Potential for Unregulated Fuel Efficiency Savings in Vermont

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Prepared for

VERMONT
DEPARTMENT OF PUBLIC SERVICE

by

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INTRODUCTION

BACKGROUND AND PURPOSE OF STUDY

The Vermont Public Service Department ("Department" or "PSD") commissioned this study to evaluate the potential for unregulated thermal process fuel efficiency programs in Vermont. Led by Optimal Energy, Inc. with assistance from Grasteu Associates, Inc., this study provides estimates of the economic and achievable potential efficiency savings available to Vermont. By "potential" we mean the potential for increased adoption of energy efficient technologies above and beyond that which would naturally occur in the absence of funded programs to promote their adoption. This report presents our findings for the unregulated fuels portion of the analysis, which was done over a 10-year study period from 2015-2024.

10 V.S.A §581 set comprehensive building efficiency goals for the state. As a state heavily dependent on fuel oil and propane for its heating and process needs, these goals recognized the significant opportunity for Vermonters to save on their heating costs. However, there is currently only limited funding (revenues from the Regional Greenhouse Gas Initiative, revenues from electric efficiency participation in the Forward Capacity Market, and Low-income Weatherization funding for low-income customers from a State Gross Receipts Tax) available for thermal, unregulated efficiency programs in the state. These programs are operated by Vermont's Energy Efficiency Utilities and the Office for Economic Opportunity.

STUDY SCOPE AND APPROACH

This section provides a brief overview of the study scope and approach, with more detail provided in the Methodology section below. The study included the following key components:

- Two 10-year efficiency potential scenarios for the period 2015-2024: economic potential and achievable potential
- The economic efficiency potential includes all efficiency potential that is cost-effective, assuming no or limited market barriers[1]
- The achievable efficiency potential includes the likely amount of efficiency in response to specified levels of program support in the form of financial incentives, marketing and education, and technical support. This scenario considers real-world market barriers that often prevent people from adopting all cost-effective efficiency
- The scenarios are analyzed at the sector level, with residential standing alone and commercial and industrial combined together[2]

[1] Over time, economic potential could grow as measures that are not currently cost-effective become cost-effective due to increasing energy prices and avoided costs as well as advances in technology. Market barriers to adoption of cost-effective efficiency include the initial cost, lack or disbelief of information, perceived risk, hassle factor, etc.

- Petroleum fuels include distillate (#2 and #4), residual (#6) fuel oil, propane, and kerosene. The fuels are aggregated (their sales forecasts and prices), rather than being analyzed individually.
- Biomass includes cord wood and wood pellets.

The focus of this report is the potential for unregulated thermal process fuel savings. This potential includes the likely amount of efficiency in response to specified levels of program support in the form of financial incentives, marketing and education, and technical support as well as consideration of real-world market barriers that often prevent people from adopting all cost-effective efficiency. Overall, the generic efficiency programs used for the study (described in the Methodology section) are all cost-effective from both a Societal Cost Test (SCT) and Utility Cost Test (UCT) perspective. The estimate also considers the distribution of savings over time, allowing for gradual increases in potential as programs and supporting infrastructure build capacity to support efficiency investments in the market.

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[2] The multifamily (MF) sector was not separately assessed. According to the U.S. Census Bureau's American Community Survey, 10% of Vermont dwelling units are MF, and we assumed these account for less than 10% of residential building energy. Some MF shared systems may appear under the commercial sales forecast, in which case their efficiency potential is captured under the commercial sector.

METHODOLOGY

OVERVIEW

This section provides a brief overview of our approach to the study analysis. The subsequent sections provide more detailed descriptions of the analysis methodology and assumptions.

The energy efficiency potential analysis involves several steps. The first several are required regardless of the scenario being analyzed. These steps include:

- Estimate the unregulated fuel sales (or usage) forecast, including only the energy available for building efficiency opportunities, and which reflects expected sales assuming no efficiency programs are operating in the future. This forecast becomes the basis for assessing the efficiency potential.
- Disaggregate the adjusted energy forecast by sector (residential, commercial, industrial), by market segment (e.g., building types), and end uses (e.g., space heating, water heating, etc.)
- Characterize efficiency measures, including estimating costs, savings, lifetimes, and share of end-use level usage from the adjusted sales forecast for each market segment

To develop each scenario (i.e., economic and achievable potential) requires additional steps specific to the assumptions in each scenario. These steps include:

- Build up savings by measure/segment based on measure characterizations calibrated to total energy usage
- Account for interactions between measures, including savings adjustments based on other measures as well as ranking and allocating measures when more than one measure can apply to a particular situation
- Run the stock adjustment model to track existing stock and new equipment purchases to capture the eligible market for each measure in each year[3]
- Run the efficiency potential model to estimate the total potential for each measure/segment/market combination to produce potential results
- Screen each measure/segment/market combination for cost-effectiveness. Remove failing measures from the analysis and rerun the model to re-adjust for measure interactions

The annual energy sales forecast was derived from the Vermont Total Energy Study (2014)[4] for each sector for the 10-year study period. The sales forecast was then disaggregated by end use and building type in order to apply each efficiency measure to the appropriate segment of

[3] Energy from expired measures is returned to the stock available for energy efficiency programs, allowing for measures to be reinstalled and incur additional incentive payments

[4] See http://publicservice.vermont.gov/publications/total_energy_study

energy use. This study applied a top-down analysis of efficiency potential relative to the energy sales disaggregation for each sector, merged with a bottom-up measure level analysis of costs and savings for each applicable technology.

The efficiency potential estimate includes savings from a wide range of efficiency measures (i.e., efficient technologies and practices). The study analyzed both technologies that are commercially available now and emerging technologies considered likely to become commercially available over the study horizon.

The study applied a Societal Cost Test (SCT) to determine measure cost-effectiveness. As described below, the SCT considers the costs and benefits of efficiency measures from the perspective of society as a whole. Efficiency measure costs for market-driven measures represent the incremental cost from a standard baseline (non-efficient) piece of equipment or practice to the high efficiency measure. For retrofit markets the full cost of equipment and labor was used because the base case assumes no action on the part of the building owner. Measure benefits are driven primarily by energy savings over the measure lifetime, but also include other benefits associated with the measures, including water savings, and operation and maintenance savings. The energy impacts may include multiple fuels and end uses. For example, efficient pre-rinse spray values reduce water consumption in addition to water heating energy use. All of these impacts are accounted for in the estimation of the measure's costs and benefits over its lifetime.

The primary scenario for the study was the achievable potential, which more closely reflects what could actually be accomplished by efficiency programs given real-world constraints. We have also estimated the economic potential. The general approach for these scenarios differed as follows:

- **Economic potential scenario:** We generally assumed that all cost-effective measures would be immediately installed for market-driven measures such as for new construction, major renovation, and natural replacement ("replace on failure")[5]For retrofit measures we generally assumed that resource constraints (primarily contractor availability) would limit the rate at which retrofit measures could be installed, but that all efficiency retrofit opportunities would be realized over the 10-year study period. Spreading out the retrofit opportunities, rather than assuming they could all be done in the first year, results in a more realistic scenario, providing a better basis for the achievable scenarios. Because all retrofit opportunities are captured over the 10-year study period, different assumptions regarding the rate at which retrofit opportunities are captured would change the cost and benefit outcomes, but would not significantly change the total energy savings potential over the study period.

[5] Assumptions for fuel switching measures were made separately. See the description of fuel switching measures in the Methodology section of the report for additional information.

- **Achievable potential scenario:** This scenario is based on the economic potential but accounts for real-world market barriers. We assumed that efficiency programs would provide incentives to cover, on average, 50% of the incremental costs of efficiency measures. This level of incentives is considered adequate to provide aggressive, sustained funding and market interventions. Measure penetration rates were then estimated assuming best practice program delivery, recognizing that market barriers remain even after program incentives and supporting activities.

UNREGULATED FUELS SALES FORECAST

The unregulated fuels forecast was developed using forecasts from the Vermont Total Energy Study (2014).[6] The petroleum fuels forecast is based upon heating oil (distillate and industrial diesel) and propane. The biomass forecast uses the combined total for cord wood and pellets.

The commercial and industrial sales forecasts were taken directly from the Vermont 2014 Total Energy Study. The Total Energy Study's residential forecast, however, was considered to be overly optimistic regarding increased usage of natural gas and corresponding decreased usage in other thermal fuels over the 10-year study period. We therefore revised the residential forecast based on the current natural gas sales forecast provided by Vermont Gas Systems, Energy Information Agency data[7], and the Vermont Residential Fuel Use Assessment for 2007-2008.[8]

No adjustments were made to add or remove ineligible customers or consumption that would not be serviceable by efficiency programs. It was assumed that existing efficiency programs were small enough in scope as to not necessitate an adjustment to remove their savings.

Appendix B provides the fuel sales forecast by sector and year.

FORECAST DISAGGREGATION BY SEGMENT AND END USE

The sector-level sales disaggregations draw upon several sources. The residential building type and end use disaggregation was developed using data from the EIA 2009 Residential Energy Consumption Survey (RECS),[9] and the most recent American Community Survey from

[6] See http://publicservice.vermont.gov/publications/total_energy_study

[7] U.S. Energy Information Administration, Table CT4, Residential Sector Energy Consumption Estimates 1960-2012, Vermont (all end uses).

[8] Frederick, Paul, VT Dept. of Forests, Parks and Recreation. Aug 2011. *Vermont Residential Fuel Assessment for the 2007-08 Heating Season*.

[9] U.S. Energy Information Administration, Residential Energy Consumption Survey, "Table CE4.4 Household Site End-Use Consumption by Fuel in the South Region, Totals, 2009," August 2011

the U.S. Census Bureau.[10] Low income usage was segmented based on Vermont Gas Systems' guidelines for low income being below 185% of the poverty line, with per household income estimated from the RECS data for the New England census region[11].

