Potential for Natural Gas Fuel Efficiency Savings in Vermont

Final Report

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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 natural gas and 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 natural gas portion of the analysis, which was done over a 15-year study period from 2015-2029.

Natural gas efficiency programs in Vermont are currently delivered by Vermont Gas Systems (VGS), an investor-owned natural gas supply company servicing Chittenden and Franklin counties. VGS has offered energy efficiency programs to its customers for over 20 years and has recently been officially designated as an "Energy Efficiency Utility" (EEU) by the Public Service Board. As an EEU, it will deliver programs under a budget and performance targets set through a Public Service Board stakeholder process. VGS has also received approval from the Vermont Service Board to expand service south into Addison County. As part of the Certificate of Public Good, VGS is required to "develop an aggressive new energy efficiency program" for its customers. Further, VGS has proposed to deliver efficiency programs to households who are not VGS customers but have or are expected to have availability of natural gas within a short timeframe. All of these efficiency programs must meet the requirements of Vermont statute, in particular relevant portions of 30 V.S.A. §218c and 30 V.S.A. §209(d) and (e), which directly discuss least-cost planning and energy efficiency requirements. The study will provide information valuable to stakeholders to set budgets and performance targets in meeting the goals of Vermont statute, Public Service Board Order, and State energy policy.

SUMMARY OF RESULTS

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

As discussed in detail in the Methodology section below, 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 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.[1] The program achievable scenario presents energy efficiency that can be attained through program efforts to overcome barriers.

Several notes related to the presentation 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[2]
- When savings are presented for a specific year, they reflect the *cumulative* annual savings in that year, accounting for measures that have expired[3] – 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 the years 2015-2029

Scenario Summaries

Table 1 provides a summary of the economic and achievable potential for natural gas relative to the sales forecast.[4] Overall, economic potential for natural gas is 27.3% of the forecasted load in 2029. The achievable potential for natural gas is 8.2% by 2029, less than a third of the economic potential once market barriers are taken into consideration. Achievable potential is lower than economic potential due to numerous market barriers and many measures screening as only marginally cost-effective. The achievable potential scenario represents realistic customer behavior patterns and penetration rates of efficiency measures.

[1] While the economic assessment ignores market barriers, we did assume that retrofit measure opportunities would be spread out over the 15-year study period, rather than having them all implemented in year 1.

[2] 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.

[3] 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.

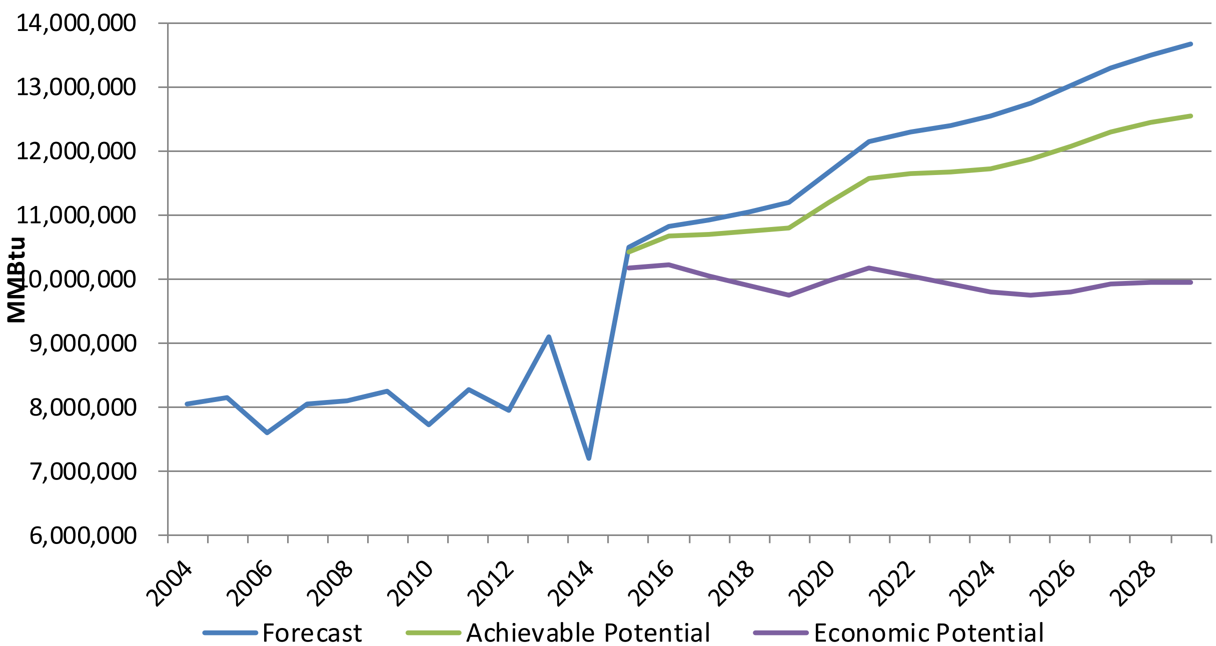
[4] As described in the Methodology section, the sales forecast was adjusted to represent the forecast with no energy efficiency programs.

Table 1 | Cumulative Natural Gas Potential Relative to Sales Forecast, 2029

	% of Sales Forecast
Economic Potential	27.3%
Program Achievable Potential	8.2%

Figure 1 shows the historic and forecasted sales of natural gas. With the exception of moderate fluctuations in recent years, natural gas consumption has been relatively steady over the past ten years. Consumption in Vermont is forecasted to rise sharply in 2015, then gradually through 2029, owing largely to growing demand for relatively low-cost natural gas and the expansion of VGS's service area. With the economic potential scenario, gas sales would remain essentially flat over the 15-year study period; however, this scenario ignores market barriers.

