Natural Gas Energy Efficiency Potential in Massachusetts

Final Report

April 22, 2009

Prepared for GasNetworks

By

GDS Associates, Inc.
Engineers and Consultants

And

Summit Blue Consulting

GDS Associates, Inc. • 1850 Parkway Place • Suite 800 • Marietta, GA 30067 • **www.gdsassociates.com**
Marietta, GA • Austin, TX • Auburn, AL • Manchester, NH • Madison, WI • Augusta, ME

Table of Contents

1.0 EXECUTIVE SUMMARY 1
1.1 Energy Efficiency Savings Potential 1
1.2 Overview of Study Methodology 6
2.0 INTRODUCTION 7
3.0 CHARACTERIZATION OF NATURAL GAS USE 8
3.1 Natural Gas Sales 8
3.2 Forecasted Natural Gas Sales 10
3.3 Households and Residential End-Use Saturations 11
4.0 ENERGY EFFICIENCY POTENTIAL METHODOLOGY 12
4.1 Overview of Methodology 12
4.2 General Methodological Approach 14
4.2.1 Core Equations for Estimating Technical Potential 15
4.2.2 Rates of Implementation for Energy Efficiency Measures 16
4.2.3 Achievable Market Penetration Rate Scenarios 17
5.0 RESIDENTIAL SECTOR EFFICIENCY POTENTIAL 20
5.1 Introduction and Summary of Results 20
5.2 Residential Energy Efficiency Measures 21
5.3 Characteristics of Residential Energy Efficiency Measures 22
5.4 Residential Measure Cost Effectiveness 23
5.5 Residential Savings Potential 24
5.6 Market Penetration Scenario Results 26
6.0 COMMERCIAL SECTOR ENERGY EFFICIENCY POTENTIAL 28
6.1 Introduction and Summary of Results 28
6.2 Commercial Sales by Business Segment & End Use 29
6.3 Commercial Energy Efficiency Measures 31
6.4 Characteristics of Commercial Energy Efficiency Measures 35
6.5 Commercial Measure Cost Effectiveness 38
6.6 Commercial Savings Potential 41
6.7 Market Penetration Scenario Results 45
7.0 INDUSTRIAL SECTOR ENERGY EFFICIENCY POTENTIAL 47
7.1 Introduction and Summary of Results 47
7.2 Industrial Sector Segmentation & End Use Breakdown 49
7.3 Industrial Energy Efficiency Measures 53
7.4 Industrial Measure Cost Effectiveness 55
7.5 Industrial Energy Efficiency Potential 58
7.6 Market Penetration Scenario Results 61

List of Appendices

Appendix A – Residential Sector Data
A-1 Residential Energy Efficiency Measure Descriptions
A-2 Residential Sector Measure Data
A-3 Residential Sector Factor Data
Appendix B – Commercial Sector Data
B-1 Commercial Energy Efficiency Measure Descriptions

B-2 Commercial Sector Measure Data
B-3 Commercial Sector Factor Data

Appendix C – Industrial Sector Data

C-1 Industrial Energy Efficiency Measure Descriptions
C-2 Industrial Energy Efficiency Measure Data

Appendix D – Benefit/Cost Model Inputs & Assumptions

ACKNOWLEDGEMENTS

This report was prepared for GasNetworks by GDS Associates, Inc. (GDS), assisted by their subcontractor, Summit Blue Consulting who played a key role in the development of the residential sector energy efficiency potential estimates. GDS would also like to acknowledge the insights, information and critical review of key study inputs and assumptions provided by the GasNetworks' companies and the overall project leadership that was provided by the GasNetworks' project manager, Dave Weber (NSTAR).

NOTICE

This report was prepared by GDS Associates, Inc., in the course of performing work contracted for and sponsored by the GasNetworks Companies. The opinions expressed in this report do not necessarily reflect those of the Sponsors, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, the Sponsors, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. The Sponsors and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

1.0 EXECUTIVE SUMMARY

1.1 Energy Efficiency Savings Potential

This study estimates the potential for natural gas energy efficiency savings in the state of Massachusetts. The study was commissioned by GasNetworks, which is a collaborative consisting of natural gas companies serving residential, commercial and industrial customers throughout New England.

Energy-efficiency opportunities typically are physical, long-lasting changes to buildings and equipment that result in decreased energy use while maintaining the same or improved levels of energy service. For this study, the **cost-effective** energy efficiency potential is defined as the potential over time of energy efficiency measures that are cost effective according to the Total Resource Cost (TRC) test. All measures were screened for cost effectiveness at the measure level, excluding program costs such as administration and marketing. This screening is conducted solely for the purpose of identifying individual measures to be included in the cost-effective natural gas energy efficiency potential, independent of how these measures might ultimately be bundled and included in GasNetworks' programs. The impact on cost-effectiveness of bundling measures into programs, including the addition of program overhead expenses and the effect of measure interactions on overall program savings, is routinely considered by the GasNetworks' member companies in their program planning and review process.

GDS estimated the energy efficiency savings potential for more than 150 natural gas measures in the residential, commercial and industrial sectors. The types of measures for which potential energy efficiency savings are identified include:

- Energy efficient water heaters and related water heating measures such as low flow shower heads, faucet aerators, pipe insulation and heat recovery systems.
- Energy efficient boilers and furnaces and related space heating measures such as pipe insulation, boiler maintenance and control, heat recovery and ventilation control.
- Building envelope improvements including insulation and energy efficient windows
- HVAC controls including programmable thermostats and energy management systems
- Energy efficient cooking including commercial griddles, ovens, broilers, fryers and steamers

- Energy Efficient clothes washers, dryers and commercial laundry systems such as ozone.
- Energy efficient industrial process heating technologies

The technical, economic and achievable economic potential was estimated for each energy efficiency measure. These are defined as follows:

Technical Potential is energy efficiency savings that would result from the complete and immediate penetration of all analyzed energy efficiency measures in applications where they are deemed to be technically feasible, from an engineering perspective.

Economic Potential represents that portion of the total technical potential that is cost effective in accordance with the TRC test.

Achievable Economic Potential is defined as savings that would result given an expected market penetration rate of all technically feasible and cost-effective measures over the ten year study horizon. Because market penetration is highly dependent on program design and delivery, including most importantly incentive levels, GDS did not attempt to estimate specific market penetration rates for individual measures. This can be done more appropriately when new programs are developed or existing programs are enhanced to target measures identified in this study. Instead this study presents a range of achievable potential assuming maximum market penetration rates of 60 and 80 percent. The market penetration rate is defined for this study as the percent of cost-effective, technically feasible energy efficiency measures that will be installed by customers over the 10 year study horizon. The assumed range of market penetration rates is intended to capture likely outcomes of successful, well managed and well funded programs. The 80 percent market penetration scenario would require very aggressive funding, and a concerted, sustained campaign involving highly aggressive programs and market interventions. It should be viewed as a best estimate of the maximum achievable cost effective potential for the natural gas measures included in this study.

The achievable economic potential also reflects the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, it was assumed that existing inefficient equipment will be replaced at the end of the equipment's effective useful life. For example, only half of the boilers with a 20 year useful life are assumed to be replaced over the 10 year study horizon, while all of the natural gas fryers with a 10 year useful life are assumed to be replaced. Market penetration rates of 60 and 80 percent are applied to the equipment that is assumed to be replaced over the 10 year study horizon to determine the number of replaced units that will be energy efficient for each of the market penetration rate scenarios. For purposes of this study, retrofit measures are limited to the application of supplemental measures (such as the

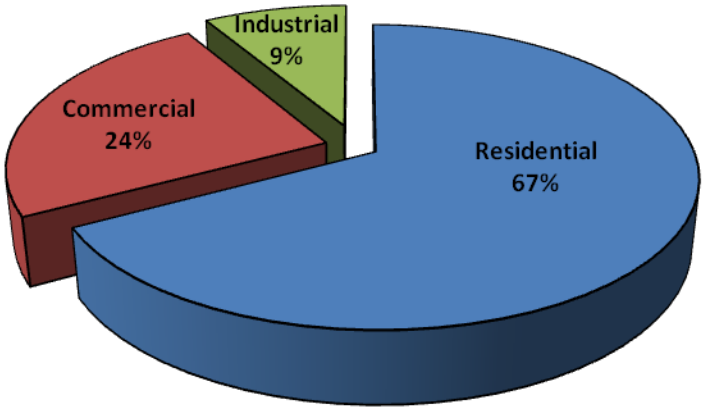
addition of a low-flow device to a showerhead or increased levels of insulation), and do not include the early replacement of operational equipment.

Table and Figure 1-1 below provide a summary of the technical, economic and achievable economic potential estimates for natural gas energy efficiency in the State of Massachusetts for the residential, commercial and industrial sectors. GDS estimates that the total economic potential for natural gas energy efficiency savings in Massachusetts is 81,583,945 MMBtu, which represents approximately 36% of the forecasted retail natural gas sales in 2018. Sixty eight percent (67%) of this economic potential is in the residential sector. It is estimated that with aggressive energy efficiency programs and funding that 50% to 70% of the total economic natural gas energy efficiency potential can be captured by the year 2018.