For the commercial sector, Vermont-specific data on fuel usage by building type were not available. As a result, the analysis started with the disaggregation of total forecasted energy sales across building types and end uses using data recently developed by Optimal Energy for upstate New York.[12] That analysis began with the disaggregated electric load by building type. Based on average existing building energy intensities per square foot by building type for electricity and fuel, the analysis estimated the fuel consumption by building type. The estimates of energy intensity by building type were derived from 2002 Itron "eShapes" data. The eShapes data provide annual hourly "8760" end-use energy load shapes by building type. These are based on Itron modeling of thousands of existing commercial facilities audits. The eShapes data were then used to further disaggregate the building-type sales forecasts into five separate end uses (space heating, water heating, food service, cooling, and miscellaneous) using end-use energy intensities (MMBtu/sq. ft.) by building type.

Sales were further disaggregated into sales for new construction and major renovation spaces and those for existing facilities. New construction activity for commercial and industrial facilities was estimated using national projections of new additions and surviving square footage from the EIA 2013 Annual Energy Outlook and assuming simple sector-wide energy use intensities. Residential new construction was projected assuming the 9-year average annual growth rate (2005-2013) in housing units for Vermont from the U.S. Census Bureau Building Permits Survey.[13] Growth in number of housing units was translated to energy sales using average electric/fuel consumption per housing unit estimated from EIA 2009 Residential Energy Consumption Survey.

Note that the multifamily (MF) sector was not separately assessed. According to the U.S. Census Bureau's American Community Survey, 10% of Vermont dwelling units are MF. The average MF unit consumes less petroleum and biomass fuels than the average residential unit since MF units share interior walls and are smaller on average than non-MF units. We thus assumed that the MF sector accounts for less than 10% of residential building energy. In addition, some MF shared systems may by on commercial meters, and thus appear under the commercial sales forecast, in which case their efficiency potential is captured under the commercial sector.

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[10] U.S. Census Bureau, 2007-2011 American Community Survey, "DP04 Selected Housing Characteristics"

[11] This definition for low income is different than the one currently used by Efficiency Vermont for its unregulated fuels efficiency program, as a result costs and savings will not be an exact match to the existing program.

[12] Optimal Energy Inc. April 2014. *Energy Efficiency and Renewable Energy Potential Study of New York State*. Prepared for the NYSERDA. http://www.nyserda.ny.gov/Energy-Data-and-Prices-Planning-and-Policy/Energy-Prices-Data-and-Reports/EA-Reports-and-Studies/EERE-Potential-Studies.aspx

[13] U.S. Census Bureau Building Permits Survey, "Table 2au. New Privately Owned Housing Units Authorized Unadjusted Units for Regions, Divisions, and States," 1995-2012

Appendix C provides the disaggregated annual energy forecast. The available forecast data relied upon was either not developed with (or the data was not available to understand) detailed end use modeling and explicit assumptions about future codes and standards, changes in baseline practices, or major shifts among fuels. As a result, we assumed the forecast represented the best estimate of future weather normalized loads and reflected assumptions about future baselines and codes and standards consistent with our analysis at the measure level.

MEASURE CHARACTERIZATION

The first step for developing measure characterizations is to define a list of measures to be considered. This list was developed and qualitatively screened to eliminate measures that could not be characterized due to lack of data, or which were not expected to become viable during the study period. The final list of measures considered in the analysis is shown with their characterizations in Appendix D, which also shows the markets for which each measure was considered.

A total of 78 measures were included and characterized for up to three applicable markets (new construction/major renovation, natural replacement, and retrofit). This is important because the costs and savings of a given measure can vary depending on the market to which it is applied. For example, a retrofit or early retirement of operating but inefficient equipment entails covering the costs of entirely new equipment and the labor to install it and dispose of the old equipment. For new construction or other market-driven opportunities, installing new high efficiency equipment may entail only the incremental cost difference between a standard efficiency piece of equipment and the high efficiency one, as other labor and capital costs would be incurred in either case. Similarly, on the savings side, early-retirement retrofit measures can initially save more when compared to older existing equipment, while market-driven measure savings reflect only the incremental savings over current standard efficiency purchases. For early-retirement retrofit measures, often we model a baseline efficiency shift in the future, at the assumed end-of-life of the equipment being replaced.

For each measure, in addition to separately characterizing them by market, we also separately analyze each measure/market combination for each building segment (e.g., office vs. retail vs. hospital, etc.). The result is that we modeled 555 distinct measure/market/segment permutations for each year of the analysis.

The overall potential model relies on a top-down approach that begins with the forecast and disaggregates it into loads attributable to each possible measure, as described in the following section. In general, measure characterizations include defining the following characteristics for each combination of measure, market, and segment:

- Measure lifetime (both baseline and high efficiency options if different)
- Measure savings (relative to baseline equipment)
- Measure cost (incremental or full installed depending on market)
- O&M impacts (relative to baseline equipment)
- Water impacts (relative to baseline equipment).

Energy Savings

For each technology, we estimated the energy usage of baseline and high efficiency measures based primarily on engineering analysis. We relied heavily on the Vermont Technical Reference Manual (TRM) and other regional TRMs for measures covered by these documents. For more complex measures not addressed by the TRMs engineering calculations are used based on the best available data about current baselines in Vermont and the performance of high efficiency equipment or practices.[14] We drew upon recent baseline and saturation studies for Vermont for the residential and commercial sectors to identify baseline efficiency levels and practices wherever possible.[15] No building simulation modeling or other sophisticated engineering approaches to establishing detailed, weather normalized savings were included as part of the analysis.

Costs

Measure costs were drawn from Optimal Energy's measure characterization database when no specific Vermont costs were available. These costs have been developed over time, and are continually updated with the latest information, including recent updates for potential studies in Delaware and New York. Major sources include the TRMs, baseline studies, incremental cost studies, and direct research into incremental costs.

Lifetimes

As with measure costs, lifetimes are drawn from Optimal's measure characterization database. These have been developed over time, and were revised as needed for this study.

Additional aspects of measure characterization are described in the following sections, along with other factors that merge the measure level engineering data with the top-down forecast of applicable loads to each measure.

Industrial Measures Limited to Petroleum Fuels

We restricted the industrial efficiency measures to petroleum fuels. While there may be custom measures that could be applied to industrial biomass applications, we did not have reliable data to support including such measures in the analysis. We therefore did not include any biomass measures for the industrial sector. This assumption limits the potential for the biomass C&I sector since the industrial subsector represents about three quarters of the C&I sector forecast. The biomass results are thus limited to the residential and commercial sectors.

TOP-DOWN METHODOLOGY

The general approach for this study, for all sectors, is "top-down" in that the starting point is the actual forecasted loads for each fuel and each sector. As described above, we then break

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[14] Appendices D and F provide the data sources used for measure characterizations.

[15] See Appendix F for full citations to all referenced documents.

these down into loads attributable to individual building equipment. In general terms, the top-down approach starts with the energy sales forecast and disaggregation and determines the percentage of the applicable end use energy that may be offset by the installation of a given efficiency measure in each year. This contrasts with a "bottom-up" approach in which a specific number of measures are assumed installed each year.

Various measure-specific factors are applied to the forecasted building-type and end use sales by year to derive the potential for each measure for each year in the analysis period. This is shown in the following central equation:

Measure Savings	=	Segment/ End use AnnualSales	x	Applica-bility Factor	x	Feasibility Factor	x	Turnover Factor (replace-ment only)	x	Not Complete Factor (retrofit only)	x	Savings Fraction	x	Net Penetra-tion Rate

Where:

- **Segment/End Use Annual Sales** is the annual energy sales by building type and end use, from the sales disaggregation (e.g., water heating energy in office buildings, in MMBtu).
- **Applicability** is the fraction of the end use energy sales (from the sales disaggregation) for each building type and year that is attributable to equipment that could be replaced by the high-efficiency measure. For example, for replacing tank-type residential water heating with heat pump water heaters, we would use the portion of total residential fuel sales consumed by water heating. The main sources for applicability factors were the recent Vermont baseline studies.
- **Feasibility** is the fraction of end use sales for which it is technically feasible to install the efficiency measure. Numbers less than 100% reflect engineering or other technical barriers that would preclude adoption of the measure. Feasibility is not reduced for economic or behavioral barriers that would reduce penetration estimates. Rather, it reflects technical or physical constraints that would make measure adoption impossible or ill advised. An example might be that heat pump water heaters require a condensate drain, which may preclude their use in certain locations. The main sources for feasibility factors are the Recent Vermont baseline studies and engineering judgment.
- **Turnover** is the percentage of existing equipment that will be naturally replaced each year due to failure, remodeling, or renovation. This applies to the natural replacement ("replace on failure") and renovation markets only. In general, turnover factors are assumed to be 1 divided by the baseline equipment measure life (e.g., assuming that 5% or 1/20th of existing stock of equipment is replaced each year for a measure with a 20-year estimated life).

- **Not Complete** is the percentage of existing equipment that already represents the high-efficiency option. This only applies to retrofit markets. For example, if 30% of current single family homes already have high-efficiency clothes washers, then the not complete factor for that measure would be 70% (1.0-0.3), reflecting that only 70% of the total potential remains. The main sources for not complete factors are the Vermont baseline studies, and the findings of other baseline and potential studies (see Appendix F).
- **Savings Fraction** represents the percent savings (as compared to either existing stock or new baseline equipment for retrofit and non-retrofit markets, respectively) of the high efficiency technology. Savings fractions are calculated based on individual measure data and assumptions about existing stock efficiency, standard practice for new purchases, and high efficiency options.
    - **Baseline Adjustments** adjust the savings fractions downward in future years for early-retirement retrofit measures to account for the fact that newer, standard equipment efficiencies are higher than older, existing stock efficiencies. We assumed average existing equipment being replaced for retrofit measures was at 60% of its estimated useful life.
- **Annual Net Penetrations** are the difference between estimated base case measure penetrations and the measure penetrations that are assumed for an achievable potential. For the economic potential, it is assumed that 100% penetration is captured for all markets, with retrofit measures generally being phased in and spread out over time to reflect resource constraints such as contractor availability.