Figure 1 | Natural Gas Savings Relative to Sales Forecast without Energy Efficiency



The natural gas annual forecast increases a full 30% over the 15-year study period. This has an impact on the potential assessment, particularly for measures with longer lifetimes, as is the case for many gas measures. Savings incurred in the early years are a lower percent of the forecast in year 15 (2029) than in the year they are installed. For example, measures installed in 2015 (with a life of 15 years) that save 1.00% of the 2015 forecast only save 0.77% of the 2029 forecast. Therefore, the long-term potential as a percent of forecast would be significantly higher for a forecast with a lower growth rate.

In addition, the sales forecast to which potential savings are compared includes the building energy of opt-out customers[5], which are not eligible for efficiency program services. The opt-out energy amounts to about 10% of the C&I forecast. Thus measures that save 1.0% of the forecast would save about 1.1% of forecast if the opt-out energy were not included.

Achievable Potential Results Summary

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. Further disaggregation of the sector totals can be found in the sector-specific results sections further below.

Savings

Table 2 provides a summary of the cumulative savings in 2029, by sector, in both absolute terms and relative to the associated sales forecasts. The commercial and industrial (C&I) sector has higher absolute savings, due to the fact that about two-thirds of the sales forecast is in the C&I sector.

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 current leading programs. When market barriers are taken into account under an achievable potential scenario, the remaining C&I potential represents 33% of the potential estimated under the economic potential scenario. The residential achievable potential estimate is just 27% of the economic potential estimate. This indicates that market barriers have a greater impact on energy efficiency potential for the residential sector than the C&I sector.

Table 2 | Cumulative Achievable Potential by Sector, 2029

	Cumulative Savings 2029 (BBtu)	% of Sales Forecast	Achievable % of Economic
Economic Potential	**3,732**	**27.3%**	
Residential	1,634	36.6%	
Commercial & Industrial	2,098	22.8%	
Achievable Potential	**1,117**	**8.2%**	**29.9%**
Residential	435	9.7%	26.6%
Commercial & Industrial	682	7.4%	32.5%

[5] Opt-out energy refers to the Self-Managed Energy Efficiency Program, a Department authorized program that permits an eligible customer to opt out of the energy efficiency charge and administer its own energy efficiency program meeting certain conditions

Table 3 shows the incremental annual savings for natural gas by sector in absolute terms as well as relative to forecast load. The savings as a percent of forecast ramp up gradually and level off after three years, while the absolute savings continue to grow (as does the sales forecast – see Figure 1 above).

Table 3 | Achievable Incremental Annual Savings, 2015-2029

	2015	2016	2017	2018	2019	2020	-	2029
Incremental Annual Savings (BBtu)								
Residential	40.5	45.1	49.2	49.7	50.3	50.7		59.3
Commercial & Industrial	36.2	43.3	49.9	50.4	51.0	53.1		61.3
Savings relative to forecast								
Residential	1.16%	1.26%	1.36%	1.36%	1.35%	1.35%		1.33%
Commercial & Industrial	0.52%	0.60%	0.68%	0.68%	0.68%	0.67%		0.67%

Note: Savings for years 2021-2028 are omitted from the table for simplicity and are similar to savings presented for years 2020 and 2029.

Economics

Table 4 shows the cumulative costs and benefits that would result from implementing programs to the achievable potential through 2029 under the Societal Test.[6] This scenario is highly cost-effective. In addition, the results by sector are consistent with similar program portfolios of this type around the country. Total benefits amount to $290 million from an investment of $104 million. Net benefits are approximately $186 million in present value 2014 dollars. The benefit-cost ratio indicates that the programs would return $2.8 for every dollar invested. Economic results from Utility Cost Test screening are shown in Tables 9 and 13.

Table 4 | Achievable Societal Cost Test Economics by Sector, Cumulative 2015-2029

	Costs (Million$)	Benefits (Million$)	Net Benefits (Million$)	BCR
Residential	$52	$118	$66	2.3
Commercial & Industrial	$52	$172	$120	3.3
Total	**$104**	**$290**	**$186**	**2.8**

[6] Throughout this report, Societal Test refers to the Vermont Societal Test, which is further described in the "Methodology" section of the report.

Emissions Reductions

Table 5 shows the total cumulative emissions reductions due to reduced natural gas usage in the achievable scenario.[7] Note that there would also be reduced emissions due to electricity savings, however, this study did not quantify all electric savings associated with the natural gas efficiency measures. The carbon dioxide emissions reductions are equivalent to removing approximately 1,175 cars from the road for each year of the study period.[8]

Table 5 | Cumulative Emissions Reductions, 2015-2029

Source Fuel	CO_2 (metric tons)	NO_x (metric tons)	SO_2 (metric tons)
Natural Gas	83,736	74	0.4

STUDY SCOPE AND METHODOLOGY OVERVIEW

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

- Two 15-year efficiency potential scenarios for the period 2015-2029: economic potential and achievable potential
- The economic efficiency potential includes all efficiency potential that is cost-effective, assuming no or limited market barriers[9]
- 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[10]

The focus of this report is exclusively on the potential for natural gas 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-

[7] Emissions reductions represent the CO_2 equivalency for natural gas burned as a fuel, not natural gas released to the atmosphere. The estimate includes zero biofuel displacement.

[8] 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

[9] 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.

[10] 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 assume 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.

effective efficiency. Overall, the programs are all cost-effective from a Societal Cost Test (SCT) 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.

ACHIEVABLE POTENTIAL DETAILED RESULTS

This section presents 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 and industrial (C&I) sector
- Costs and program budgets
- Fuel switching measures, which describes the study's limited use of fuel switching measures and their cost-effectiveness results
- Supply curves

A full description of the methodology used to arrive at these results can be found in the "Methodology" section that follows in the report.