Table 1-1
Natural Gas Energy Efficiency Potential
State of Massachusetts (MMBtu)

	Technical Potential	Economic Potential	Achievable Economic Potential (80% Scenario)	Achievable Economic Potential (60% Scenario)
Residential	69,869,063	54,812,792	40,075,441	30,940,124
Commercial	21,780,523	19,763,923	12,390,547	7,346,619
Industrial	7,204,215	7,007,230	4,734,653	2,840,792
Total	98,853,801	81,583,945	57,200,641	41,127,535
Percent of 2018 Sales	44.0%	36.3%	25.5%	18.3%

Figure 1-1
Economic Natural Gas Energy Efficiency Potential by Market Sector - Massachusetts



Figures 1-2, 1-3 and 1-4 show the breakdown of economic potential by type of energy efficiency measure for the residential, commercial and industrial sectors respectively. The dominant residential measures are shell insulation, air sealing, high efficiency boilers & furnaces, high efficiency water heaters and hot water use limiting devices (faucet aerators/low flow shower heads). Together they account for 74% of the residential sector economic potential. In the commercial sector a number of different measures offer significant opportunity for savings with heating system and control measures providing 24% of the commercial sector economic potential, followed by building shell and heat recovery measures which each account for 16% of the commercial sector economic potential. Boilers offer the most opportunity for economic energy efficiency potential in the Industrial sector. High efficiency boilers, boiler controls, boiler tune-up and pipe insulation account for 56% of the total industrial sector economic potential.

Figure 1-2
Residential Sector Economic Potential by Measure

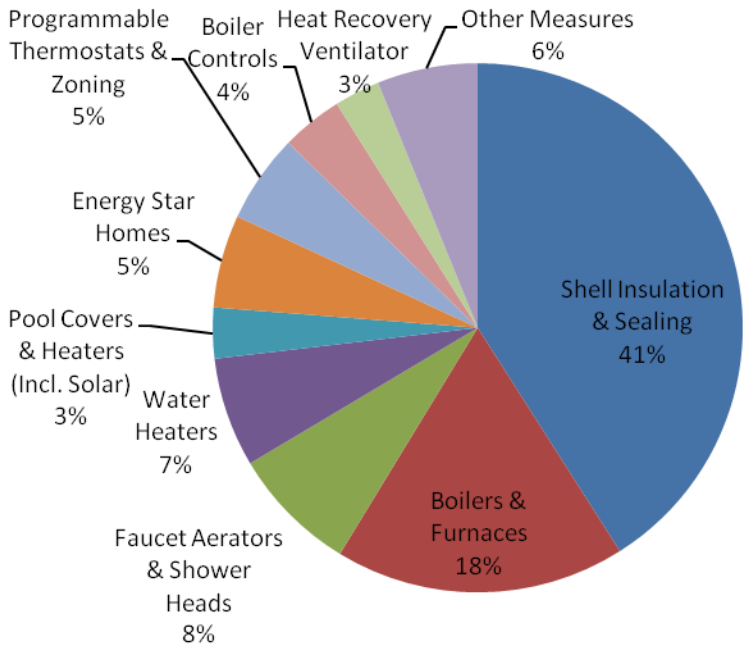


Figure 1-3
Commercial Sector Economic Potential by Measure

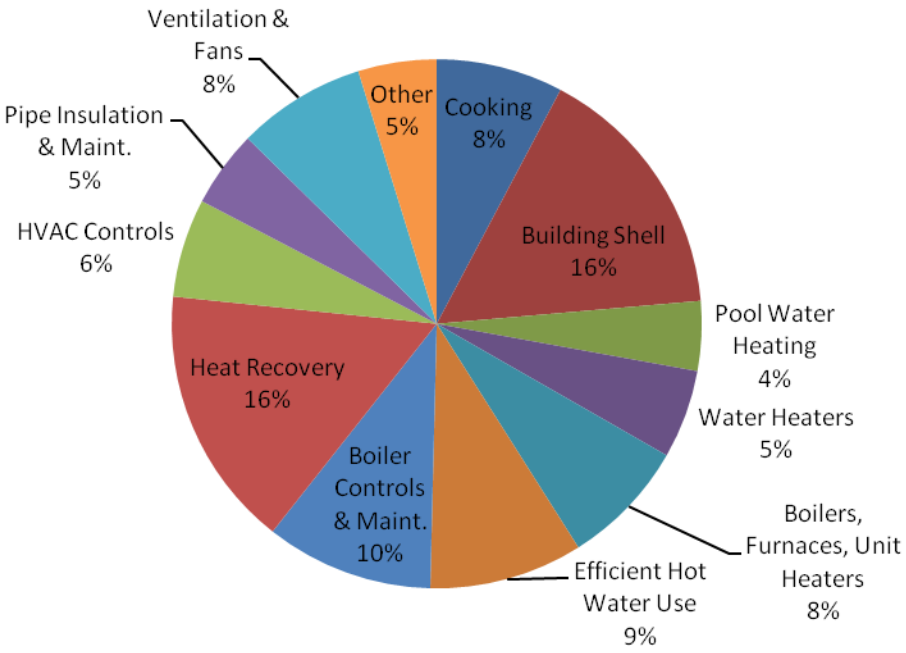
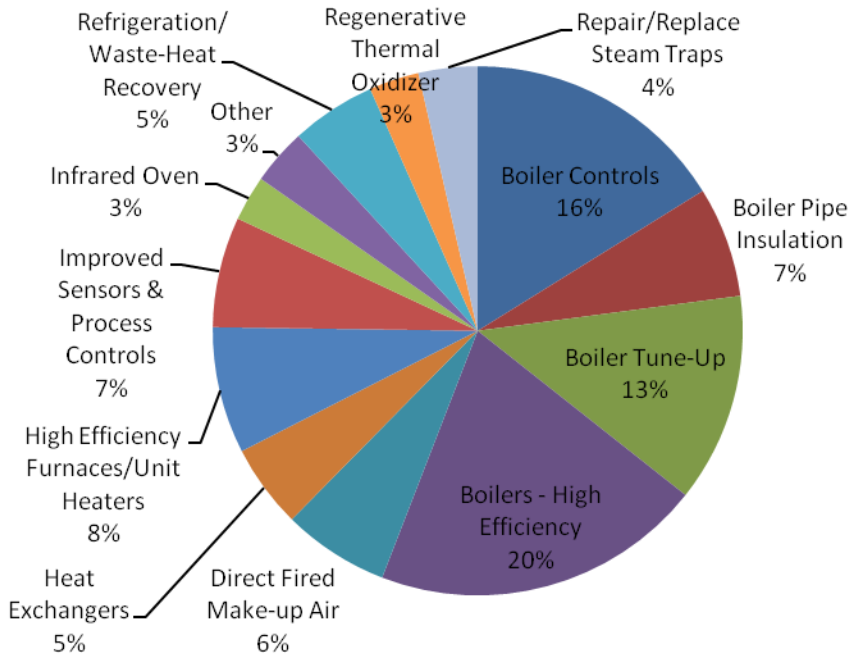


Figure 1-4
Industrial Sector Economic Potential by Measure



1.2 Overview of Study Methodology

The general methodology used for estimating the potential for natural gas energy efficiency in the residential, commercial and industrial sectors included the following major steps:

1. Identify natural gas energy efficiency measures to be included in the assessment.
2. Collect and analyze the baseline and forecasted characteristics of the natural gas end use markets, including residential equipment saturations and commercial and industrial consumption, by market segment and end use.
3. Determine the characteristics of each energy efficiency measure including the saturation of the end-use or percent of applicable gas use to which the measure applies, its incremental or full cost, natural gas savings, associated electric and water savings, the percent of homes or businesses that have already installed the measure, the effective useful life of the measure and its technical feasibility.
4. Screen each measure to determine cost effectiveness according to the Total Resource Cost (TRC) Test
5. Sort measures from most to least cost effective.
6. Estimate technical potential (immediate penetration of all measures) by integrating measure characteristics such as savings factors, base saturations and use, the remaining end uses to be replaced with the measure, and the technical feasibility.
7. Produce estimates of economic potential by removing measures from the technical potential analysis that are not cost-effective.
8. Apply achievable penetration rates and natural equipment replacement rates for market driven measures to determine a range of the achievable economic potential over the ten year study horizon.

2.0 INTRODUCTION

GasNetworks commissioned this study for the purpose of determining the technical and cost-effective potential for natural gas energy efficiency potential in Massachusetts. The study conducted by GDS Associates with the assistance of Summit Blue Consulting examines the potential for an extensive list of energy efficiency measures that are applicable to the residential commercial and industrial customer segments. Energy efficiency potential was assessed over a ten year period from 2009 through 2018.

As with any assessment of energy efficiency potential, this study necessarily builds on a large number of assumptions, from average measure lives, savings and costs, to the discount rate for determining the net present value of future savings. While the authors, with the assistance of GasNetworks, have sought to use the best available data, primary data collection to inform the analysis was not called for in the study scope. Furthermore, while the list of analyzed measures is extensive and represents most, if not all, commercially available and some emerging measures, no attempt was made to forecast future technologies. Also, there was no attempt to place a dollar value on some difficult to quantify benefits that may result from some measures, such as increased comfort or reduced maintenance, which may in turn support some personal choices to implement particular measures that may otherwise not be cost-effective or only marginally so. Thus, the various potential estimates are specific to and limited by the detailed measures lists and assumptions described in this study.