The product of all these factors results in the annual savings potential for each measure, over its lifetime, in each market (new construction, natural replacement, retrofit) and building type. Costs are then developed by using the "cost per energy saved" for each measure applied to the total savings produced by the measure. The same approach is used for other measure impacts, e.g., operation and maintenance savings.

COST-EFFECTIVENESS ANALYSIS

Cost-Effectiveness Tests

This study applies the Societal Cost Test (SCT) as the basis for excluding non-cost-effective measures from the potential. The SCT considers the costs and benefits of efficiency measures from the perspective of society as a whole. In addition, for the achievable potential scenario we report the cost-effectiveness at the program level using the Utility Cost Test (also known as the

Program Administrator Cost Test). The principles of these cost tests are described in the *California Standard Practice Manual,*[16] though Vermont has customized its Societal Cost Test.[17]

The following table provides the costs and benefits from the perspective of each cost-effectiveness test.

Table 1 | Overview of Cost-Effectiveness Tests

Monetized Benefits / Costs	Societal Cost Test (SCT)	Utility Cost Test (UCT)
Measure cost (incremental over baseline)	Cost	
Program Administrator incentives		Cost
Program Administrator non-incentive program costs	Cost	Cost
Energy & electric demand savings	Benefit	Benefit
Fossil fuel increased usage	Cost	Cost
Non-energy benefits (Operations & Maintenance, water savings, etc.)	Benefit	
Deferred replacement credit*	Benefit	
Externalities	Benefit	

*For early-retirement retrofit measures, the Deferred Replacement Credit is a credit for when the existing equipment would have needed replacement. The equipment's replacement cycle has been deferred due to the early replacement.

Some measures were not cost-effective in the initial years, but became cost-effective in later years due to the increasing annual avoided costs (which lead to higher benefits in later years). If a measure was nearly cost-effective in the early years and became cost-effective by year 5 (2019), the measure was included in the analysis.

Discounting the Future Value of Money

Future costs and benefits are discounted to the present using a real discount rate of 3%. This is standard practice in Vermont. Furthermore, the U.S. Department of Energy recommends a real discount rate of 3% for projects related to energy conservation, renewable energy, and water conservation as of 2010, which is consistent with the Federal Energy Management Program (FEMP).[18] For discounting purposes we assumed that initial measure costs are incurred at the beginning of the year, and that annual energy savings are incurred, on average, halfway through the year.

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[16] California Standard Practice Manual: Economic Analysis Of Demand-Side Programs And Projects, July 2002; Governor's Office of Planning and Research, State of California; http://www.calmac.org/events/SPM_9_20_02.pdf

[17] The Vermont Societal Cost Test is similar to the Total Resource Cost Test. The Societal Cost Test essentially uses the same input variables as the Total Resource Cost Test, but includes an environmental externality adder as approved by the Public Service Board in Docket 5270, a risk adjustment to account for the diversification benefits of energy efficiency measures and programs, and non-energy benefits.

[18] See page 1 in http://www1.eere.energy.gov/femp/pdfs/ashb10.pdf.

Gross and Net Energy Savings

We report potential estimates in terms of net savings. Net energy savings take into account free-riders, who would have installed the measures in the absence of the program, and spillover customers, who install measures due to program activities but never receive a program incentive. The formula for net savings is:

Net savings = Gross savings * (1 – FR + SO) = Gross savings * NTGR

where

FR = free-ridership rate as a % of program participation

SO = spillover rate as a % of program participation

NTGR = net-to-gross ratio

We based program net-to-gross ratios on knowledge of net-to-gross ratios used by relevant programs in other New England jurisdictions. The assumed values represent what we expect programs would average over the 10-year study period. Table 2, in the Achievable Potential Scenario section below, provides the net-to-gross ratio assumptions used for this study.

AVOIDED ENERGY SUPPLY COSTS

Overview

Avoided energy supply costs are used to assess the value of energy savings or increased usage. We have used the avoided costs provided by the *Avoided Energy Supply Costs in New England: 2013 Report* as the basis for this study.[19] The following elements have been applied for the avoided costs for this study, as per Vermont standard practice:

- Included costs for externalities, including avoided compliance costs for SO_2 and NO_x emissions and the value of reduced greenhouse gas emissions, based on $100/ton of CO_2e (CO_2 equivalent)
- Included a wholesale risk premium of 10 percent.[20]
- Did not include the avoided costs of price suppression, or demand reduction induced price effect (DRIPE).

The study used four fuel avoided cost categories, covering both heating and non-heating usage for both the residential and commercial/industrial (C&I) sectors. The avoided costs are provided in Appendix A.

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[19] "Avoided Energy Supply Costs in New England: 2013 Report", Synapse Energy Economics, 2013, http://www.synapse-energy.com/Downloads/SynapseReport.2013-07.AESC.AESC-2013.13-029-Report.pdf.

[20] Wholesale risk premiums are estimated and provide energy savings benefits for some efficiency programs. For example, see "Avoided Energy Supply Costs in New England: 2013 Report", Synapse Energy Economics, 2013, http://www.synapse-energy.com/Downloads/SynapseReport.2013-07.AESC.AESC-2013.13-029-Report.pdf.

It is important to note that during the course of this study the standard benchmark for oil in the United States, West Texas Intermediate, fell by approximately 50%. While this is not expected to be perfectly correlated with unregulated fuel avoided costs, it would be reasonable to assume that current and future avoided costs may be lower than those used in this study.

Non-Energy Benefits

Water savings generate non-energy benefits. Water avoided costs account for both water supply and sewer costs. The water avoided costs are estimated at $10.63/CCF (1.42 cents/gallon), based on the value used by Efficiency Vermont for cost-effectiveness analysis.

Consistent with Vermont standard practice, we applied a 15% adder for non-energy benefits to each measure's energy benefits. In addition, we included a 15% adder for low-income non-energy benefits, applied to low-income measures, in addition to the general 15% adder.

ECONOMIC POTENTIAL ANALYSIS

The top-down analysis applied to the data inputs produces the measure-level potential, with the economic potential being limited to installation of cost-effective measures. However, the total economic potential is less than the sum of each separate measure potential. This is because of interactions between measures and competition between measures. Interactions result from installation of multiple measures in the same facility. For example, if one insulates a building, the heating load is reduced. As a result, if one then installs a high efficiency furnace, savings from the furnace will be lower because the overall heating needs of the building have been lowered. Interactions between measures are taken into account to avoid over-estimating the savings potential. Because the economic potential assumes all possible measures are adopted, interactions assume every building includes all applicable measures. Interactions are accounted for by ranking each set of interacting measures by total savings, and assuming the highest savings measure is installed first, and then the next highest savings measure. This is a conservative approach in that it is more likely that some measures with marginal savings may not pass the cost-effectiveness test after all interactions are accounted for.

It is also necessary to adjust for measures that compete for the same applicable end-use energy. This applies to two or more efficiency measures that can both be installed or employed for the same application, in which case only one should be chosen. An example is choosing between replacing a baseline tank-type water heater with either a high-efficiency tank-type heater, an indirect-fired hot water storage tank, or a heat-pump water heater – but not more than one of these. For the economic potential the total market penetration for the competing measures is 100%, with priority generally given to the measures with highest savings. If the measure with highest savings is applicable in all situations, it would have 100% penetration and all other competing measures would show no potential. If on the other hand, if the highest-saving measure could only be installed in 50% of opportunities, then the other measures would capture the remaining opportunities.

Fuel switching measures compete with non-fuel switching measures for the same applications. However, they are an exception to the "competitive measure" approach. For fuel switching we selected a modest level of market penetration in order to be able to assess the potential impact, rather than having the measure either dominate or be dominated by other competing measures. See the Fuel Switching Measures section below for more detail.

To estimate the economic potential we generally assumed 100% installation of market-driven measures (natural replacement, new construction/renovation) constrained by measure cost-effectiveness and other limitations as appropriate, such as to account for competing measures.

Implementation of retrofit measures was considered to be resource-constrained, i.e., it would not be possible to install all cost-effective retrofit measures all at once. For the economic potential we assumed retrofit penetrations increased from 7% to 9% per year. Many retrofit measures also have market-driven (new construction, renovation, and/or natural replacement) opportunities. With these assumptions the economic potential thus captures nearly all of the available cost-effective efficiency potential for retrofit measures by the end of the study period.

For measures that are market-driven only and which have measure lives longer than 10 years, the turnover rate is such that not all of the economic potential will be captured over the 10-year study period. For example, a high-efficiency boiler measure with a 20-year measure life may not be cost-effective for early-retirement retrofit, but passes for natural replacement. If so, only about 10% (1/10th) of the market turns over every year, so the entire market would not be replaced within the 10-year study period. For this measure the 10-year economic potential would be less than the 10-year economic potential. However, all end-uses have retrofit as well as market driven opportunities, so those measures for which the market-driven economic potential is not fully realized are complemented by the retrofit potential. Between the market-driven and retrofit opportunities, the full economic potential is nearly realized over the 10-year study period.

ACHIEVABLE POTENTIAL SCENARIO

The estimates of achievable potential energy savings that can be captured through realistic program designs have been developed through a sequential and systematic process that combined a detailed review of available cost-effective savings at the measure or project level with a higher level review of applicable best practices in program implementation.