RESIDENTIAL

Residential Savings

Cumulative results through 2029 for the residential sector are presented by program in Table 6 below. The largest share of savings (51%) is from the Retrofit program, followed by Residential Products (30%) and New Construction (9%). Fuel switching measures accounted for 11.7% of the total residential savings.

Table 6 | Cumulative Residential Savings by Program, 2029

Program	Efficiency Savings (MMBtu)	Savings From Fuel-Switching (MMBtu)	Total Savings (MMBtu)
Residential New Construction	36,743	4,371	41,114
Residential Retrofit	193,211	28,769	221,980
Residential Products	112,651	17,713	130,364
Residential Low Income	21,012	0	21,012
Residential Behavior	20,513	0	20,513
Total	**384,129**	**50,853**	**434,982**

Residential gas savings are limited to space heating and water heating, as potential savings from cooking and appliances are negligible. Figure 2 shows the 2029 cumulative savings by end use.

Figure 2 | Residential Natural Gas Savings by End Use, 2029

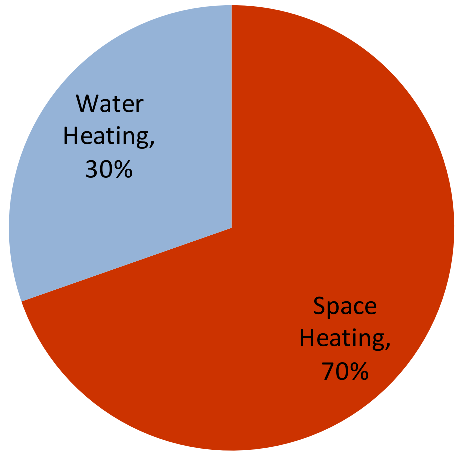


Table 7 shows the top natural gas measures generating savings under the achievable potential analysis. Of these measures, space heating accounts for 61% of the gas savings (seven measures), with an additional 17% from water heating (three measures). The top five measures represent nearly half of all cumulative residential sector savings by 2029. Twenty-five measures account for the remaining 22% savings.

Table 7 | Residential Top Saving Measures, 2029

Measure Name	Cumulative MMBtu (2029)	Percent of Total	BCR
WiFi T-stats - NG	56,220	13%	4.3
Air Sealing, Natural Gas -Heat	50,828	12%	5.1
Wall Insulation, Natural Gas -Heat	39,099	9%	3.0
Attic Insulation, Natural Gas -Heat	33,532	8%	1.9
Gas Furnace ESTAR	28,841	7%	8.7
Res FF Heat/Room AC to DMSHP -gas, heat	28,769	7%	1.6
Duct Sealing, Natural Gas -Heat	28,672	7%	5.4
Faucet Aerator -Gas	27,192	6%	10.9
Integrated hot water heater replace tankless coil -Gas	23,685	5%	2.2
Res Heat Pump Water Htr replace Gas	22,085	5%	1.7
Total	**338,921**	**78%**	

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).

All of the proposed residential programs are cost effective through 2029 from a Societal Cost Test (SCT) perspective, as shown in Table 8. Program-level benefit-cost ratios (BCRs) range from 1.9 to 3.2. At the sector level, the residential programs have an aggregate BCR of 2.3 representing $65.5 million in present-value net benefits.[11]

The results in Table 9 reflect a Utility Cost Test (UCT) perspective. These cost-effectiveness tests are further described in the "Methodology" section of the report. All of the programs are cost effective, including the low income program with a BCR of 1.3. The sector level UCT BCR is 1.6. The programs' cumulative net benefits through 2029 are $26 million.

Table 8 | Residential Societal Cost Test Economics by Program, 2015-2029

Program	Costs (Million$)	Benefits (Million$)	Net Benefits (Million$)	BCR
Residential New Construction	$4.0	$11.0	$7.0	2.7
Residential Retrofit	$33.9	$63.3	$29.3	1.9
Residential Products	$10.3	$32.7	$22.4	3.2
Residential Low Income	$2.6	$7.1	$4.5	2.7
Residential Behavior	$1.1	$3.5	$2.4	3.1
Total	**$52.0**	**$117.5**	**$65.5**	**2.3**

Table 9 | Residential Utility Cost Test Economics, by Program, 2015-2029

Program	Costs (Million$)	Benefits (Million$)	Net Benefits (Million$)	BCR
Residential New Construction	$2.8	$6.7	$4.0	2.4
Residential Retrofit	$28.0	$35.0	$7.0	1.2
Residential Products	$6.2	$19.8	$13.6	3.2
Residential Low Income	$2.8	$3.6	$0.8	1.3
Residential Behavior	$1.2	$1.9	$0.7	1.6
Total	**$41.0**	**$67.0**	**$26.0**	**1.6**

[11] 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 AND INDUSTRIAL

C&I Savings

Cumulative results through 2029 for the commercial and industrial (C&I) sector are presented by program in Table 10. The C&I Retrofit Program achieves the majority of energy savings, with 71% of the sector total, followed by New Construction (20%) and Equipment Replacement (9%). The large savings from the C&I Retrofit Program are due primarily to industrial savings, which are all accounted for in the retrofit program. Fuel switching measures accounted for 10.5% of the total C&I savings.

Table 10 | Cumulative C&I Savings by Program, 2029

Program	Efficiency Savings (MMBtu)	Fuel-Switching Savings (MMBtu)	Total Savings (MMBtu)
C&I New Construction	110,402	26,645	137,047
C&I Retrofit	443,568	38,146	481,713
C&I Equipment Replacement	56,733	6,983	63,715
Total	**610,703**	**71,773**	**682,476**

Figure 3 shows the natural gas savings from the commercial and 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 46% of the total C&I savings. Of the commercial measures, space heating makes up 34% of the total C&I savings, with water heating at 16%.