The remainder of this report is organized as follows:

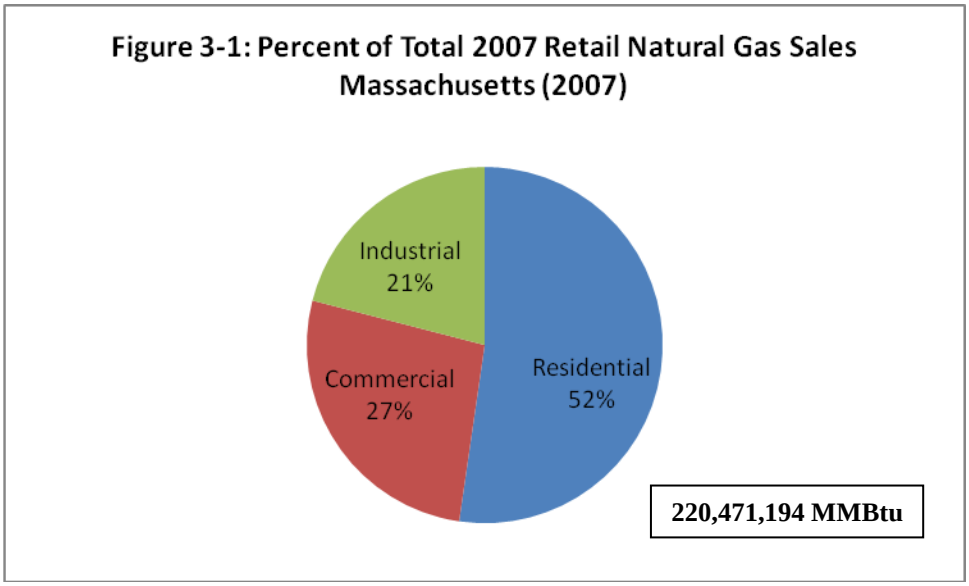
- Section 3 - Characterization of Natural Gas Use
- Section 4 - Energy Efficiency Potential Methodology
- Section 5 - Residential Sector Natural Gas Energy Efficiency Potential
- Section 6 - Commercial Sector Natural Gas Energy Efficiency Potential
- Section 7 - Industrial Sector Natural Gas Energy Efficiency Potential

3.0 CHARACTERIZATION OF NATURAL GAS USE

This section provides an overview of current and projected natural gas use and residential households in Massachusetts that are used in the development of energy efficiency potential estimates. In order to develop estimates of natural gas savings potential, it is important to understand how natural gas is used by households and businesses in Massachusetts.

3.1 Natural Gas Sales

Figure 3-1 shows the breakdown of retail natural gas sales by major customer class (Residential, Commercial, and Industrial) for Massachusetts. This natural gas sales breakdown is based on actual natural gas consumption data reported by the Energy Information Administration.[1] As can be seen, more than half of all retail natural gas sales in Massachusetts are to residential customers, representing a significant potential market opportunity for the implementation of energy efficiency measures.



Estimates of commercial and industrial energy efficiency potential require further breakdown of natural gas sales by commercial business segment and type of industry. The breakdown of commercial natural gas sales by business segment shown in Figure 3-2 is based on the latest available natural gas consumption estimates for the Northeast Census Region and the U.S., where Northeast data

[1] Energy Information Administration, Natural Gas Consumption by End Use, Massachusetts, Annual, January 2009.

is not available.[2] The Office and Other business segments are responsible for approximately 42% of the natural gas sales. The Other business segment includes buildings used for public assembly, public order and safety, religious worship and services such as repair shops, dry cleaners, salons, post offices, postal centers, copy centers, car washes, kennels, laboratories and data centers.

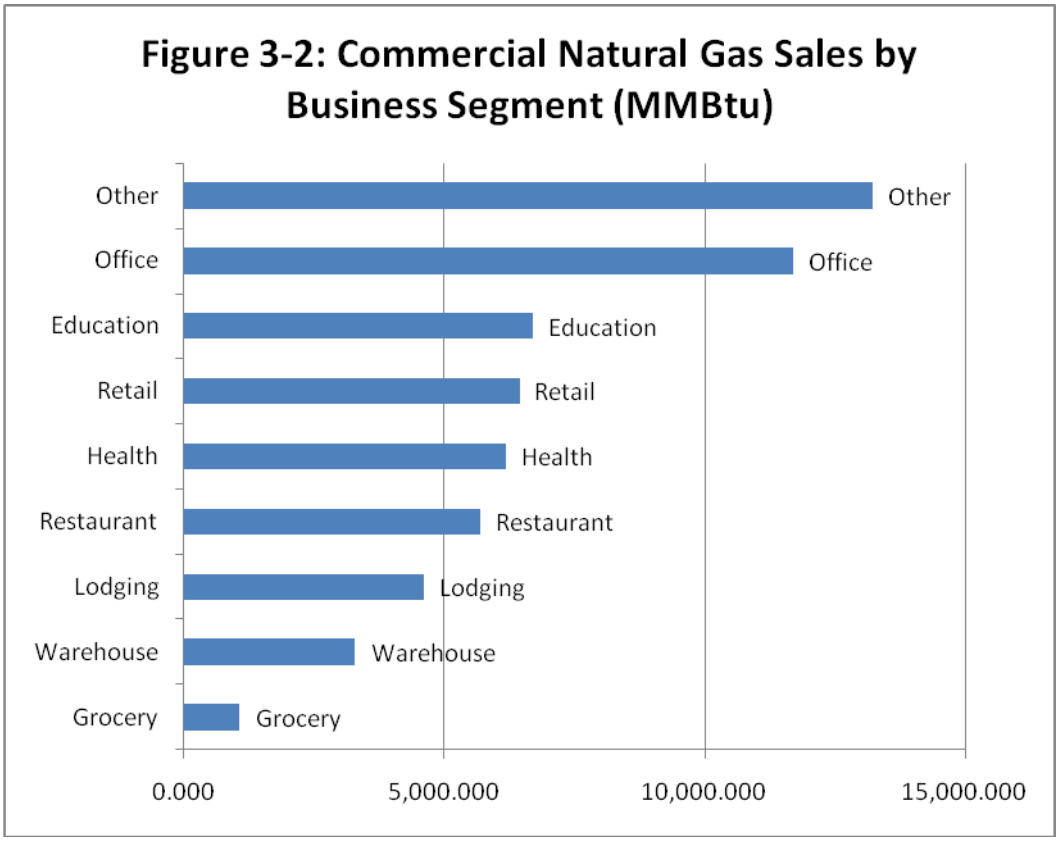
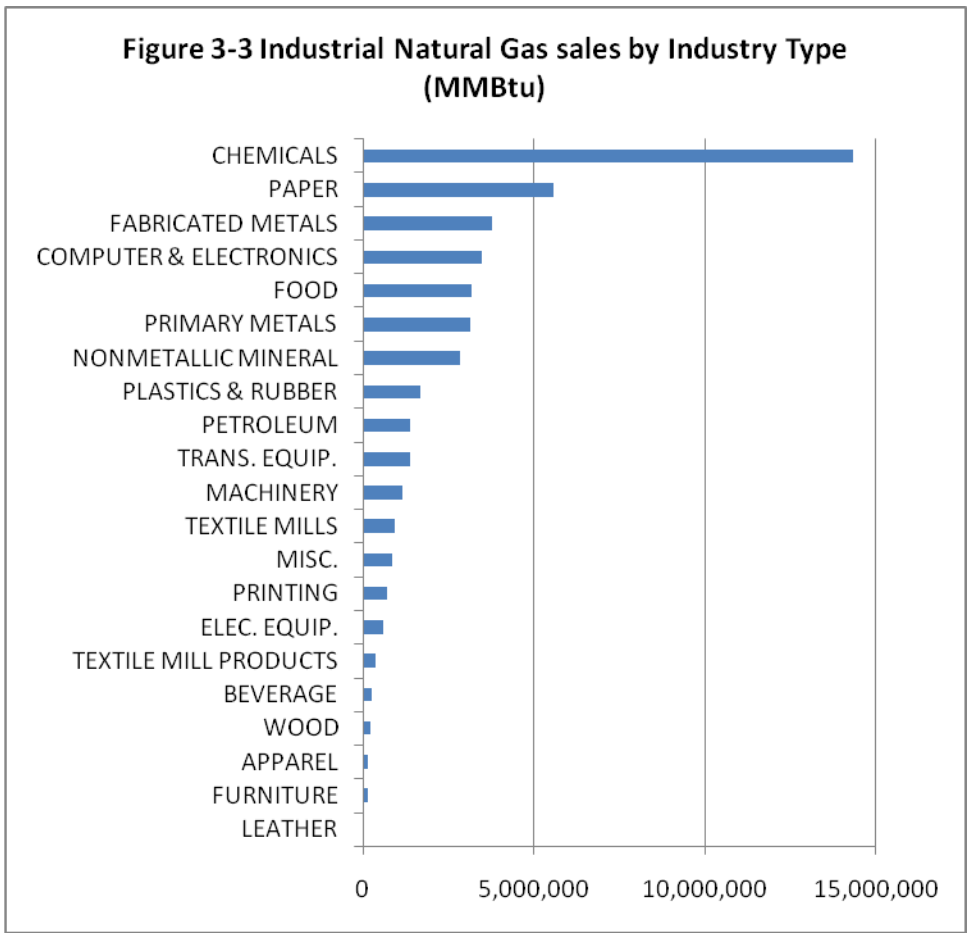


Figure 3-3 below shows the distribution of industrial gas sales by industry type in Massachusetts.[3] The chemicals industry is by far the dominant industrial user of natural gas, consuming more that 14 million MMBTU, which represents nearly 31% of total industrial sales. Other major industrial users of user of natural gas include the paper, fabricated metals, computer and electronics food, primary metal and non-metallic mineral industries. These industries along with chemicals are responsible for 78% of total retail industrial gas consumption.