Measure Selection

Achievable potential is based on analysis of the energy savings of a wide range of energy efficiency measures. Estimated savings and costs for these measures were reviewed for a variety of different applications to determine which measures could be cost-effectively supported. This analysis involved reviewing an exhaustive list of possible measures and then grouping them in combinations based on how they can best reach Vermont customers. For example, residential high efficiency furnaces can be promoted as a stand-alone measure for homeowners whose existing furnaces have failed, as an energy-saving "early retirement" program before they have failed, or for installation in a newly-constructed home. The costs of upgrading to a high efficiency furnace are different in each of these examples, and the amount of energy that can be saved compared with business as usual will also vary. Therefore, in this example each of these different scenarios was tested to determine where the measure could be cost-effectively promoted.

Program Definition

Measures were organized into generic programs corresponding to the major markets that are the focus of typical efficiency initiatives. The programs included:

- Residential New Construction
- Residential Products
- Residential Retrofit
- Residential Low Income
- C&I New Construction
- C&I Equipment Replacement
- C&I Retrofit

Measure Incentives and Penetration Rates

Measure penetration rates, or adoption rates, are affected by a broad variety of factors depending on the measure: the market barriers that apply and to what degree, the program delivery strategy, incentive levels, marketing and outreach, technical assistance to installers, etc. Penetrations are heavily influenced by market barriers relating to consumer economics and behavior, and how effectively programs are designed to overcome those barriers. All else equal, consumers are more likely to install efficiency measures that have shorter payback periods and lower overall costs. Credit constraints represent a barrier to high-cost measures, and high personal discount rates are a barrier to measures whose benefits are derived from a long life. The correlation between societal cost-effectiveness and participant cost-effectiveness thus has a strong impact on penetrations. Adjustments are made for cases where there may be a disconnect between societal costs and benefits and personal costs and benefits, such as when peak day cost reductions or emissions externalities are not realized by the participant.

While penetration rates will generally increase with increased spending, how the spending is applied can have a huge impact on actual participation rates. Due to the complexity and interrelated nature of market barriers and the various methods used to promote efficiency measures, we base our assumptions for penetration rates on actual experience from efficiency programs coupled with the specific assumptions for individual measures and programs, rather than broadly applying a general formula based on a subset of factors. We believe this approach provides the best estimates of actual measure performance in an achievable potential scenario.

Incentive levels have been established as a percent of measure incremental cost at the program level. While in practice the incentive levels for individual measures will vary within a program, there is typically a good degree of commonality across measures and incentive levels can reliably be set at the program level for the achievable scenario. In this analysis, we developed an average incentive level for each program to simplify the analysis. In reality, different measures would receive incentives that represent different proportions of the measure cost. For each measure, the model multiplies the per-measure incentive by the penetration rate to establish the overall incentive spending for that measure in each year. Non-incentive program budgets are then estimated relative to incentive spending, as described in the following section.

The achievable scenario was constrained to paying incentives that are, on average, 50% of measure incremental costs. Thus the total incentives paid are 50% of total incremental costs, with variation in incentive levels between programs. This represents a higher level of investment in efficiency for unregulated fuels than is occurring today. We therefore assumed that in response to increased spending, measure penetration rates would ramp up over the first three years to levels that would then remain steady in response to the constant incentive levels.

Table 2 below provides the incentives as a percent of incremental cost assumed for each program.

Non-Incentive Program Budgets

Non-incentive costs include the costs of general administration, technical assistance, marketing, EM&V, and performance incentives. The non-incentive costs were set at the program level relative to the incentives, which are calculated based on individual measure incentives and each measure's market penetration for each year. Rather than create an administrative "program" that captures cross-program spending and common support services (e.g., information technology and general marketing), but which generates no savings, we allocated all non-incentive spending across all of the programs.

Non-incentive costs were estimated by reviewing natural gas program incentive and non-incentive costs for Vermont Gas Systems (for 2012-2014, with 2014 being projected costs), and for Efficiency Vermont, Massachusetts, and Rhode Island for 2013. These incentives, costs, and net-to-gross ratios, shown in the table below, are assumed to be the same for unregulated fuel programs. The same ratios were used for all program years.

Table 2 | Program Incentives, Non-Incentive Costs, and Net-to-Gross Ratios

Program	Incentive % of Incremental Cost	Program Spending		Net-to-Gross Ratio
		Incentives	Non-incentive Costs	
Residential New Construction	46%	50%	50%	0.98
Residential Products	33%	71%	29%	0.70
Residential Retrofit	50%	53%	47%	0.85
Residential Low Income	100%	69%	31%	1.00
C&I New Construction	46%	56%	44%	0.98
C&I Natural Replacement	33%	59%	41%	0.82
C&I Retrofit	57%	51%	49%	0.80

FUEL SWITCHING MEASURES

We included several selected fuel switching measures in the analysis due to their emerging potential for cost-effective energy and cost savings. Fuel switching measures compete with non-fuel switching measures for the same applications. However, they are an exception to the "competitive measure" approach described above in the Economic Potential Analysis section. For fuel switching we selected a modest level of market penetration in order to be able to assess the potential impact, rather than having the measure either dominate or be dominated by other competing measures. In practice, actual levels of investment in fuel-switching measures is a matter of efficiency program policy that has not been addressed in this study.

All of the fuel switching measures replaced petroleum fuels for space and water heating. Table 3 shows the fuel switching measures included in the study. The measures fall into four categories:

- air source heat pumps for space conditioning
- air source heat pumps for water heating
- biomass for space heating
- solar hot water.

Regarding heat pumps for space conditioning, we assumed these would be installed where cooling already exists or would be installed, so these would not add new cooling load. While some adopters of heat pumps for space conditioning may not previously have had air conditioning, we assumed that the addition of air conditioning was a desired benefit that would otherwise be met by adding other air conditioning equipment. We acknowledge that in some cases this may accelerate the installation of new air conditioning equipment, but have not corrected for that potential aspect of installed heat pumps. However, we assume this would have a small impact on overall cost-effectiveness. As heat pumps are promoted for their overall efficiency, program evaluations should investigate this aspect of their adoption.

We also assumed that heat pumps for space heating would be supplemented by a backup heating source, as is normally necessary for the coldest temperatures. As emerging technologies, particularly for the heat pumps, it should be kept in mind that the costs and savings for these measures are likely to be refined in the coming years as the technology continues to evolve, and as more knowledge is gained as to their performance.

Fuel switching from petroleum fuels to biomass presents a special case in that both petroleum fuels and biomass are types of unregulated fuels. These measures incur program costs but do not reduce the overall use of unregulated fuels since the petroleum fuel savings are offset by increased biomass usage. Therefore, these measures generally increase the overall program cost per annual MMBtu saved relative to measures that reduce the use of unregulated fuels.

Driven by the high avoided costs of petroleum fuels, all fuel switching measures passed the cost-effectiveness tests. Benefit-cost ratios (BCRs) vary substantially, with heat pump water heaters proving very cost-effective in the new construction and replacement markets, whereas the other fuel switching measures are more marginally cost-effective.

Table 3 | Fuel Switching Measures

Sector	Type	Measure	Market
Residential	Space Conditioning	Res Petroleum Fuel Heat/Room AC to Ductless Mini-Split Heat Pump	Retrofit
		Cord Wood Boiler Fuel Switch from Petroleum Fuels	New Construction
			Replacement
		Central Pellet Boiler Fuel Switch from Petroleum Fuels	New Construction
			Replacement
		Cord Wood Stove Fuel Switch from Petroleum Fuels	Retrofit
		Pellet Stove Fuel Switch from Petroleum Fuels	Retrofit
	Water Heating	Res Heat Pump Water Heater replace Petroleum Fuels	New Construction
			Replacement
			Retrofit
		Res Solar DHW replaces Petroleum Fuels	Retrofit
Commercial	Space Conditioning	Com Boiler/RoomAC to Ductless Mini-Split Heat Pump	Retrofit
		Com Boiler/Unitary AC to Variable Refrigerant Flow Heat Pump	New Construction
		Petroleum fuel switch to Biomass Boiler (<300 kBtu/h)	New Construction
			Replacement
		Petroleum fuel switch to Biomass Boiler (>300 kBtu/h)	New Construction
			Replacement
	Water Heating	Com Heat Pump Water Heater replace Petroleum Fuels	New Construction
			Replacement
			Retrofit
		Com Solar DHW offsets Petroleum Fuels	Retrofit

Cost-effective fuel switching measures could dominate the economic potential, since they save 100% of the fuel that they displace. To prevent this, we limited the fuel switching measure penetrations so that they would not represent more than about 5% of the sector savings for their respective end uses. This limitation was somewhat arbitrary but provided a reasonable level of fuel switching potential, which would vary in practice depending on policies for investment in fuel switching technologies. The same approach for limiting the savings from fuel switching was applied to the achievable potential.

RESULTS

As discussed in the Methodology section, this study assessed two levels of potential:

- Economic – The level of savings if all cost-effective energy efficiency measures are adopted by utility customers. Measures are defined as cost-effective if the present value of the benefits exceeds the present value of the costs over the measure's useful life. Economic potential assumes no or limited market barriers to the adoption of efficiency measures.
- Achievable – A level of possible savings given a set of programs targeting specific markets. Achievable potential also considers the administrative costs necessary to capture the potential

The two scenarios offer a strong context for understanding the bounds of energy efficiency potential. The economic scenario presents cost-effective potential given perfect information, no market barriers, and optimal resource allocation, effectively providing an upper theoretical limit for energy efficiency opportunities that carry a positive societal benefit.[21] The program achievable scenario presents energy efficiency that can be attained through program efforts to overcome barriers.