Figure 3 | Commercial Natural Gas Savings by End Use, 2029

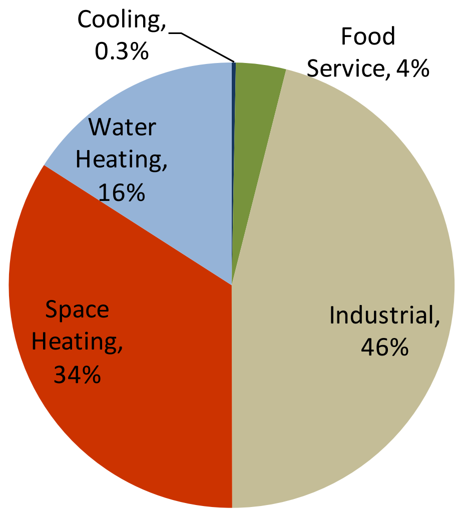


Table 11 presents the top saving measures in the commercial sector; the industrial measures are not included since they are highly aggregated.[12] None of the commercial measures are dominant in terms of sector savings. Instead, the top saving measures range from 9% to 4% of the total 2029 commercial potential and represent 61% of the total savings.

Table 11 | Commercial Natural Gas Top Saving Measures, 2029

Measure Name	Cumulative MMBtu (2029)	Percent of Total	BCR
Integrated bldg design Tier I -NG	36,775	9%	4.3
High-efficiency boiler -NG	34,702	9%	9.6
Envelope Upgrade - NG	30,957	8%	6.8
High-efficiency natural gas furnace	28,110	7%	12.1
Com Boiler/Unitary AC to VRF -gas, heat	23,168	6%	4.5
Com Heat Pump Water Htr replace Gas DHW	20,932	5%	2.0
Gas HE tank-type water heater	20,912	5%	2.6
Com Solar DHW offsets Gas	18,832	5%	2.0
Indirect water heater, natural gas heat	17,867	4%	5.2
Boiler reset controls, NG	16,808	4%	16.9
Total	**249,063**	**61%**	

*Industrial measures are not included, since they are highly aggregated

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 12, all of the proposed C&I programs are cost-effective through 2029 from a Societal Cost Test (SCT) perspective. The benefit-cost ratios (BCRs) range from 2.8 (C&I New Construction) to 5.3 (Equipment Replacement). At the sector level, the C&I programs have an aggregate BCR of 3.3 representing $120.4 million in net benefits through 2029. 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.

[12] 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.

Table 12 | C&I Societal Cost Test Economics by Program, 2015-2029

Program	Costs (Million$)	Benefits (Million$)	Net Benefits (Million$)	BCR
C&I New Construction	$17.2	$47.5	$30.3	2.8
C&I Retrofit	$31.1	$106.4	$75.4	3.4
C&I Equipment Replacement	$3.4	$18.2	$14.8	5.3
Total	**$51.7**	**$172.1**	**$120.4**	**3.3**

The results in Table 13 reflect a Utility Cost Test perspective. As with the SCT results, all of the programs are cost-effective with BCRs ranging from 1.7 (New Construction) to 5.4 (Equipment Replacement). The sector level Utility Cost Test BCR is 2.1. The programs' cumulative net benefits through 2029 are $46.5 million.

Table 13 | Commercial and Industrial Utility Cost Test Economics by Program, 2015-2029

Program	Costs (Million$)	Benefits (Million$)	Net Benefits (Million$)	UCT BCR
C&I New Construction	$11.4	$19.2	$7.8	1.7
C&I Retrofit	$27.2	$57.2	$30.0	2.1
C&I Equipment Replacement	$2.0	$10.7	$8.7	5.4
Total	**$40.6**	**$87.1**	**$46.5**	**2.1**

PROGRAM BUDGETS

Table 14 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 continue to grow with the sales forecast (see Figure 1). We assume that program annual budgets will increase in step with the increased sales, which results in increasing annual incremental savings (see Table 3). Also, the budgets are presented in nominal dollars, assuming an inflation rate of 2%. For additional information about program budget development, see the "Achievable Potential Scenario" description under the "Methodology" section of the report.

Table 14 | Budgets by Sector (Nominal Thousand$)

Sector	2015	2016	2017	2018	2019	2020	-	2029
Residential	$2,446	$2,963	$3,475	$3,581	$3,696	$3,803		$4,611
C&I	$2,383	$2,889	$3,393	$3,498	$3,608	$3,779		$4,686
Total	**$4,829**	**$5,852**	**$6,867**	**$7,079**	**$7,305**	**$7,582**		**$9,297**

Note: Budgets for years 2021-2028 are omitted from the table for simplicity. The budgets continue to rise from 2021 through 2029, due mainly to growth in the sales forecast. Annual program budgets for all years can be found in Appendix G.

Table 15 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 15 | Residential Budgets by Program (Nominal Thousand$)

Program	2015	2016	2017	2018	2019	2020	-	2029
Residential New Construction	$195	$218	$239	$245	$251	$256		$305
Residential Retrofit	$1,562	$1,958	$2,358	$2,436	$2,520	$2,599		$3,164
Residential Products	$440	$494	$541	$553	$566	$578		$691
Residential Low Income	$157	$196	$236	$244	$253	$261		$317
Residential Behavior	$92	$96	$99	$103	$106	$109		$133
Total	**$2,446**	**$2,963**	**$3,475**	**$3,581**	**$3,696**	**$3,803**		**$4,611**

Note: Budgets for years 2021-2024 are omitted from the table for simplicity and are similar to budgets presented for years 2020 and 2029.

As shown in Table 16, the C&I Retrofit program has the highest budget, driven largely by the industrial subsector. The Equipment Replacement budget is the lowest, owing to the fact that there are relatively few natural gas measures in the replacement market, and the number of equipment replacement opportunities is substantially reduced by early-retirement retrofit measures.