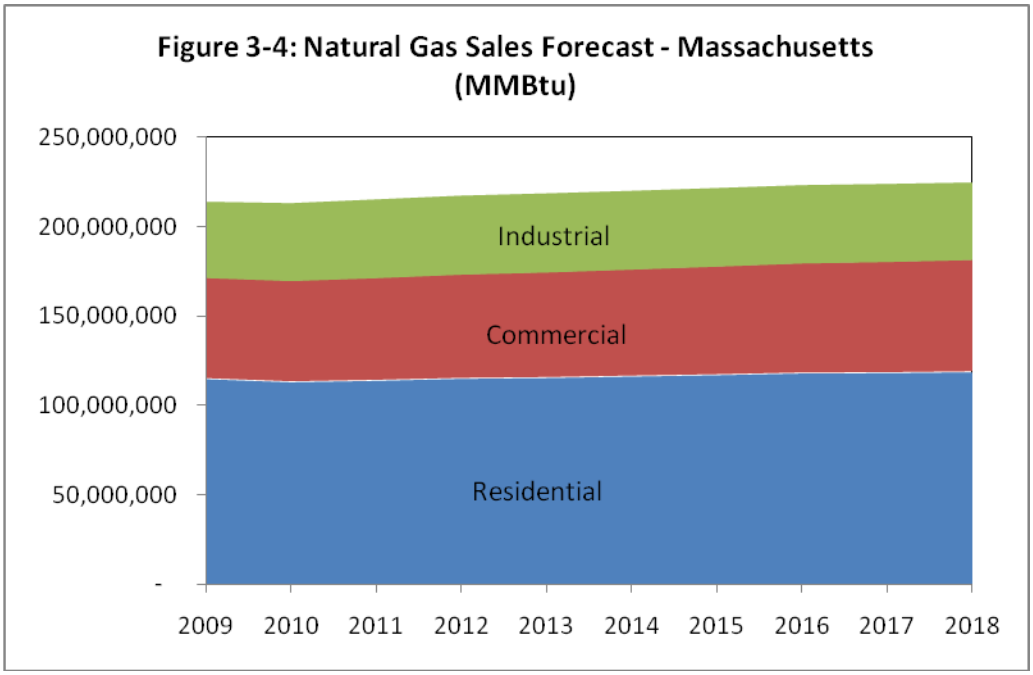
[2] Energy Information Administration, Commercial Buildings Energy Consumption Survey, 2003 Data Tables.
[3] http://www.eia.doe.gov/emeu/states/_seds.html



3.2 Forecasted Natural Gas Sales

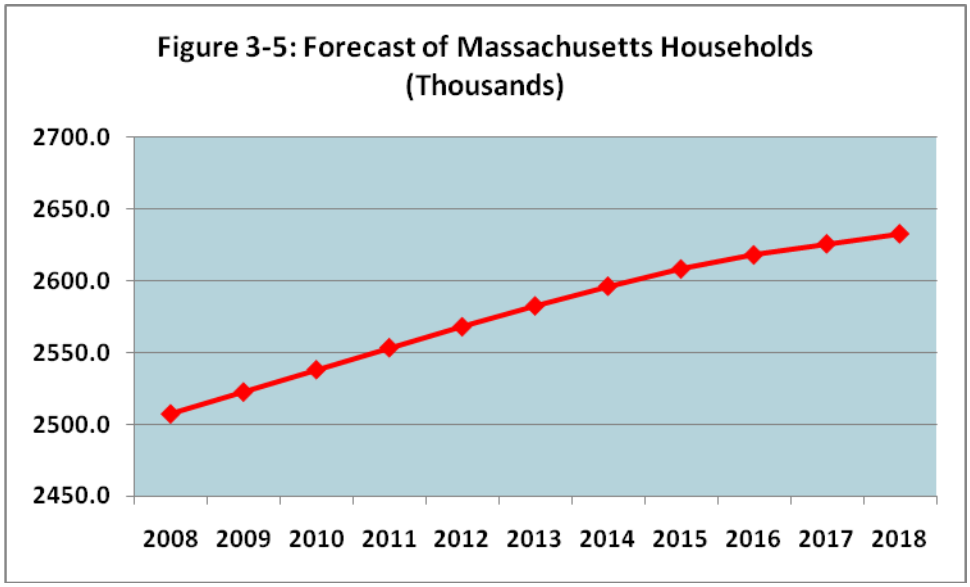
The Massachusetts gas sales forecast developed by GDS is based on the Energy Information Administration's June 2008 natural gas demand forecast for New England. Long range natural gas sales growth rates were applied to actual 2007 natural gas sales to estimate the level of sales in 2018. EIA estimates that between 2007 and 2018 the demand for natural gas New England will increases at 0.57% per year for the commercial sector, 0.27% for residential and that industrial sales will decline -0.64% per year.

Forecasted Massachusetts natural gas sales for years 2009 through 2018 are shown in Figure 3-4.



3.3 Households and Residential End-Use Saturations

The number of households is a key factor in the development of energy efficiency potential estimates for the residential sector. The household forecast for Massachusetts is taken from ISO New England's Forecast Report of Capacity, Energy, Loads and Transmission (CELT) 2008 – 2017, April 2008. Figure 3-5 shows the forecast of Massachusetts households used in this study.



4.0 ENERGY EFFICIENCY POTENTIAL METHODOLOGY

This section of the report presents an overview of the analytical approach that was used to determine the potential for natural gas energy efficiency in Massachusetts.

The analytical approach that was used by GDS to determine the potential for natural gas energy efficiency relies on three key calculations which are described below.

- The first step was to estimate the technical potential for natural gas energy efficiency savings. **Technical Potential** is defined as the complete penetration of all measures analyzed in applications where they are deemed to be technically feasible from an engineering perspective The total technical potential for natural gas energy efficiency for each sector was developed from estimates of the technical potential of individual energy efficiency measures applicable to each sector (energy efficient space heating, energy efficient water heating, etc.). For each energy efficiency measure, GDS calculated the natural gas energy savings that could be captured if 100 percent of inefficient gas equipment were replaced instantaneously (where they are deemed to be technically feasible). Technical potential in the new construction market was estimated for the residential and commercial gas customer sectors based on projected household and commercial sales growth. Industrial sales are projected to decline over the 10 year study period.

- The second step was to estimate the **economic potential**. Economic potential is defined as that portion of the technical potential that is cost effective according to the Total Resource Cost Test.

- The final step was to estimate the **achievable economic potential.** Achievable economic potential is defined as that portion of the economic potential that is likely to be attainable based on an estimate of market acceptance. Achievable economic potential also reflects the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, it was assumed that they would replace existing inefficient equipment at the end of the equipment's effective useful life.

4.1 Overview of Methodology

Our analytical approach began with an identification of natural gas energy efficiency measures to be included in the study and collection of data from the GasNetworks' companies to support the analysis. Energy, cost and other characteristics of each measure and the associated baseline equipment that the measures would be replacing or supplementing were then developed from

various data sources, including information provided by GasNetworks. The next step was to screen each measure for cost-effectiveness in accordance with the TRC test. Estimates of the technical, economic and achievable economic potential were then developed. The potential analysis included an assessment of the level of natural gas energy efficiency that has already been achieved in Massachusetts and the remaining potential for energy efficiency savings for a particular measure. For example, if 100 percent of the homes in a utility's service area have natural gas water heaters, and 30 percent of them are already high efficiency units, then the remaining technical potential for energy efficiency is the savings associated with replacement of the remaining 70 percent of the gas water heaters that are not already high efficiency units. This assumes that there are no technical/engineering barriers that will prevent replacement of existing units with the measure.

The general methodology used for estimating the potential for natural gas energy efficiency in the residential, commercial and industrial sectors included the following steps:

1. Identification of data sources for natural gas energy efficiency measures
2. Identification of natural gas energy efficiency measures to be included in the assessment based on measures currently included in GasNetworks' programs, measures in the GDS and Summit Blue in-house libraries, and a review of measures included in other studies such as the Massachusetts Market Transformation Scoping Study conducted for GasNetworks' companies in 1997[4] and more recent studies such as the 2009 study of "Additional Opportunities for Energy Efficiency in New Hampshire."[5] Only measures that are commercially available were considered.
3. Determination of the characteristics of each energy efficiency measure including its cost, energy savings and effective useful life. This was based on the GDS Team's database of measures, an extensive search of other secondary sources, discussions with equipment suppliers and contractors, and information provided by GasNetworks.
4. Cost-effectiveness screening based on the TRC Test benefit cost ratio using the latest avoided natural gas, electric and water costs[6]
5. Collection and analysis of the baseline and forecasted characteristics of the natural gas end use markets, including gas equipment saturation levels and consumption, by market segment and end use over the forecast period.

[4] Massachusetts Market Transformation Scoping Study, Arthur D. Little, September 30, 1997.
[5] Additional Opportunities for Energy Efficiency in New Hampshire, by GDS Associates, RLW, RKM Research, for the New Hampshire Public Utilities Commission, January 2009.
[6] Avoided Energy Supply Costs in New England:, Synapse Energy Economics, August 10, 2007.

6. Assessment of existing level of natural gas energy efficiency that has already been accomplished in Massachusetts and the remaining potential for energy efficiency savings by end-use.
7. Integrate measure characteristics and baseline data to produce estimates of technical potential.
8. Eliminate measures that are not cost effective, according to the TRC test, to determine the economic potential.
9. Apply maximum achievable penetration rates to determine the achievable economic potential.

In the calculation of a measure's cost-effectiveness all measures are treated *independently*; that is, the savings of each measure are not reduced or otherwise adjusted for overlap between competing or interacting measures. By analyzing measures independently, no assumptions are made about the combinations or order in which they might be installed in customer buildings. This approach evaluates energy-efficient technologies on their own merit, and does not unfairly exclude one measure in favor of another. However, the cumulative savings potential cannot be estimated by adding the savings from each individual savings estimate because some savings would be double-counted. For example, the savings from a measure that reduces heat loss from a building, such as insulation, are partially dependent on other measures that affect the efficiency of the system being used to heat the building, such as a high-efficiency furnace. The more efficient the furnace, the less energy saved from the installation of the insulation. In general it is assumed that measures with the lowest levelized cost per lifetime MMBtu saved would typically be installed first, followed by the measures with the next lowest levelized cost.