The nature of the petroleum fuels annual sales forecast has some impact on the study results. The residential petroleum fuels forecast decreases by 29% over the 10-year study period. This impacts the residential cumulative year-10 potential as a percent of forecast. Savings incurred in the early years are a higher percentage of the forecast in year ten (2024) than in the year they are installed. For example, measures installed in 2015 (with a life of 10 or more years) that save 1.0% of the 2015 sales forecast will save about 1.4% of the lower 2029 forecast. The impact of this effect decreases the closer you get to year ten. Therefore, the long-term potential as a percent of the 2024 forecast would be somewhat lower if there were no decline in sales. The same effect occurs for the commercial/industrial sector but to a lesser degree since C&I sales are projected to decrease by only 12% over the 10-year study period.

Several notes related to the results presented in this report are listed below.

- All dollar values are in real 2014 dollars, unless otherwise noted
- All savings are net rather than gross, meaning they have been adjusted for anticipated impacts of free-ridership[22]
- When savings are presented for a specific year, they reflect the *cumulative* annual savings in that year, accounting for measures that have expired[23] –

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[21] While the economic assessment ignores market barriers, we did assume that retrofit measure opportunities would be spread out over the 10-year study period, rather than having them all implemented in year 1.

[22] Free-ridership refers to the fact that some program participants would have selected high-efficiency options even in the absence of the program. Savings from free-riders are not included in overall program savings totals, but the costs associated with these participants are.

unless specified that the annual savings are *incremental*, for only measures installed that year

- When costs and benefits are presented for different cost-effectiveness tests, they reflect the cumulative present value for program years 2015-2024, including the lifetime benefits of measures installed in those years
- Biomass results are presented "stand-alone", or net of fuel switching measures, unless otherwise noted. This is because there are fuel switching measures that switch from petroleum fuels to biomass, increasing biomass usage and offsetting the biomass energy efficiency savings. There are no fuel switching measures that switch from biomass to other fuels.

PORTFOLIO-LEVEL RESULTS

This section presents the study results as the aggregate potential of all sectors addressed by efficiency programs, comparing outputs from the different levels of potential assessed in the study. More detailed sector-level results are provided in the following sections.

Economic and Achievable Potential Relative to Sales Forecasts

Table 4Table 4 provides a summary of the economic and achievable potential for petroleum fuels and biomass relative to the sales forecast. Overall, economic potential for petroleum fuels is 28.8% of the forecasted load in 2024 and 10.9% for biomass. The achievable potential for petroleum fuels is 8.5% by 2024 and 3.2% for biomass, roughly one third of the economic potential for both fuels once market barriers are taken into consideration.[24] Because the achievable potential scenario represents realistic customer behavior patterns and penetration rates of efficiency measures in the presence of incentives that cover only part of the incremental cost of these measures, achievable potential is lower than economic potential.

Biomass results are reported in Table 4 in a combined context, including fuel switching measures that shift away from petroleum fuels to increased biomass consumption. This reduces the stand-alone biomass savings due strictly to energy efficiency. While the potential for the stand-alone component of biomass efficiency is higher than the net, biomass has much less potential overall than petroleum fuels. Biomass has fewer applicable end-uses and high-efficiency options available to energy consumers, resulting in a limited portfolio of efficiency measures. The stand-alone potential for biomass is reported with the sector-level results further below.

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[23] Put another way, cumulative savings in a given year include the annual savings from all installed measures up to that year that have not yet reached the end of their measure lives.

[24] Biomass potential in a stand-alone scenario (without fuel switching from petroleum fuels to biomass) rises to 21.2% for economic and 5.0% for achievable.

Table 4 | Portfolio Cumulative Potential Relative to Sales Forecast, 2024

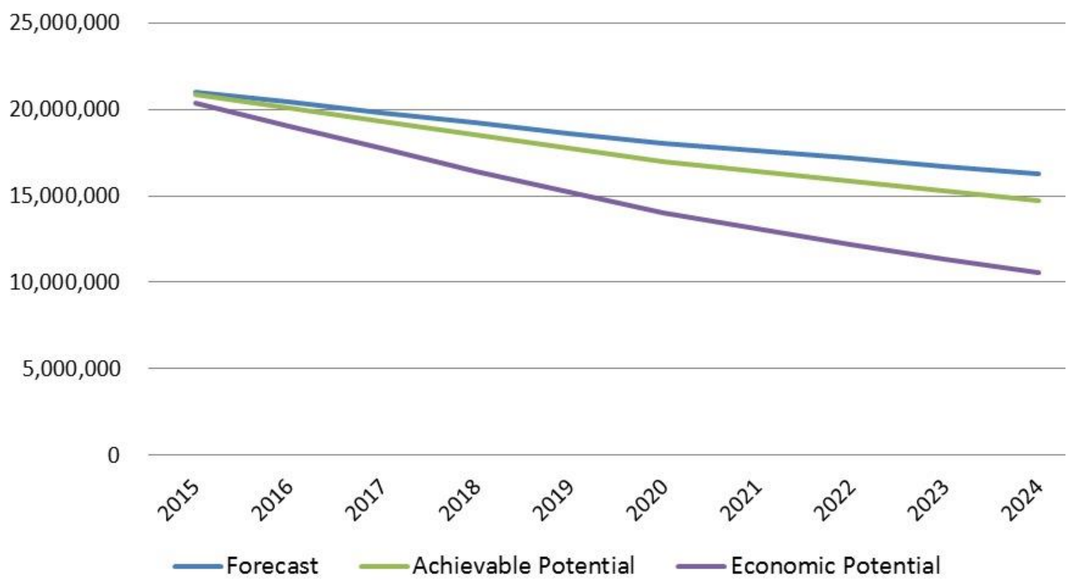
	% of Forecast
Petroleum Fuels	
Economic Potential	35.2%
Achievable Potential	9.3%
Biomass[25]	
Economic Potential	16.3%
Achievable Potential	3.3%

Figure 1 shows the forecasted sales of petroleum fuels in Vermont.[26] Consumption is forecasted to fall gradually through 2024, owing largely to fuel switching to natural gas due to its relatively low cost and new availability connected with the expansion of Vermont Gas Systems' service area. Capturing the achievable potential for petroleum fuels would further reduce forecast loads that are already predicted to drop as a result of the significant economic savings of conversions to gas and environmental policies to reduce carbon and particulate emissions from fuel oil.

[25] As noted in the Methodology section, biomass results are limited to the residential and commercial sectors, and do not include the industrial sector.

[26] The source of the petroleum fuels sales forecast is described in the Unregulated Fuels Sales Forecast section, under the Methodology section.

Figure 1 | Petroleum Fuel Savings Relative to Sales Forecast

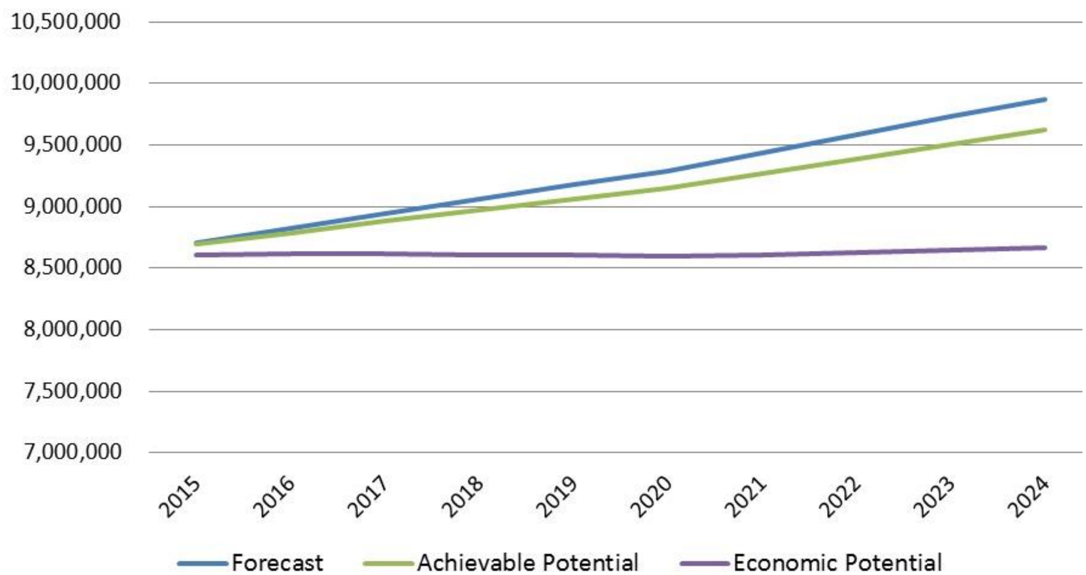


Source of sales forecast: Vermont Total Energy Study (2014), adjusted as described in the Unregulated Fuels Sales Forecast section, under the Methodology section.

Figure 2 shows the forecasted sales of biomass.[27] Consumption over the 10-year period is forecasted to increase steadily following general growth in heating demand (due to population growth) and an increase in the availability of more convenient systems for heating with biomass such as pellet stoves and boilers. Capturing the achievable potential would significantly reduce the increase in biomass consumption. This scenario includes fuel switching measures that switch from petroleum fuels to biomass, and thus increase biomass consumption, offsetting the savings from efficiency measures; if those fuel switching measures had not been included, the achievable potential would be somewhat higher and the increase in biomass consumption somewhat lower.

[27] The source of the biomass sales forecast is described in the Unregulated Fuels Sales Forecast section, under the Methodology section.

Figure 2 | Biomass Savings Relative to Sales Forecast



Source of sales forecast: Vermont Total Energy Study (2014), adjusted as described in the Unregulated Fuels Sales Forecast section, under the Methodology section.