Table 16 | C&I Budgets by Program (Nominal Thousand$)

Program	2015	2016	2017	2018	2019	2020	-	2029
C&I New Construction	$732	$850	$974	$1,021	$1,064	$1,078		$1,293
C&I Retrofit	$1,498	$1,872	$2,239	$2,297	$2,362	$2,518		$3,176
C&I Equipment Replacement	$152	$167	$180	$181	$182	$183		$216
Total	**$2,383**	**$2,889**	**$3,393**	**$3,498**	**$3,608**	**$3,779**		**$4,686**

Note: Budgets for years 2021-2024 are omitted from the table for simplicity and are similar to budgets presented for years 2020 and 2029.

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. 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.

Table 17 shows the fuel switching measures included in the study and the results of cost-effectiveness testing based on the Societal Cost Test. The measures fall into three categories: heat pumps for space conditioning, heat pumps for water heating, and solar hot water. Regarding heat pumps for space conditioning, we assume these are being installed where cooling already exists or would be installed, so these would not add new cooling load. We also assume that heat pumps for space heating would be supplemented by a backup heating source, as is normally necessary for the coldest temperatures.[13] 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.

Table 17 | Fuel Switching Measures

Sector	Type	Measure	Market	Cost-Effective
Residential Market Rate	Space Conditioning	Res Fossil Fuel Heat/Room AC to Ductless Mini-Split Heat Pump -Gas Heat	Retrofit	Yes
	Water Heating	Res Heat Pump Water Heater replace Gas	New Construction	Yes
			Replacement	Yes
			Retrofit	No
		Res Solar DHW replaces Gas	Retrofit	No
Residential Low Income	Water Heating	Res Heat Pump Water Heater replace Gas	Replacement	Yes
Commercial	Space Conditioning	Com Boiler/RoomAC to Ductless Mini-Split Heat Pump - Gas Heat	Retrofit	Yes
	Space Conditioning	Com Boiler/Unitary AC to Variable Refrigerant Flow Heat Pump -Gas Heat	New Construction	Yes
	Water Heating	Com Heat Pump Water Heater replace Gas	New Construction	Most *
			Replacement	Most *
			Retrofit	Most *
		Com Solar DHW offsets Gas	Retrofit	Half *

[13] Air source heat pumps will typically require a backup heating source for very cold conditions. Often this is provided by electric resistance heating coils in the heat pump unit. However, when fuel switching the option to retain the existing gas heating system as a backup source can be the most cost-effective choice for consumers. If that were done, the benefits from gas savings we estimate would be somewhat less. This is because gas avoided costs assume a typical space heating load shape and include significant costs related to peak day usage.

* Passes in most or about half of commercial building types.

Cost-effective fuel switching measures could dominate the economic potential, since they save 100% of the natural gas that they displace. To prevent the analysis from not considering any gas efficiency opportunities, we limited the measure penetrations so that the measures would not represent more than about 5% of the end-use savings in each sector. The same approach was applied to the achievable potential.

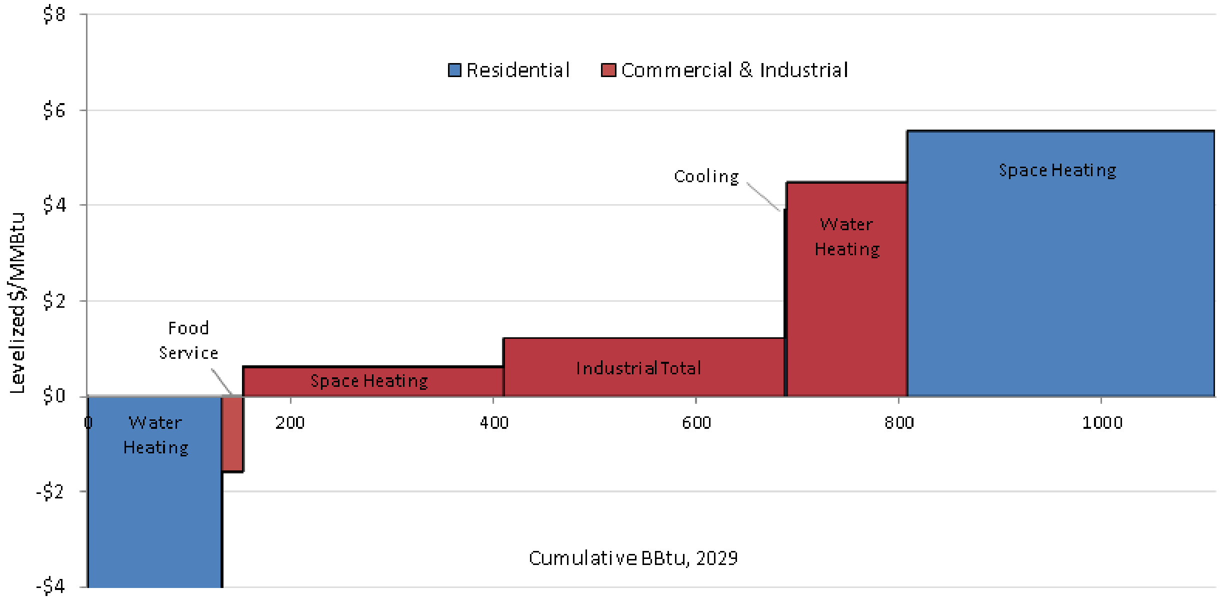
SUPPLY CURVE

The figure below shows the cost curve for energy savings 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 15 (2029), 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 natural gas, 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 cost, which ignores the non-gas benefits. The net levelized cost is also more comparable to the avoided costs of gas savings, since it reflects the measures' non-gas benefits. In contrast, a measure's gross levelized cost might be considerably higher than the avoided costs of gas savings, since the gross cost ignores the non-gas benefits.