In instances where there were two (or more) competing technologies for the same natural gas end use, such as high efficiency storage water heater, tank-less water heaters, and solar water heating, GDS assigned a percent of the available population to each measure.

4.2 General Methodological Approach

This section describes the calculations used to estimate the energy efficiency potential in the residential, commercial, and industrial sectors. There is a core equation, shown in Tables 4-1 and 4-2, used to estimate the technical potential for each individual efficiency measure and it is essentially the same for each sector. However, for the residential sector, the equation was applied using a "bottom-up" approach where the equation inputs are displayed in terms of the number of homes or the number of high efficiency units (i.e., high efficiency heating systems, programmable thermostats, etc.). For the commercial and industrial (C&I) sectors, a "top-down" approach was used for developing the technical potential estimates. In this case, the equation units are displayed in terms of energy rather than number of units.

4.2.1 Core Equations for Estimating Technical Potential

The core equation used to calculate the natural gas energy efficiency technical potential for each individual efficiency measure for the residential sector is shown below in Table 4-1.

Table 4-1 – Core Equation for Residential Sector

Technical Potential of Efficient Measure	=	Total Number of Residential Households	X	Base Case Equipment End Use Intensity (annual MMBtu use per home)	X	Base Case Factor	X	Remaining Factor	X	Convertible Factor	X	Savings Factor

where:

- **Number of Households** is the number of households in Massachusetts.
- **Base-case equipment end use intensity** is the natural gas used per customer per year by each base-case technology in each market segment. This is the consumption of the energy using equipment that the efficient technology replaces or affects. For example, if the efficient measure were a high efficiency gas furnace, the base end use intensity would be the annual MMBtu use per furnace per household associated with a standard efficiency furnace.
- **Base Case factor** is the fraction of the end use energy that is applicable for the efficient technology in a given market segment. For example, for residential water heating, this would be the fraction of all residential customers that have gas water heating in their household.
- **Remaining factor** is the fraction of applicable households that have not yet been converted to the natural gas energy efficiency measure; that is, one minus the fraction of households that already have the energy-efficiency measure installed.
- **Convertible factor** is the fraction of the applicable households that are technically feasible for conversion to the efficient technology from an engineering perspective (e.g., it may not be possible to install high efficiency natural on-demand tankless or condensing gas water heaters in every home because of technical/engineering or other limiting factors such as the amount of water use).
- **Savings factor** is the percentage reduction in natural gas consumption resulting from application of the efficient technology.

The core equation used to calculate the natural gas efficiency technical potential for each individual efficiency measure for the commercial and industrial sectors is shown below in Table 4-2.

Table 4-2 – Core Equation for C&I Sectors

Technical Potential of Efficient Measure	=	Total End Use MMBtu sales by Industry Type	X	Base Case Factor	X	Remaining Factor	X	Convertible Factor	X	Savings Factor

where:

- **Total end use MMBtu sales (by segment)** is the forecasted level of natural gas sales for a given end-use (e.g., space heating) in a commercial or industrial market segment (e.g., office buildings).
- **Base Case factor** is the fraction of the end use energy that is applicable for the efficient technology in a given market segment. For example, for gas space heating, this would be the fraction of all gas heating use in a given market segment that is associated with gas furnaces.
- **Remaining factor** is the fraction of applicable therm sales that are associated with equipment that has not yet been converted to the energy efficiency measure; that is, one minus the fraction of the market segment that already have the energy-efficiency measure installed.
- **Convertible factor** is the fraction of the equipment or practice that is technically feasible for conversion to the efficient technology from an engineering perspective (e.g., Stack heat exchangers are most applicable for large boilers with high stack temps and either high make-up water needs or significant hot water needs).
- **Savings factor** is the percentage reduction in natural gas consumption resulting from application of the efficient technology.

4.2.2 Rates of Implementation for Energy Efficiency Measures

For new construction, energy efficiency measures can be implemented when each new home or building is constructed, thus the rate of availability is a direct function of the rate of new construction. For existing buildings, determining the annual rate of availability of savings is more complex. Energy efficiency potential in the existing stock of buildings can be captured over time through two principal processes:

1. as equipment replacements are made normally in the market when a piece of equipment is at the end of its effective useful life (we refer to this as "market-driven") and,

2. at any time in the life of the equipment or building (which we refer to as the "retrofit").

Market-driven measures are generally characterized by incremental measure costs and savings (e.g., the incremental costs and savings of a high-efficiency versus a standard efficiency water heater); whereas retrofit measures are generally characterized by full costs and savings (e.g., the full costs and savings associated with retrofitting ceiling insulation into an existing attic

For market driven measures, we assume that existing equipment will be replaced with high efficiency equipment at the end of its effective useful life. Using this assumption, equipment that needs to be replaced in a given year is eligible to be upgraded to high efficiency equipment. For the retrofit measures, savings can theoretically be captured at any time; however, in practice it takes many years to retrofit an entire stock of buildings, even with the most aggressive of efficiency programs.

4.2.3 Achievable Market Penetration Rate Scenarios

GDS estimated the achievable economic potential for two market acceptance scenarios: 80% and 60% maximum long term (by 2018) market penetration of energy efficiency measures. Market penetration is defined for this study as the percent of cost-effective, technically feasible energy efficiency measures that will be installed by customers over the 10 year study horizon. Market penetration rates are applied to the equipment that is assumed to be replaced over the 10 year study horizon to determine the number of replaced units that will be energy efficient for each of the market penetration rate scenarios.

The 80% market penetration scenario assumes aggressive program designs that include high incentive levels and strong educational and marketing campaigns. It is intended to define an upper limit of economic savings from market interventions The 60% market penetration scenario assumes a program design that includes smaller incentive levels with less aggressive program promotion targeting consumers already knowledgeable and more willing to make an investment in energy efficient technologies.

GDS has reviewed penetration rate forecasts from other recent energy efficiency technical potential studies, actual penetration experience for electric and natural gas energy efficiency programs operated by energy efficiency organizations (Efficiency Vermont, Efficiency Maine, Pacific Gas and Electric, KeySpan Energy Delivery, NEEP, NYSERDA, Northwest Energy Efficiency Alliance, BPA, Wisconsin Focus on Energy, other electric and gas utilities, etc.), and penetration data from other sources (program evaluation reports, market progress reports, etc.) to estimate terminal penetration rates in 2018 for the achievable economic potential scenarios. In addition, GDS has conducted a survey of nationally recognized energy efficiency experts requesting their estimate of the achievable penetration rate over the long-term for a state or region, assuming

implementation of aggressive programs and assuming aggressive funding. The terminal year (2018) market penetration estimates used in this study (60 to 80 percent) are based on a thorough review of all of this information.

Examples of US Efficiency Programs with High Market Penetration

GDS has collected information on electric and gas energy efficiency programs conducted during the past three decades where high penetration has been achieved. Examples of such programs are listed below:

1. The Residential Multifamily/Low-Income Program in Vermont achieved a market share of over 90 percent for new construction and nearly 30 percent for existing housing.[7]
2. The residential water heater bundle-up program conducted by Central Maine Power Company has achieved a market penetration of over 80 percent of residential electric water heaters in the Company's service area. This program has been operated by CMP since the 1980's.
3. The Northwest Energy Efficiency Alliance reported that the market share of ENERGY STAR windows in the Northwest reached 75 percent by mid-2002 and is continuing to increase.[8]
4. Vermont Gas Systems' reported that 68 percent of new homes in their service territory were ENERGY STAR Homes in 2002.[9]
5. Gaz Metro in Quebec reported that the national market share of high efficiency furnaces in Canada has reached 40 percent due to years of energy efficiency programs.[10]
6. In the State of Wisconsin, a natural gas energy efficiency program to promote high efficiency gas furnaces attained a penetration rate of over 90 percent.[11]
7. KeySpan Energy Delivery's high efficiency residential furnace program achieved a market share of approximately 70 percent over eight years (1997-2005).[12]

GDS finds that the actual market penetration experience from electric and gas energy efficiency programs in New England and in other regions is useful and

[7] York, Dan; Kushler, Martin; America's Best: Profiles of America's Leading Energy Efficiency Programs," published by the American Council for an Energy Efficient Economy, March 2003. Report Number U032.
[8] Id.
[9] American Council for an Energy Efficient Economy, "America's Best Gas Energy Efficiency Programs", 2003.
[10] Id.
[11] Hewitt, David. C., "The Elements of Sustainability", paper presented at the 2000 ACEEE Summer Study on Energy Efficiency in Buildings. Washington: American Council for an Energy Efficient Economy. Pages 6.179-6.190. The Wisconsin furnaces case study data can be found in the 2000 ACEEE Summer Study Proceedings on pages 6.185-6.186.
[12] American Council for an Energy Efficient Economy, "America's Best Gas Energy Efficiency Programs", 2003.

pertinent information in developing long-term market penetration estimates for natural gas energy efficiency programs in Massachusetts. In addition, recent technical potential studies in such states as California, Connecticut, Florida, Georgia, Kentucky, New Mexico, North Carolina, Utah and Vermont also have used a maximum achievable penetration rate of 80 percent.