Emissions Reductions

Table 5 shows the total cumulative emissions reductions due to reduced petroleum fuel and biomass usage in the achievable scenario.[28] Note that there would also be reduced emissions due to electricity savings, however, this study did not quantify all electric savings associated with the thermal process fuel efficiency measures. The carbon dioxide emissions reductions are equivalent to removing approximately 2,156 cars from the road for each year of the study period.[29]

Table 5 | Cumulative Emissions Reductions by Fuel Type, 2015-2024

Source Fuel	CO_2 (metric tons)	NO_x (metric tons)	SO_2 (metric tons)
Petroleum Fuels	102,413	121	81.7
Biomass	0	55	2.8
Total	**102,413**	**176**	**84.5**

28 Emissions reductions represent the CO_2 equivalency for fuel burned. For petroleum fuels, this is a weighted average of the fuels and does not include emissions during extraction or processing of the fuel. Biomass emissions are assumed to be carbon-neutral, and likewise do not include emissions released during processing or transportation of the fuel.

29 Calculated using the EPA estimated 4.75 metric tons of CO_2 emitted per vehicle per year. http://www.epa.gov/cleanenergy/energy-resources/refs.html

ACHIEVABLE POTENTIAL SECTOR-LEVEL RESULTS

This section provides a summary of the achievable potential results, with some of the economic potential results for comparison. We focus on the achievable scenario because it most closely reflects viable future energy efficiency investments and plans in Vermont. The results in this section are broken out for comparison across sectors and fuels. Further disaggregation of the sector totals can be found in the sector-specific results sections further below.

Savings

Table 6 provides a summary of the cumulative savings in 2024, by sector and fuel, in both absolute terms and relative to the associated sales forecasts. The residential sector represents the greatest potential for both petroleum fuel and biomass savings, in both absolute and percentage terms. This results in part from the fact that residential consumption of these fuels is far higher than in the commercial/industrial (C&I) sector, and thus provides a better target market for efficiency initiatives.

Achievable potential is a subset of the economic potential, and represents the energy savings that are possible in the context of current market barriers and high-performing efficiency programs. When market barriers are taken into account, the remaining potential represents about 26% of the economic potential estimated for petroleum fuels, regardless of sector, and less than 10% of the sales forecast. As noted above, biomass has a lower potential as a percent of forecast in part due to fuel switching from petroleum fuels to biomass, which increases biomass usage. In the C&I sector the impact of these fuel switching measures is particularly large because the petroleum fuels forecast was about three times larger than the biomass forecast (thus the increased biomass usage is a relatively high percent of the biomass forecast). Biomass also has fewer efficiency opportunities than for petroleum fuels, contributing to the smaller level of savings relative to the sales forecast.

Table 6 | Cumulative Achievable Potential by Sector and Fuel, 2024

	Cumulative Savings 2024 (BBtu)	% of Sales Forecast	Achievable % of Economic
Petroleum Economic Potential	**5,772**	**35.2%**	
Residential	3,531	38.1%	
Commercial & Industrial	2,191	31.3%	
Petroleum Achievable Potential	**1,515**	**9.3%**	**26.5%**
Residential	899	9.7%	25.5%
Commercial & Industrial	616	8.8%	28.1%
Biomass Economic Potential	**1,208**	**16.3%**	
Residential	1,297	19.0%	
Commercial	-88	-14.5%	
Biomass Achievable Potential	**248**	**3.3%**	**20.5%**
Residential	256	3.8%	19.7%
Commercial	-8	-1.3%	N/A*

*Commercial net biomass savings are negative due to fuel switching from petroleum fuels, which increases biomass usage in the relatively small commercial biomass market. The ratio of net negative achievable to economic savings would not be a valid comparison.

Table 7 shows the incremental annual savings for each fuel in absolute terms as well as relative to forecast load. The savings rate increases slightly for the first few years due to the assumed ramp-up of efficiency measure adoption rates, but is largely constant over the analysis period.

Table 7 | Achievable Incremental Annual Savings, 2015-2024

	2015	2016	2017	2018	2019	2020	-	2024
Incremental Annual Savings (BBTu)								
Petroleum Fuels	154	173	190	184	178	171		152
Biomass	17	21	24	25	26	26		29
Savings relative to forecast								
Petroleum Fuels	0.7%	0.8%	1.0%	1.0%	1.0%	0.9%		0.9%
Biomass	0.2%	0.3%	0.3%	0.4%	0.4%	0.4%		0.4%

Note: Savings for years 2021-2023 are omitted from the table for simplicity and are similar to savings presented for years 2020 and 2024.

Economics

Table 8 shows the cumulative present-value (PV) costs and benefits that would result through 2024 under the Vermont Societal Cost Test.[30] Results suggest that implementing programs under the achievable potential scenario is highly cost-effective. Total benefits amount to $817 million from an investment of $231 million. Net benefits are approximately $586 million in present value 2014 dollars. The benefit-cost ratio indicates that the programs would return $3.50 in societal benefit for every dollar invested. Economic results from Utility Cost Test screening are shown in Table 13 and Table 18.

Table 8 | Unregulated Fuels Societal Cost Test Economics by Sector, 2015-2024

	Costs (PV Million$)	Benefits (PV Million$)	Net Benefits (PV Million$)	BCR
Residential	$167	$536	$370	3.2
Commercial & Industrial	$64	$281	$217	4.4
Total	**$231**	**$817**	**$586**	**3.5**

ACHIEVABLE POTENTIAL DETAILED RESULTS

This section presents program-level and other detailed results from our analysis of the achievable potential scenario. The results are divided into the following sections.

- Results for the residential sector
- Results for the commercial/industrial (C&I) sector
- Program budgets
- Efficiency measure supply curves
- Sensitivity analysis results

Residential Sector

Sector Savings Summary

Cumulative results through 2024 for the residential sector are presented by program and fuel in Table 9. The largest share of total savings (61%) is from the Retrofit program, followed by Residential Products (25%). Fuel switching measures accounted for 7% of the total residential savings. Fuel switching included switching from petroleum fuels to electric, solar, and biomass. Switching to biomass resulted in petroleum fuel savings but increased biomass usage. We did not apply fuel switching measures to the Low Income program only because they would more likely be promoted through the other residential programs; in practice they could be applied to the Low Income program as well.

30 Throughout this report, Societal Cost Test refers to the Vermont Societal Cost Test that is further described in the Methodology section of the report.

Table 9 | Cumulative Residential Savings by Program, 2024

Program	Petroleum Fuels Efficiency (BBtu)	Biomass Efficiency (BBtu)[31]	Fuel Switching (BBtu)	Total Savings (BBtu)[32]
Residential New Construction	63.1	26.6	(0.4)	89.2
Residential Retrofit	428.2	198.4	79.1	705.7
Residential Products	193.3	95.4	4.4	293.1
Residential Low Income	44.3	22.2	0.0	66.5
Total	**728.8**	**342.6**	**83.1**	**1,154.6**

Residential Savings Detail

Residential petroleum fuel savings are limited to space heating and water heating, as potential savings from other end uses are negligible. Figure 3 shows the 2024 cumulative savings by end use. All biomass savings come from space heating measures.

Figure 3 | Residential Petroleum Fuel Savings by End Use, 2024

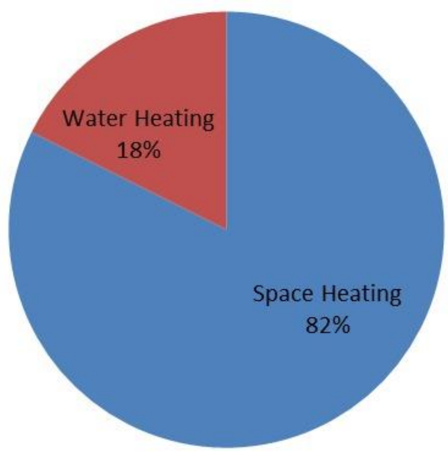


Table 10 shows the top petroleum fuel measures generating savings under the achievable potential analysis, with benefit-cost ratios (BCRs) based on the Societal Cost Test. Of the top petroleum fuel measures, space heating accounts for 65% of the total savings (seven measures), with an additional 12% from water heating (three measures). The top five petroleum fuel measures represent more than half of all petroleum fuel cumulative residential sector savings by 2024. Fourteen petroleum fuel measures account for the remaining 23% savings. Note that a measure with a relatively high BCR may have a lower percent of program savings because it

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[31] Stand-alone biomass savings, not reduced for fuel switching from petroleum fuels to biomass.

[32] Total savings include increased biomass fuel use from fuel switching measures.

may apply to a smaller portion of end-use energy, or may compete with other measures for the same application, or due to having higher market barriers to adoption.

Table 10 | Petroleum Fuel Residential Top Saving Measures, 2024

Measure Name	Cumulative BBtu (2024)	Percent of Total	BCR
Air Sealing, Oil -Heat	160	18%	8.4
WiFi T-stats - Oil	150	17%	7.1
Wall Insulation, Oil -Heat	82	9%	4.9
Attic insulation, Oil -Heat	71	8%	3.2
Duct Sealing, Oil Heat -Heat	60	7%	8.8
Faucet Aerator -Oil	46	5%	15.1
Integrated hot water heater replace tankless coil -Oil	35	4%	7.5
Propane Furnace ESTAR	32	4%	11.8
Res Heat Pump Water Htr replace Oil	28	3%	7.5
Propane Boiler ESTAR	25	3%	14.2
Total	**688**	**77%**	

As show in Table 11, five biomass measures passed cost-effectiveness screening. Of these measures, space heating accounts for all of the residential sector savings by 2024. Note that all of the biomass efficiency measures were thermal shell measures; we did not evaluate the potential for higher-efficiency biomass unit heaters relative to standard-efficiency units.