The study found that achievable costs of efficiency start at negative $4.10/MMBtu of savings from residential water heating improvements. The negative net levelized cost value reflects the value of non-gas resource savings (such as water or maintenance savings), which are greater than the incremental costs for some measures.

Figure 4 | Natural Gas Supply Curve



The supply curve demonstrates that the opportunities for natural gas savings are fairly balanced between end uses. Food service and cooling are exceptions, accounting for relatively minimal savings potential. Space heating in both the C&I and residential sectors provides significant opportunities for natural gas savings, part of an overall distribution that roughly reflects consumption patterns. Residential water heating represents a significant 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.

SENSITIVITY ANALYSIS

Sensitivity analyses assess the impact of changing a key input variable. This study included a sensitivity analysis to examine the impact that higher avoided energy supply costs would have on the potential assessment. The sensitivity scenario demonstrates the value that would come from the increased benefits of future energy savings.

Higher avoided costs reflect the possibility that the cost of energy may increase due to market disruptions. Projected avoided costs of electricity and natural gas have decreased in recent years due to the sharp decline in the cost of natural gas. The economic recession that started in 2008 reduced demand for energy in general and also suppressed the cost of energy.

We modeled the impact of increased avoided costs to determine the associated changes to measure and program cost-effectiveness and net benefits. In general, the sensitivity case does not change whether individual measures pass or fail cost-effectiveness screening, except for a few marginal measures (i.e., those with a benefit-cost ratio close to 1.0). Therefore, the impact on overall savings is generally quite low.

For the case of 50% higher avoided costs, several C&I measures passed cost-effectiveness in one to three additional building types: heat pump water heaters in the new construction and natural replacement markets, point-of-use water heaters in new construction, solar hot water and ozone laundry in retrofit, and high-efficiency tank-type water heaters in all markets.. Adding these measures to the analysis for the limited number of building types had a small impact on total costs and energy savings. In the residential sector, heat pump water heaters passed for market rate residences, providing significant additional potential for this fuel-switching measure.

Table 18 shows the results for the sensitivity scenario. The benefits are much higher than in the base case, which results in substantially higher BCRs for all programs. The overall portfolio BCR is 3.2, compared to 2.8 in the base case. Total net benefits increased from $186 million to $272 million, or 46%, reflecting the increased value of energy savings.[14]

[14] The increase in benefits is less than 50% because the value of externalities, and the avoided costs for water savings, remained the same as for the base case.

Table 18 | Sensitivity for 50% Higher Avoided Costs, 2029

	Sensitivity Scenario				Base Case			
Program	**Costs (Million$)**	**Benefits (Million$)**	**Net Benefits (Million$)**	**BCR**	**Costs (Million$)**	**Benefits (Million$)**	**Net Benefits (Million$)**	**BCR**
Res New Construction	$4.0	$14.7	$10.7	3.7	$4.0	$11.0	$7.0	2.7
Res Retrofit	$36.7	$84.6	$47.9	2.3	$33.9	$63.3	$29.3	1.9
Res Products	$10.3	$43.5	$33.2	4.2	$10.3	$32.7	$22.4	3.2
Res Low Income	$2.6	$9.4	$6.8	3.6	$2.6	$7.1	$4.5	2.7
Res Behavior	$1.1	$4.6	$3.5	4.1	$1.1	$3.5	$2.4	3.1
C&I New Construction	$18.6	$64.7	$46.1	3.5	$17.2	$47.5	$30.3	2.8
C&I Retrofit	$47.9	$151.5	$103.6	3.2	$31.1	$106.4	$75.4	3.4
C&I Equip. Replacement	$3.9	$24.6	$20.6	6.2	$3.4	$18.2	$14.8	5.3
Total	**$125.2**	**$397.5**	**$272.3**	**3.2**	**$103.7**	**$289.6**	**$186.0**	**2.8**

While the avoided costs do not have a large impact on the measures that pass cost-effectiveness screening, they can make the difference for marginally cost-effective measures in the future. Both emerging and long-standing technologies that are marginally cost-effective should be re-evaluated as avoided energy supply costs fluctuate over time.

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:

- Assess the natural gas sales (or usage) forecast to derive an adjusted forecast that includes only the energy available for building efficiency opportunities, and which reflects expected sales assuming no efficiency programs are operating in the future. This adjusted 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[15]
- 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 provided by VGS for each sector for the 15-year study period. The sales forecast was then disaggregated by end use and building type in order to

[15] 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

apply each efficiency measure to the appropriate segment of 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 valves 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"[16]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 15-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 15-year study period, different assumptions regarding the rate at which retrofit opportunities are captured would change the cost and benefit outcomes, but not the total energy savings potential over the study period.

[16] Assumptions for fuel switching measures were made separately. See the fuel switching measure description 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.

NATURAL GAS SALES FORECAST

The natural gas forecast was developed using a sales forecast provided by VGS. Several adjustments were made to the VGS forecast to develop both an adjusted forecast for purposes of the potential analysis and for use as a reference forecast for purposes of reporting efficiency potential as a fraction of forecast sales. Table 19 below summarizes these adjustments. First, both the reference forecast and the adjusted forecast include an amount of efficiency savings assumed to result from "business-as-usual" (BAU) efficiency efforts, based on VGS' recent performance.[17] Second, the adjusted forecast is created from the reference forecast by removing the consumption attributable to consumers to whom efficiency programs are not applicable. Because the top-down approach to determining potential begins from total applicable energy consumption, including their usage would overstate potential.

The resulting adjusted forecast represents a weather normalized forecast with an average annual growth rate of 1.98% per year. Appendix B provides the gas sales forecast by sector and year.

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[17] The BAU efficiency in the VGS forecast was based on the average of VGS reported savings for 2009-2014, but excluding 2011 as an outlier due to its relatively high savings (presumably due to one or more exceptionally high-savings projects). Future annual BAU savings were projected to increase in proportion to growth in the sales forecast.

