but supply of such alternatives is unlikely to meet demand. The desire to maintain competitiveness in the state's manufacturing sector will likely drive expansion of natural gas accessibility (via pipeline or truck). Even if competing jurisdictions share Vermont's greenhouse gas and renewable energy trajectory, supply limitations of alternatives that can meet the demands of some industrial processes will restrict the sector's ability to meet 90% of its energy needs with renewable sources.

6.3 Variation among possible paths forward

Vermont's greenhouse gas and renewable energy targets are aggressive. Concerted effort will be required across all sectors in order to achieve them. It remains an open question, however, the breadth of the range of technology deployment pathways that remain available for Vermont to choose at reasonable cost. Reductions in energy demand will be essential to achieving the State's goals, and greater energy demand reductions will increase the flexibility to choose different energy supply options. Two primary axes of variation among energy supply pathways emerged in our research and stakeholder conversations:

1) Scale: small scale/local/distributed versus larger/perhaps out-of-state
2) Fuel mix: Electrification versus the direct use of biomass. Of the four primary sources of renewable energy (wind, water, sun, and biomass), only biomass can be used directly for heating and transportation. All can generate electricity.[12]

As part of its analysis, the Department will explore four technology pathways that span the two dimensions (scale and fuel mix) discussed above. Each pathway selects one answer to each of the two questions inherent in the two dimensions: 1) More local/small scale or more large/potentially imported? 2) More direct use of biomass, or more electrification? By evaluating both the costs and benefits of

[12] The question of biomass versus electrification also has feedback implications for the state's energy demand because electrical end-use technologies (particularly heat pumps and electric vehicles) can be much more efficient than their combustion-based alternatives. Overall energy demand implications also depend on how the electricity is generated.

these four pathways, the Department hopes to learn the size and scope of the remaining options facing Vermont that can be achieved with acceptable costs and benefits.

The technology pathway the state follows, with likely variation in the distribution along both of these axes over time, will have a significant impact on both the state's net cost of infrastructure and fuel and the economic benefits that flow to the state as a result of capital flows into and out of the state. For example, smaller-scale electric generators are likely to be more expensive than larger (due to the lack of economies of scale), and are also more likely to be in Vermont as opposed to out. Solid biomass is likely to be sourced in Vermont or close by, while liquid biomass (unless produced from in-state agricultural products) is more likely to come from out of state. The interaction of these two effects, in the context of increased efficiency reducing capital outflows for the purchase of fossil fuel, will shape the net economic benefit accruing to the state as a result of the clean energy transition. The Department's further analysis seeks to identify optimal pathways, recognizing that the definition of "optimal" may vary according to different perspectives, in terms of both total cost and benefit and net economic impact on the state.

7 Next steps

This report serves as a snapshot of the status and interim results of an ongoing research and analysis project, which will be completed in the summer of 2014. As such, it raises questions for which it does not provide answers. The Department will continue to work with its sister Agencies and Departments, as well as with the public, legislators, and other stakeholders, to expand and refine analysis of policies and technologies Vermont might pursue in service of greenhouse gas emissions reduction and increased use of renewable energy.

The Department welcomes comments on this report, or the TES process in general, through January 22, 2014. Comments may be submitted electronically to PSD.TotalEnergy@state.vt.us.

The Department plans to release the results of additional analysis during 2014, with additional opportunities for comment and public engagement. A Total Energy Study Final Report will be issued in the summer of 2014. Please refer to the Total Energy Study webpage throughout the spring for updates.