Table 11 | Biomass Residential Top Saving Measures, 2024

Measure Name	Cumulative BBtu (2024)	Percent of Total	BCR
Air Sealing, Biomass -Heat	113	33%	4.8
WiFi T-stats - Biomass	105	31%	3.9
Wall Insulation, Biomass -Heat	58	17%	2.8
Attic insulation, Biomass -Heat	50	15%	1.8
High performance window - Biomass	17	5%	5.4
Total	**343**	**100%**	

Residential Costs and Cost-Effectiveness

This study applies the Societal Cost Test (SCT) as the basis for excluding non-cost-effective measures from the potential. The SCT considers the costs and benefits of efficiency measures from the perspective of society as a whole. In addition, for the achievable potential scenario we report the cost-effectiveness at the program level using the Utility Cost Test (also known as the

Program Administrator Cost Test). While a measure or program could pass the SCT but fail the UCT, there were no such cases for this study.

All of the proposed residential programs are cost effective through 2024 from a Societal Cost Test (SCT) perspective, as shown in Table 12. Program-level benefit-cost ratios (BCRs) range from 5.0 to 18.5. At the sector level, the residential programs have an aggregate BCR of 3.2 representing $369.6 million in present-value (PV) net benefits.[33] The results in Table 13 reflect a Utility Cost Test (UCT) perspective for petroleum fuels. These cost-effectiveness tests are further described in the Methodology section of the report. All of the programs are cost effective from the UCT perspective, including the low income program with a BCR of 2.6. The sector level UCT BCR is 3.1, with cumulative net benefits through 2024 of $256.1 million.

Table 12 | Residential Societal Cost Test Economics by Program, 2015-2024

Program	Costs (PV Million$)	Benefits (PV Million$)	Net Benefits (PV Million$)	BCR
Residential New Construction	$12.0	$47.9	$35.9	4.0
Residential Retrofit	$120.3	$329.7	$209.5	2.7
Residential Products	$26.2	$127.2	$100.9	4.8
Residential Low Income	$8.2	$31.4	$23.3	3.9
Total	**$166.7**	**$536.3**	**$369.6**	**3.2**

Table 13 | Residential Utility Cost Test Economics, by Program, 2015-2024

Program	Costs (PV Million$)	Benefits (PV Million$)	Net Benefits (PV Million$)	BCR
Residential New Construction	$9.0	$34.6	$25.6	3.8
Residential Retrofit	$90.8	$234.4	$143.6	2.6
Residential Products	$17.1	$91.8	$74.7	5.4
Residential Low Income	$7.9	$20.2	$12.3	2.6
Total	**$124.8**	**$380.9**	**$256.1**	**3.1**

[33] All cost and benefit calculations represent the net present value of lifetime costs and energy savings. For example, the results in Figure 8 represent the net present value of costs and benefits that occur as a result of programs *delivered* from 2015 through 2029, including those costs and benefits that may occur in 2030 or later.

Commercial/Industrial Sector

C&I Savings Summary

Cumulative results through 2024 for the commercial/industrial (C&I) sector are presented by program in Table 14. The C&I Retrofit Program achieves the majority of the sector total energy savings (64% of the sector total), followed by New Construction (28%) and Equipment Replacement (8%). Fuel switching from petroleum fuels accounted for 13% of the total C&I savings. Fuel switching included switching from petroleum fuels to electric, solar, and biomass. Switching to biomass resulted in petroleum fuel savings but increased biomass usage.

Table 14 | Cumulative C&I Savings by Program, 2024

Program	Petroleum Fuels Efficiency (BBtu)	Biomass Efficiency (BBtu)[34]	Fuel Switching (BBtu)	Total Savings (BBtu)[35]
C&I New Construction	138.6	8.4	25.5	172.5
C&I Retrofit	329.1	18.9	40.6	388.5
C&I Equipment Replacement	33.8	0.0	13.4	47.2
Total	**501.5**	**27.3**	**79.5**	**608.2**

C&I Savings Detail

Figure 4 shows the petroleum fuel savings from the commercial/industrial sector. Commercial savings are broken out by end use while industrial savings include all end uses for this subsector. The industrial subsector accounts for 6% of the total C&I savings. Of the commercial measures, space heating makes up 61% of the total C&I savings, with water heating at 31%. All biomass savings come from space heating measures.

[34] Stand-alone biomass savings, not reduced for fuel switching from petroleum fuels to biomass.

[35] Total savings include increased biomass fuel use from fuel switching measures.

Figure 4 | Commercial Petroleum Fuel Savings by End Use, 2024

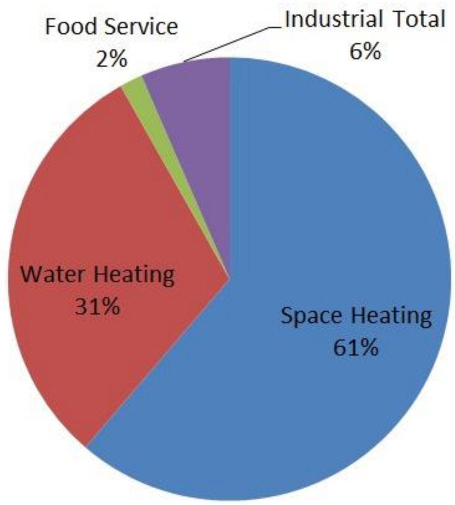


Table 15 presents the top petroleum fuel saving measures in the commercial/industrial sector. None of the C&I measures is dominant in terms of sector savings. Instead, the top saving measures range from 11% to 4% of the total 2024 commercial potential and represent 63% of the total savings. Note that the "industrial oil/propane boiler equipment" measure is highly aggregated, representing various boiler efficiency measures.[36]

Table 15 | Petroleum Fuel Commercial Top Saving Measures, 2024

Measure Name	Cumulative BBtu (2024)	Percent of Total	BCR
Indirect water heater, oil heat	69	11%	9.2
Retrocommissioning -Oil	66	11%	14.0
Steam Traps, Oil	48	8%	43.7
Envelope Upgrade - Oil	42	7%	6.5
EE Industrial Oil/Propane Boiler Equipment	31	5%	36.5
Commissioning -Oil	29	5%	2.7
High-efficiency large boiler -Oil	27	4%	6.5
Boiler reset controls, Oil	26	4%	24.9
Boiler/furnace burner replacement, Oil	24	4%	22.7
Com Heat Pump Water Htr replace oil DHW	23	4%	17.6
Total	**385**	**63%**	

[36] In total, 33 individual efficiency measures were analyzed for the industrial sector. To facilitate the analysis and because of uncertainties regarding the specific opportunities in Vermont's industrial building stock, their respective costs and savings characteristics were then aggregated to the following representative categories: heating, ventilation, and air-condition (HVAC) improvements, boiler replacements and improvements, and direct process heating improvements.

As shown in Table 16As show in Table 11, five biomass measures passed cost-effectiveness screening. Of these measures, space heating accounts for all of the residential sector savings by 2024. Note that all of the biomass efficiency measures were thermal shell measures; we did not evaluate the potential for higher-efficiency biomass unit heaters relative to standard-efficiency units.

Table 11, eight biomass measures passed cost-effectiveness screening for the C&I sector, all of which derive from the space heating end use.

Table 16 | Biomass Commercial Top Saving Measures, 2024

Measure Name	Cumulative BBtu (2024)	Percent of Total	BCR
Retrocommissioning -Biomass	6	22%	5.2
Integrated bldg design Tier I - Biomass	5	20%	5.1
Demand controlled ventilation -Cool/Biomass Heat	5	19%	7.4
Envelope Upgrade - Biomass	4	16%	2.2
Commissioning -Biomass	3	11%	1.7
Deep Energy Retrofit - Biomass	2	6%	2.3
Duct insulation and sealing, biomass heat	1	5%	5.7
Programmable thermostat, Biomass	0	2%	13.6
Total	**27**	**100%**	

C&I Costs and Cost-Effectiveness

The tables below show the cost-effectiveness of the C&I programs from the perspectives of the Societal and Utility Cost Tests. As shown in Table 17, all of the proposed C&I programs are cost-effective through 2024 from a Societal Cost Test (SCT) perspective. The benefit-cost ratios (BCRs) range from 4.2 to 5.4. At the sector level, the C&I programs have an aggregate BCR of 4.4 representing $216.7 million in present-value (PV) net benefits through 2024. Note that the magnitude of net benefits from each program are not necessarily correlated with the BCR. The former is a result of the amount of energy usage being addressed and the opportunities for efficiency savings, whereas the latter is simply a unit-less measure of the relationship between benefits and costs, regardless of the size of the program.

Table 17 | C&I Societal Cost Test Economics by Program, 2015-2024

Program	Costs (PV Million$)	Benefits (PV Million$)	Net Benefits (PV Million$)	BCR
C&I New Construction	$22.2	$95.3	$73.0	4.3
C&I Retrofit	$35.9	$151.7	$115.8	4.2
C&I Equipment Replacement	$6.3	$34.3	$27.9	5.4
Total	**$64.5**	**$281.2**	**$216.7**	**4.4**

The results in Table 18 reflect a Utility Cost Test perspective. As with the SCT results, all of the programs are cost-effective with BCRs ranging from 3.7 to 5.9. The sector level Utility Cost Test BCR is 4.1. The programs' cumulative present-value (PV) net benefits through 2024 are $143.1 million.