Table 19 | Sales Forecast Adjustments

Forecast Component	VGS Sales Forecast	Reference Forecast for Reporting "% of Forecast"	Adjusted Forecast for Top-Down Potential Analysis
BAU energy efficiency	excluded*	add back in	add back in
Opt-out (IBM) sales	included	include	remove
Compressed Natural Gas sales	included	include	remove
Transportation	included	exclude	exclude
Phase 1 expansion (Middlebury & Vergennes)	included	include	include
Phase 2 expansion (Shoreham & Cornwall)	excluded	exclude	exclude

* "Excluded" BAU efficiency means that the VGS sales forecast assumes that business-as-usual energy efficiency will continue to take place, reducing the volume of gas sales.

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),[18] and the most recent American Community Survey from the U.S. Census Bureau.[19] Low income usage was segmented based on VGS' 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.

For the commercial sector, Vermont-specific data on gas 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.[20] 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 gas, the analysis estimated the natural gas 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 disaggregated 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 (1995-2001) in housing units for Vermont from the U.S. Census Bureau Building Permits Survey.[21] 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, and we assume these account for less than 10% of residential building energy. Some MF shared systems

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[18] 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

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

[20] 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

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

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.

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 assume the forecast represents the best estimate of future weather normalized loads and reflects 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 66 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, 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 retrofit measures, often we model a baseline efficiency shift at the time when the retrofit measure being replaced is assumed to have needed to be replaced anyway.

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 452 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. 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.[22] 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, direct research into incremental costs, and other analyses and databases that are publicly available.

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 more fully described below in the potential analysis section, along with other factors that merge the measure level engineering data with the top-down forecast of applicable loads to each measure.

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 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.

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

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 below 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 gas 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.

- **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 assume average existing equipment being replaced for retrofit measures is at 60% of its estimated useful life.
- **Annual Net Penetrations** are the difference between the base case measure penetrations and the measure penetrations that are assumed for an economic potential. For the economic potential, it is assumed that 100% penetration is captured for all markets, with retirement 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 total potential for each measure permutation. 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*,[23] though Vermont has customized its Societal Cost Test.[24]

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

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23 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

24 The Vermont Societal Cost Test is similar to the Total Resource Cost Test. The Societal 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 along with a risk adjustment to account for the diversification benefits of energy efficiency measures and programs.

Table 20 | 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).[25] For discounting purposes we assume that initial measure costs are incurred at the beginning of the year, and that annual energy savings are incurred, on average, half way through the year.

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:

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

$$\text{Net savings} = \text{Gross savings} * (1 - FR + SO) = \text{Gross savings} * NTGR$$

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 15-year study period. Table 21, 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 avoided costs provided by Vermont Gas Systems, which were developed from those contained in the *Avoided Energy Supply Costs in New England: 2013 Report*.[26] 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.[27]
- Did not include the avoided costs of price suppression, or demand reduction induced price effect (DRIPE).

The study used two natural gas avoided cost categories, for heating and non-heating usage. The avoided costs for gas saved by heating equipment are substantially higher than for non-heating equipment due to the higher cost of meeting peak demand during the heating season. The avoided costs are provided in Appendix A.

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.

[26] "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.

[27] 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.

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 applied to 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 first measure is applicable in all situations, it would have 100% penetration and all other competing measures would show no potential. If on the other hand, the first 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.

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 of 7% per year through year 15. This effectively represented capturing all retrofit opportunities over the 15-year study period. With these assumptions the economic potential 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 (new construction, renovation, and/or natural replacement) and which have measure lives longer than 15 years, the turnover rate is such that not all of the economic potential will be captured over the 15-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 5% (1/20th) of the market turns over every year, so the entire market would not be replaced within the 15-year study period. For this measure the 15-year economic potential would be less than the 20-year economic potential.

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 that generally correspond to VGS' existing efficiency programs, but with the separation of a Residential Low Income program due to its unique characteristics. In addition, a separate Residential Behavioral program was used for an Opower-like residential program. The resulting programs included:

- Residential New Construction
- Residential Products
- Residential Retrofit
- Residential Low Income

- Residential Behavioral
- C&I New Construction
- C&I Equipment Replacement
- C&I Retrofit

The Residential Behavioral program and its savings are based on existing energy efficiency behavioral modification initiatives that use customer feedback and guidance to encourage saving energy; it assumes a fixed percentage of total residential energy usage for potential savings. We did not include program start-up costs, assuming any such costs would be amortized by the provider. A behavioral program would not necessarily be limited to VGS customers, as it could potentially be implemented in cooperation with EVT or at a statewide level, though we have not assessed that possibility.

While a C&I behavioral or Continuous Energy Improvement (CEI) program was considered, the number of C&I gas customers was considered to be too small to support such a program. A more likely scenario would be to have such a program supported on a broader scale, including electric efficiency and not limited to the VGS service territory – however, that scenario would be outside the scope of this project.

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. Table 21 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 program incentive and non-incentive costs for VGS (for 2012-2014, with 2014 being projected costs), and for EVT, Massachusetts, and Rhode Island for 2013. As a result of this review, program incentive and non-incentive costs were broken out as shown in the table below, with the same ratios used for all program years.

Table 21 | 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%	0.90
Residential Products	33%	71%	29%	0.90
Residential Retrofit	54%	53%	47%	0.75
Residential Low Income	100%	71%	29%	1.00
Residential Behavioral	100%	87%	13%	1.00
C&I New Construction	46%	56%	44%	0.80
C&I Natural Replacement	33%	59%	41%	0.80
C&I Retrofit	57%	51%	49%	0.80

RECOMMENDATIONS

In this section we provide several general recommendations for the natural gas efficiency programs, based on the findings of this study.