5.0 RESIDENTIAL SECTOR EFFICIENCY POTENTIAL

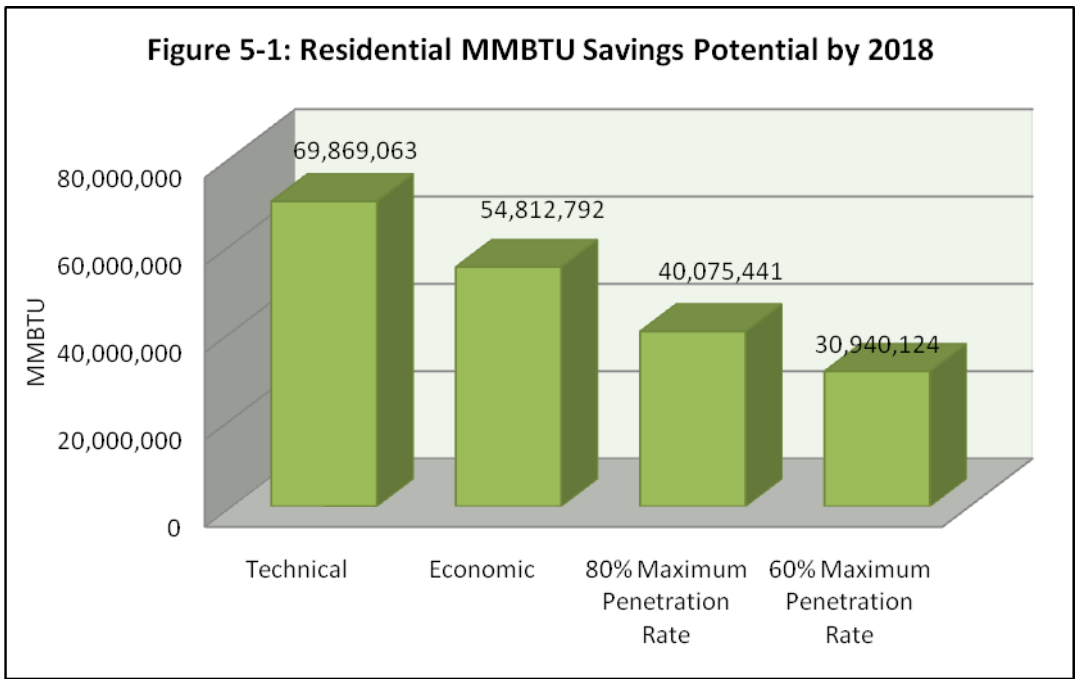
5.1 Introduction and Summary of Results

This section of the report presents the estimates of technical, economic, and achievable economic natural gas efficiency potential for the existing and new construction market segments of the residential sector in the state of Massachusetts. Estimates of achievable economic potential were developed for two scenarios, 80% and 60% maximum measure penetration rates. These scenarios also reflect the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, for these measures it was assumed that residential customers would replace existing inefficient equipment at the end of the equipment's effective useful life.

According to this analysis, there is still a large potential for natural gas efficiency savings in the residential sector. Table and Figure 5-1, below summarize the technical, economic (based on the Total Resource Cost "TRC" test), and achievable economic savings potential by 2018. As can be seen, the achievable cost-effective potential for residential natural gas savings by the year 2018 is estimated to range from 31 and 40 million MMBtu, representing as much as one third of the total projected residential natural gas sales in the year 2018.

Table 5-1
Summary of Residential Energy Efficiency Savings Potential by 2018 (MMBTU)

			Achievable Economic Potential	
	Technical	Economic	80% Maximum Penetration Rate	60% Maximum Penetration Rate
Total MMBTU Savings	69,869,063	54,812,792	40,075,441	30,940,124
Percent of 2018 Forecast Sales	58.8%	46.1%	33.7%	26.0%



5.2 Residential Energy Efficiency Measures

Fifty-two (52) residential natural gas efficiency measures were included in the energy savings analysis for the residential sector. Table 5-2 provides a brief listing of the various residential natural gas efficiency technologies considered in this analysis. The list of residential energy efficiency measures was developed by GDS and GasNetworks based on measures currently included in GasNetworks' programs, measures in the GDS and Summit Blue in-house libraries, and a review of measures included in other studies such as the Massachusetts Market Transformation Scoping Study conducted for GasNetworks' companies in 1997[13] and more recent studies such as the 2009 study of "Additional Opportunities for Energy Efficiency in New Hampshire."[14] Only measures that are commercially available were considered.

The portfolio of measures includes only those that have some level of technical feasibility for implementation either by substituting for or being applied to existing technologies on a retrofit or market driven basis. Market driven refers to equipment replacements that are made normally in the market when a piece of equipment is at the end of its effective useful life. For purposes of this study, retrofit measures are limited to the application of supplemental measures (such as the addition of a low-flow device to a showerhead or increased levels of insulation), and do not include the early replacement of operational equipment.

[13] Massachusetts Market Transformation Scoping Study, Arthur D. Little, September 30, 1997.
[14] Additional Opportunities for Energy Efficiency in New Hampshire, by GDS Associates, RLW, RKM Research, for the New Hampshire Public Utilities Commission, January 2009.

Table 5-2 List of Residential Efficiency Measures	
End-Use	Measures
Cooking	Convection Ovens
Hot Water	Faucet Aerators, Low Flow Showerheads, ShowerStart Technology, Pipe Insulation, Gravity-Film Exchange (GFX) Waste Water Heat Recovery, Solar Water Heating – drain back system/with gas backup, High Efficiency Stand Alone Water Heater, Condensing Water Heater, Indirect Water Heater, On-Demand, Tankless Water Heater
HVAC	Insulate and Seal Ducts, Insulate Unconditioned Basement/Crawl Space Piping, Heat Recovery Ventilator, Desiccant Dehumidification, Energy Star Furnace, Energy Star Gas Boiler, Engine-Driven Heat Pump, Gas Absorption Heat Pump, Energy Efficient Steam Boilers, Combination WH/Furnace, Combination WH/Boiler (Condensing)
HVAC Controls	Programmable Thermostat, Occupancy Thermostat, Boiler Controls (Non-Condensing Boiler), Zoning
HVAC Shell	Attic Hatch Insulation, Air Sealing, Improved Floor Insulation, Improved Wall Insulation, Improved Roof Insulation, Improved Below-Grade Insulation, Insulated Exterior Door, Storm Windows , Energy Star Windows
Laundry	Clothes Dryer with Moisture Sensor, Energy Star Clothes Washer (vertical and horizontal)
Pool	Solar Pool Cover (Bubble), Pool Cover (Vinyl), High Efficiency Gas Pool Heater, Solar pool heater, Outdoor Spa Cover

5.3 Characteristics of Residential Energy Efficiency Measures

GDS collected data on the energy savings, incremental costs, useful lives, and other key "per unit" characteristics for each of the residential natural gas efficiency technologies. Estimates of the size of the eligible market were also developed for each efficiency measure. For example, natural gas water heating measures are only applicable to homes that have natural gas water heating. Because there are differences in the saturation of appliances and equipment, such as natural gas water heating, for single-family and multi-family homes, GDS estimated the potential for these housing types separately. To obtain up-to-date appliance and end-use saturation data, GDS made extensive use of the various studies provided by GasNetworks, appliance saturation survey data collected as part of the 2009 study of "Additional Opportunities for Energy Efficiency in New Hampshire," and other data sources such as the U.S. Census Bureau and the U.S. DOE's Energy Information Administration.

For the residential new construction market segment, GDS assumed that there will be no retirement of existing housing stock. This simplifying assumption may slightly underestimate the number of new homes that will be built. The number of new homes estimated to be built each year is based on the housing forecast for Massachusetts included in ISO New England's Forecast Report of Capacity, Energy, Loads and Transmission (CELT) 2008 – 2017, April 2008.

The estimate of the percentage of homes that already have energy efficient measures installed (remaining factor) is based on a number of sources including various studies provided by GasNetworks, survey data collected as part of the 2009 study of "Additional Opportunities for Energy Efficiency in New Hampshire," and other data sources such as ENERGY STAR and ACEEE reports.

Appendix A provides a comprehensive listing of all residential energy efficiency measure assumptions and sources used in this study.

5.4 Residential Measure Cost Effectiveness

GDS screened individual residential natural gas efficiency measures to determine their cost effectiveness in accordance with the Total Resource Cost test. Table 5-3 below presents the screening results for each residential measure by type of home (single-family/multi-family). Those measures that did not pass the TRC test (benefit/cost ratio of less than 1.0) were not included in the estimates of economic and achievable economic potential.