Table 18 | C&I Utility Cost Test Economics by Program, 2015-2024

Program	Costs (PV Million$)	Benefits (PV Million$)	Net Benefits (PV Million$)	BCR
C&I New Construction	$14.3	$60.1	$45.8	4.2
C&I Retrofit	$28.3	$104.9	$76.7	3.7
C&I Equipment Replacement	$4.2	$24.9	$20.6	5.9
Total	**$46.8**	**$189.9**	**$143.1**	**4.1**

Program Budgets

Program budgets are presented below in nominal dollars, assuming a 2% long-term inflation rate. Table 19 shows the annual program budgets by sector for the achievable potential scenario. The budgets increase over the first three years as the programs gradually ramp up, then remain fairly steady but decline somewhat in keeping with declining petroleum fuel sales and increasing biomass sales (see Figures 1 and 2). Also, the future budgets would be somewhat lower if presented in real 2014 dollars rather than in nominal dollars. For additional information about program budget development, see the "Achievable Potential Scenario" description under the Methodology section of the report.

Table 19 | Budgets by Sector (Nominal Thousand$)

Sector	2015	2016	2017	2018	2019	2020	-	2024
Residential	$11,164	$13,051	$14,887	$14,751	$14,604	$14,448		$14,078
C&I	$4,706	$5,437	$6,194	$6,190	$6,174	$6,110		$6,173
Total	**$15,870**	**$18,488**	**$21,081**	**$20,940**	**$20,779**	**$20,558**		**$20,251**

Note: Budgets for years 2021-2023 are omitted from the table for simplicity. The budgets remain relatively flat over that period. Annual program budgets for all years can be found in Appendix G.

Table 20 shows annual budgets for the residential sector programs. The Residential Retrofit program has the highest budget over the course of the study period, due to the relatively high cost of promoting early-retirement retrofit measures, plus the high levels of trade ally and other market actor support that characterize retrofit programs. The Products program has the next highest budget, with the other programs having relatively low budgets.

Table 20 | Residential Budgets by Program (Nominal Thousand$)

Program	2015	2016	2017	2018	2019	2020	-	2024
Residential New Construction	$656	$700	$738	$724	$711	$697		$655
Residential Retrofit	$8,227	$9,803	$11,353	$11,262	$11,163	$11,055		$10,818
Residential Products	$1,425	$1,524	$1,606	$1,579	$1,552	$1,524		$1,440
Residential Low Income	$856	$1,024	$1,190	$1,185	$1,179	$1,172		$1,165
Total	**$11,164**	**$13,051**	**$14,887**	**$14,751**	**$14,604**	**$14,448**		**$14,078**

Note: Budgets for years 2021-2023 are omitted from the table for simplicity and are similar to budgets presented for years 2020 and 2024.

As shown in Table 21, the C&I Retrofit program has the highest budget. The Equipment Replacement budget is the lowest, owing to the fact that there are relatively few petroleum and biomass measures in the replacement market, and the number of equipment replacement opportunities is substantially reduced by early-retirement retrofit measures.

Table 21 | C&I Budgets by Program (Nominal Thousand$)

Program	2015	2016	2017	2018	2019	2020	-	2024
C&I New Construction	$1,468	$1,615	$1,782	$1,793	$1,794	$1,744		$1,682
C&I Retrofit	$2,940	$3,505	$4,078	$4,069	$4,059	$4,050		$4,175
C&I Equipment Replacement	$298	$317	$334	$328	$322	$316		$316
Total	**$4,706**	**$5,437**	**$6,194**	**$6,190**	**$6,174**	**$6,110**		**$6,173**

Note: Budgets for years 2021-2024 are omitted from the table for simplicity and are similar to budgets presented for years 2020 and 2024.

SUPPLY CURVES

The figure below shows the cost curve for petroleum fuel savings[37] under the achievable potential scenario. Each block corresponds to a particular end use within a sector. The width of each block represents the cumulative amount of efficiency potential in year 10 (2024), while the height corresponds to the average *net* levelized cost of that grouping of efficiency potential. The blocks are sorted and presented in order of increasing cost per unit of energy.

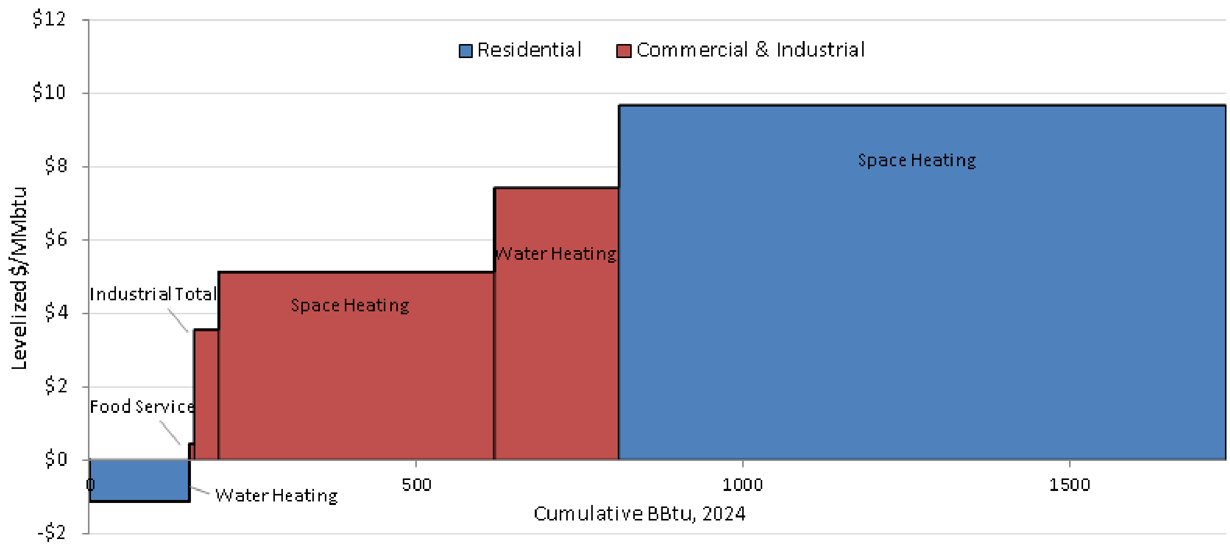
The *net* levelized cost is the net cost per MMBtu of petroleum fuel, levelized (discounted) over the lifetimes of measures contributing to each block. The net cost is the measure cost minus any benefits that accrue in addition to natural gas savings. For example, the net cost for a gas efficiency measure with associated water and electricity savings would be the measure cost minus the benefits of electricity savings, water savings, and any other non-energy benefits. This provides a more complete assessment of the value of MMBtu savings than the *gross* levelized

[37] A supply curve for biomass was not done due to only having one end use and levelized costs that are distorted by fuel switching

cost, which ignores the non-gas benefits. The net levelized cost is also more comparable to the avoided costs of fuel savings, since it reflects the measures' non-fuel benefits. In contrast, a measure's gross levelized cost might be considerably higher than the avoided costs of petroleum fuel savings, since the gross cost ignores the non-fuel benefits.

The study found that achievable costs of efficiency start at negative $1.15/MMBtu of savings from residential water heating improvements. The negative net levelized cost value reflects the value of non-fuel resource savings (such as water or maintenance savings), which are greater than the incremental costs for some measures.

Figure 5 | Petroleum Fuel Supply Curve



The supply curve demonstrates that the opportunities for petroleum fuel savings are dominated by space heating. There is moderate potential for savings in water heating and industrial, but the overall distribution of savings largely reflects consumption patterns. Residential water heating represents an opportunity for low-cost savings as demonstrated by negative net levelized costs of implementing these measures. These results are largely due to the fact that many water heating measures are inexpensive and contribute non-energy benefits in the form of water savings. The higher cost of space heating savings is due to a very wide portfolio of measures, some of which are only moderately cost-effective.

SENSITIVITY ANALYSES

Forthcoming…

RECOMMENDATIONS

In this section we provide some recommendations for the fuel efficiency programs, based on the findings of this study and a review of related data.

Increase Spending and Savings in the C&I Sector

When reviewing the results from the Thermal Energy and Process Fuels Program results reported by Efficiency Vermont, the dramatic difference in results from the Residential and Business sectors stands out as an opportunity for greater savings. In 2013, 88% of TEPF program spending was directed to the residential sector. While the annual budget estimate allocated 25% of spending to businesses, they received less than half that amount. Neither approaches their 37% share of statewide consumption. Despite this, the business sector represented nearly two-thirds of TEPF savings (63%). This results from the fact that savings from business customers are acquired at less than 10% of the cost of residential savings on a per Btu basis.

These results suggest that there may be a substantial opportunity to increase savings without increasing spending, by shifting more spending to the business sector. Simply achieving the estimated budget allocation for that sector would increase total TEPF savings by over 50%. Other aspects of the programs should be carefully reviewed as well.

Increase Total Spending to Reach Identified Potential

This study indicates an achievable potential of approximately 1,763 BBtu in annual savings by 2024, supported by total program spending of about $182 million over 10 years in real 2014 dollars. This is comparable to the recommendation of the Vermont Thermal Efficiency Task Force, which suggested that meeting Vermont's thermal efficiency goals (across all fuels, not just petroleum and biomass) would require approximately $360 million of program spending from 2014 through 2020.[38]

In contrast, EVT's Thermal Efficiency and Process Fuels (TEPF) program in 2013 spent $4.7 million and acquired 55.7 BBtu in annual savings. This rate is less than half that required to reach the achievable potential over the ten year study period and insufficient to achieve the state's thermal efficiency goals.

Consider Funding Mechanisms for Unregulated Fuels Efficiency

It bears mentioning that customers of electricity and natural gas are required to support publicly-funded efficiency programs, while users of oil and other delivered fuels are not. There are several valid logistical, cost, and policy issues surrounding the adoption of a similar funding method for the latter, yet the fact remains that the state is leaving substantial economic benefits "on the table" by failing to pursue the achievable efficiency potential in unregulated fuels and biomass identified in this report.

[38] Thermal Efficiency Task Force Analysis and Recommendations, Report to the Vermont General Assembly, January 2013, p. 80

APPENDICES