Develop a Better Understanding of VGS Program Results

Our initial review suggests that VGS's programs appear to deliver savings for lower costs (as measured in dollars per MMBtu saved) than other well-established gas programs in the northeast, such as in Massachusetts, Connecticut, and Rhode Island. On the other hand, VGS's savings as a percentage of sales are lower than some of these jurisdictions. To the extent that these data suggest VGS could expand their portfolio and acquire greater amounts of cost-effective savings, the first step is to better understand the underlying drivers.

Table 22 | Depth and Cost of Savings in Northeast Jurisdictions[28]

Jurisdiction	Depth of Savings (% of Annual Sales)	Cost of Savings ($/Annual MMBtu)
Vermont Gas	0.6%	$33
Massachusetts (Mass Save)	1.2%	$62
Columbia Gas	1.1%	$71
Rhode Island	0.9%	$59
Connecticut	0.4%	$43

There are a variety of possible causes for this result including cost accounting methods, savings verification protocols, evaluation study or TRM values, geographic, and climatic differences. We know for instance that not all energy efficiency program expenses are included in VGS reported costs, that VGS net-to-gross factors have not been evaluated, and that commercial savings claims have not been verified. Each of these factors has the potential to change the cost of savings significantly. When the Massachusetts gas program administrators first moved from deemed values and evaluated their gas programs in 2010 at the portfolio level, they experienced claimed savings reductions of over 15 percent. This significantly raised their cost to achieve savings. An effort should be made to better understanding what drives the costs of VGS's programs and the differences from other utilities and states. In addition to promoting better comparisons with other jurisdictions, this effort could also identify of areas of best

[28] Net savings were used to calculate values in this table. For VGS, Net-to-Gross ratios were adjusted based on those reported in the VGS IRPs.

practice and program strengths within VGS, which could then be leveraged for greater performance across the entire portfolio.

Develop More Detailed Reporting

In support of the above recommendation, VGS reporting should be expanded to provide more complete and detailed data regarding their programs. At a minimum, annual reports should include estimates of both net and gross savings for every program, with supporting information on net-to-gross, free-rider, and spillover assumptions and values. Savings as percentage of sales should be presented by sector and for the entire portfolio. Measure cost and savings estimates and assumptions should be documented, as in a TRM.

Enhance Cooperative Delivery of Programs with EVT and BED

One of the best practice recommendations that we make most frequently is for comprehensive multi-fuel efficiency programs that provide customers with a single point-of-contact and resource to address their energy usage. Rather than ask customers to work with two separate entities, a comprehensive program provides bundled incentives and technical support for a comprehensive, multiple end use, multiple fuels approach. This does not require new programs, but rather increased participation in energy efficiency-related market events and transactions that are occurring every day.

VGS has already done this with some of its programs, but it could still look for additional opportunities to combine energy efficiency projects with the two electric utilities that have a long history of outstanding efficiency performance, Efficiency Vermont (EVT) and Burlington Electric Department (BED). There are areas in which VGS should consider working more closely with EVT and BED.

- *Extending behavioral programs to include gas consumption* – This may be a particularly valuable area for collaboration, as VGS's customer base may be too small to attract interest from larger firms like Opower and Tendril.
- *Upstream buydown opportunities* – For measures and services that may reduce both electric and gas consumption, working with an electric utility to jointly fund upstream efforts to reduce the costs of those products could result in more cost-effective savings and lower program costs.
- *Achieving deeper reductions for participants* – By agreeing to explicitly inform each other's customers of additional energy savings opportunities available through other energy utilities, VGS and the electric utilities can increase the number of "leads" from interested and motivated customers.

Provide More Targeted Services to Commercial Customers

Another area of best practice program design is in providing services to commercial and industrial (C&I) customers that address their specific energy needs and operating characteristics. Because the Vermont C&I sector is far more diverse and each segment potentially limited in number than the residential sector, it is not practical to create separate programs to address the specific barriers and technologies of each sub-sector. Customers would face program offerings that are difficult to decipher and program administrators would find themselves struggling to manage and implement an overly complicated program suite. As a result, we typically propose three broad programs in the C&I sector, based on the most fundamental differences in the decision processes of this diverse array of customers. Instead of separate programs, the market barriers specific to certain subsectors of C&I are addressed by including multiple initiatives within each program. Initiatives are targeted in two ways. Some are directed at specific types of harder-to-reach C&I customers that may otherwise participate at very low rates. Others combine a ready set of packaged measures and services made accessible to customers with the greatest potential. In both cases the particular customized solution to customer needs is addressed without having two distinct programs.

One of the important distinctions that should be made in C&I is by the size of the customer, typically measured by their electric consumption. Small and large customers should be addressed by their own programs both because of their vastly different situations (e.g., facility characteristics, equipment types, purchasing processes, financial situation, and familiarity with energy efficiency) and because certain program approaches may not be cost-effective for both segments. For example, experience shows that one-on-one account management is highly successful in achieving significant cost-effective savings from the largest C&I customers. However, this approach cannot cost-effectively scale to customers with one or a few small-to-medium-sized facilities. Providing services to customers based on their size uses program resources more efficiently.

The results of the potential study can also be used to identify those measures, end-uses, and customer types with the greatest potential for future savings, particularly if combined with more detailed information on the characteristics of previous savings acquired by VGS. The potential study identifies, for example, residential wall insulation as a top measure. If recent program performance has been limited in this area, this may signal an area of opportunity. Conversely, the potential study may also be used to identify program activities that may need to be phased out because of diminishing potential.

APPENDICES

The following appendices are provided in a companion Excel workbook to this report:

A	Avoided Costs
B	Sales Forecast
C	Sales Disaggregation
D	Measure Characterizations
E	Other Analysis Inputs and Assumptions
F	Bibliography and Source Citations
G	Program Budgets