Table 5-3
Residential Natural Gas Efficiency Measure Screening Results

Measure Name	TRC Test Ratio (Single-Family)	TRC Test Ratio (Multi-Family)
Cooking		
Convection Ovens	0.20	0.20
Hot Water		
Faucet Aerators	96.49	96.49
Low-flow Shower Heads (1.59 GPM)	51.64	51.64
Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	21.11	21.11
Pipe Insulation	6.73	6.73
Shower Start Technology Only	3.66	3.66
On-Demand, Tankless Water Heater (>=.82, <.95 EF)	1.25	1.25
High Efficiency Stand Alone Water Heater (0.62 EF)	1.12	1.12
Condensing Water Heater	1.00	1.00
Indirect Water Heater	1.00	1.00
On-Demand, Tankless Water Heater (>=.95 EF)	0.74	0.74
Solar Water Heating – drain back system/with gas backup	0.68	0.68
Gravity-Film Exchange (GFX) Waste Water Heat Recovery	0.66	0.66
High Efficiency Stand Alone Water Heater (0.67 EF)	0.53	0.53
HVAC		
Energy Star Furnace (AFUE=90%)	11.04	5.46
CEE Tier 2 Furnace (AFUE=92%)	7.75	3.83
CEE Tier 3 Furnace (AFUE=94%)	6.56	3.24
Combination WH/Furnace (.86 EF, .90 AFUE)	5.23	3.20
Energy Star (High Performance Homes)	3.65	3.82
Desiccant Dehumidification	3.64	3.94
Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	2.42	1.20
Condensing Gas Boiler (AFUE=90%)	2.10	1.04
Combination WH/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	2.09	1.47

Table 5-3
Residential Natural Gas Efficiency Measure Screening Results

Measure Name	TRC Test Ratio (Single-Family)	TRC Test Ratio (Multi-Family)
Insulate and Seal Ducts	1.96	0.98
Combination WH/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	1.95	1.25
Energy Star Gas Boiler (AFUE=85%)	1.87	0.92
Condensing Gas Boiler (AFUE=95%)	1.86	0.92
Heat Recovery Ventilator	1.41	1.03
Energy Efficient Steam Boilers (low pressure)	1.25	0.81
Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	1.24	0.61
Insulate Unconditioned Basement/Crawl Space Piping	0.99	1.13
HVAC Controls		
Programmable Thermostat	13.46	6.74
Occupancy Thermostat	6.19	3.10
Boiler Controls (Non-Condensing Boiler)	2.86	1.43
Zoning	1.20	0.19
HVAC Shell		
Attic Hatch Insulation	14.72	14.72
Air Sealing	4.53	2.27
Improved Floor Insulation	4.12	2.47
Storm Windows	1.66	1.66
Improved Wall Insulation	1.64	1.15
Insulated Exterior Door	1.51	1.51
Improved Roof Insulation	0.70	0.35
Energy Star Windows	0.65	0.55
Improved Below-Grade Insulation	0.61	0.37
Laundry		
Clothes Dryer with Moisture Sensor	16.23	16.23
Energy Star Clothes Washer (vertical and horizontal)	4.98	4.98
Pool		
Solar Pool Cover (Bubble)	14.27	14.27
Pool Cover (Vinyl)	13.33	13.33
High Efficiency Gas Pool Heater	1.35	1.35
Solar pool heater	1.31	1.31
Outdoor Spa Cover	1.27	1.27

5.5 Residential Savings Potential

In the calculation of a measure's cost-effectiveness, all measures are treated *independently*; that is, the measure savings is not reduced or otherwise adjusted for overlap between competing or interacting measures. By analyzing measures independently, no assumptions are made about the combinations or order in which they might be installed in residential buildings. This approach evaluates energy-efficient technologies on their own merit, and does not unfairly exclude one measure in favor of another. However, the cumulative savings potential cannot be estimated by adding the savings from each individual savings estimate

because some savings would be double-counted. For example, the savings from a measure that reduces heat loss from a building, such as insulation, are partially dependent on other measures that affect the efficiency of the system being used to heat the building, such as a high-efficiency furnace. The more efficient the furnace, the less energy saved from the installation of the insulation. In general it is assumed that measures with the lowest levelized cost per lifetime MMBtu saved would typically be installed first, followed by the measures with the next lowest levelized cost.

In instances where there were two (or more) competing technologies for the same natural gas end use, such as high efficiency storage water heater, tank-less water heaters, and solar water heating, GDS assigned a percent of the available population to each measure. In the event that one of the competing measures was not found to be cost-effective, the homes assigned to that measure were transitioned over to the cost-effective alternative (if any).

The residential economic energy efficiency potential is 56,474,024 MMBtu. Figure 5-2 provides a breakdown of this economic potential by end-use. About 42% of the residential economic savings potential is from improvements to the thermal shell of existing homes, followed by heating and cooling equipment upgrades, water heating upgrades, HVAC controls, pool heating equipment, and laundry equipment. Table 5-4 provides further details on the residential economic potential by measure type.

Figure 5-2: Residential Sector End-Use Savings as a % of Total Economic Potential

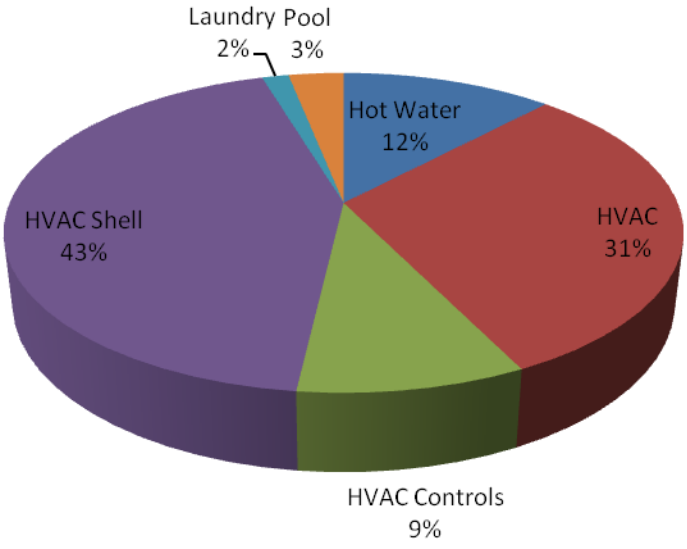


Table 5-4 Residential Natural Gas Energy Efficiency Potential by Measure	
Measure	Economic Potential
Improved Shell Insulation	13,984,761
High Efficiency Boilers & Furnaces (1)	9,722,134
Air Sealing	8,464,223
Faucet Aerators & Low Flow Shower Heads	4,240,385
High Efficiency Water Heaters (2)	3,660,749
Energy Star Homes	3,100,991
Programmable & Occupancy Thermostats and Zoning Controls	2,964,217
Boiler Controls	2,053,902
Pool Covers and Heaters (incl. Solar)	1,720,460
Heat Recovery Ventilator	1,530,310
Insulated Exterior Door	1,083,362
Energy Star Clothes Washer/Dryer	828,544
Hot water Pipe Insulation	771,882
Insulate & Seal Ducts	372,622
Storm Windows	314,249
Total Economic Potential	54,812,792

(1) Includes high efficiency gas heat pumps
(2) Includes combined water/space heating units

5.6 Market Penetration Scenario Results

Achievable potential can vary based on energy efficiency program parameters, such as the magnitude of rebates or incentives offered to customers for installing energy efficiency measures and thus, many different scenarios can be modeled. To demonstrate the range of impacts that program parameters can have on achievable economic potential, this report includes savings estimates based on a 60% market penetration scenario and an 80% market penetration scenario.

Figure 5-3 shows that the achievable savings potential by 2018 ranges from 32 to 41 million MMBtu or 56% to 73% of economic potential. The 80% market penetration scenario assumes aggressive program designs that include high incentive levels and strong educational and marketing campaigns. The 60% market penetration scenario assumes a program design that includes smaller incentive levels with less aggressive program promotion targeting consumers already knowledgeable and more willing to make an investment in energy efficient technologies.

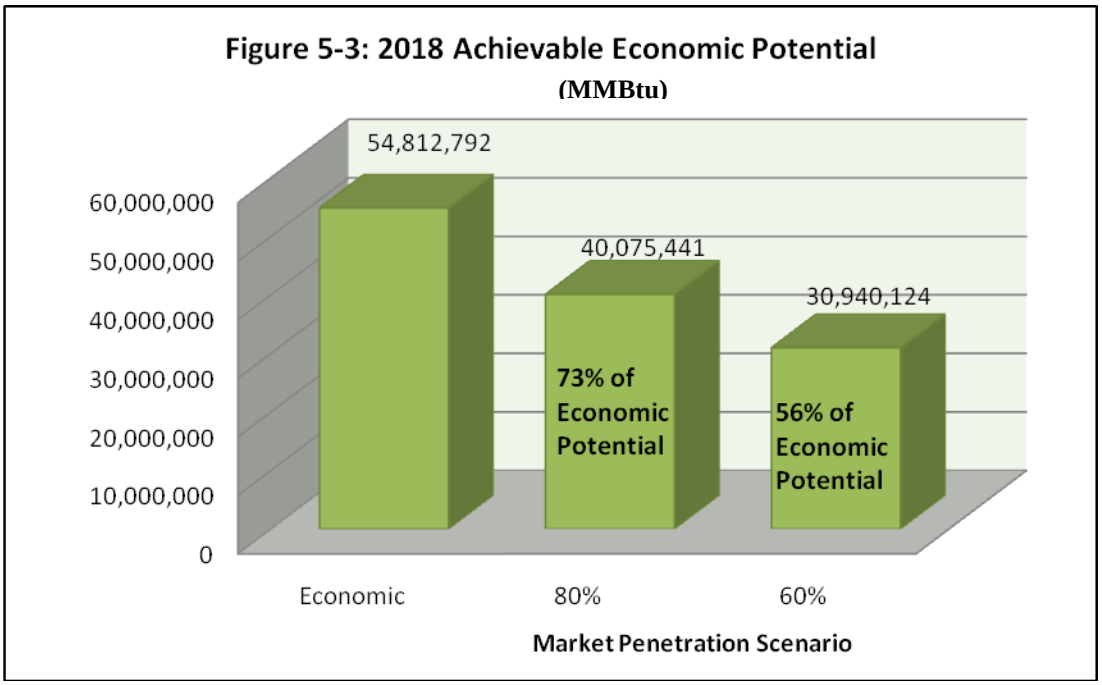


Figure 5-3: 2018 Achievable Economic Potential
(MMBtu)
54,812,792
40,075,441
30,940,124
73% of Economic Potential
56% of Economic Potential
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Economic
80%
60%
Market Penetration Scenario

6.0 COMMERCIAL SECTOR ENERGY EFFICIENCY POTENTIAL

6.1 Introduction and Summary of Results

This section of the report provides the estimates of technical, economic and achievable economic potential for natural gas energy efficiency measures for the commercial sector in Massachusetts. The commercial sector as defined in this analysis is based on the natural gas sales data for the following business segments:

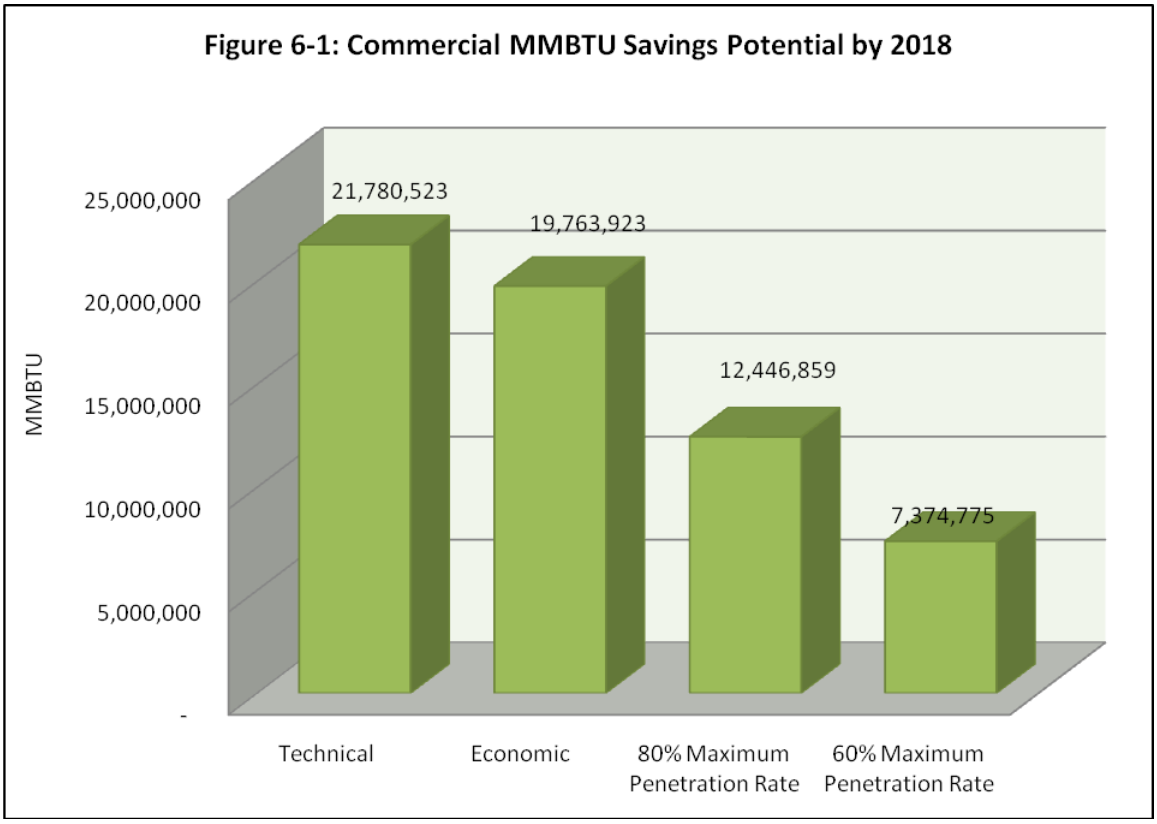
- Warehouse
- Retail
- Grocery
- Office
- Lodging
- Health
- Restaurant
- Education
- Other

Commercial efficiency potential estimates can be developed using either a top-down or a bottom-up approach, depending on data availability. The bottom up approach requires detailed equipment saturation data, which is not available for the commercial market in Massachusetts. Therefore a top-down approach was used. This approach builds an energy use profile based on estimates of sales by business segment and end use. Savings factors for energy efficiency measures are then applied to applicable end use energy estimates after assumptions are made regarding the fraction of sales that are associated with inefficient equipment and the technical/engineering feasibility of each energy efficiency measure.

According to this analysis, there is still a large potential for natural gas efficiency savings in this sector. Table and Figure 6-1, below, summarize the technical, economic (based on the TRC test), and achievable economic savings potential by 2018 for the 80% and 60% market penetration rate scenarios. These scenarios also reflect the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, for these measures it was assumed that residential customers would replace existing inefficient equipment at the end of the equipment's effective useful life.

As can be seen, most of the commercial technical potential is economic and that economic potential represents close to one-third of total 2018 commercial sales. The amount of this economic potential that can be achieved by 2018 ranges from approximately 12% to 20% of 2018 commercial sales assuming a market penetration rate of between 60% and 80% over the next ten years

Table 6-1 Natural Gas Energy Efficiency Potential Commercial Sector				
			Maximum Achievable Cost Effective Potential (2018)	
	Technical	Economic	80% Maximum Penetration Rate	60% Maximum Penetration Rate
Total MMBtu Savings	21,780,523	19,763,923	12,446,859	7,374,775
Percent of 2018 Sales	34.7%	31.5%	19.9%	11.8%

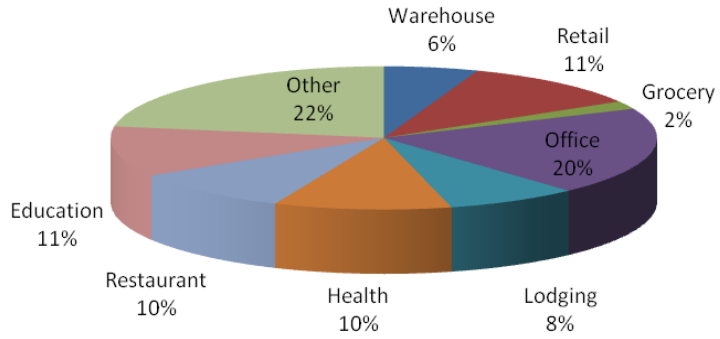


6.2 Commercial Sales by Business Segment & End Use

As discussed above, commercial natural gas energy efficiency potential was developed using a top-down approach that requires a breakdown of natural gas sales by business segment and end use. The breakdown of sales by business segment is based on natural gas consumption estimates for the Northeast

Census Region and the U.S., where Northeast data is not available.[15] Figure 6-2 illustrates the commercial sector natural gas sales based segmentation.

Figure 6-2
Commercial Natural Gas Sales by Business Segment



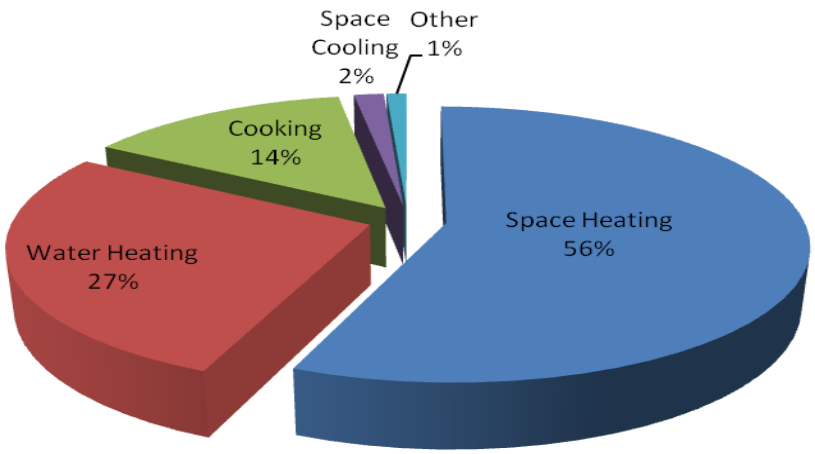
A further breakdown of commercial natural gas sales by end-use within each commercial business segment was developed based on data included in a 2006 natural gas potential study for New York State.[16] This study divided New York into two regions, upstate and downstate. End use sales breakdowns for the upstate region were used as a reasonable representation of the commercial sector in Massachusetts. The upstate region was chosen because it has a similar number of annual heating degree days to the Boston/Worcester area and is not dominated by New York City. Table 6-2 and Figure 6-3 show the resulting end use allocation used in this analysis.

Table 6-2
Commercial Natural Gas Sales Breakdown by Business Segment and End Use

	Office	Retail	Grocery	Warehouse	Education	Health	Lodging	Restaurant	Other
Space Heating	72%	62%	56%	76%	60%	45%	53%	34%	48%
Water Heating	26%	22%	25%	16%	24%	37%	34%	27%	29%
Cooking	0%	15%	17%	3%	13%	15%	9%	37%	20%
Space Cooling	2%	1%	2%	3%	1%	2%	1%	2%	1%
Other	0%	0%	0%	2%	2%	2%	3%	0%	1%

[15] Energy Information Administration, Commercial Buildings Energy Consumption Survey, 2003 Data Tables.
[16] Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Appendix C.

Figure 6-3
Commercial Gas Sales by End Use



Having established the energy use profile for the commercial sector in Massachusetts, a baseline projection of natural gas consumption in 2018 was developed. The baseline forecast includes some improvement in energy efficiency, but excludes utility-sponsored conservation efforts. The EIA's June 2008 natural gas demand forecast for New England's commercial sector was used to advance Massachusetts usage to 2018[17] EIA estimates that the demand for natural gas by commercial customers in New England will increases at a rate of 0.6% per year between 2007 and 2018. This growth rate was applied to actual commercial natural gas sales in Massachusetts as reported by EIA[18]

In order to estimate the level of commercial natural gas sales that are associated with commercial new construction, GDS assumed that half of the forecasted growth in commercial sales is attributed to new construction and the other half to the existing commercial market.

6.3 Commercial Energy Efficiency Measures

The list of commercial energy efficiency measures was developed by GDS and GasNetworks based on measures currently included in GasNetworks' programs, measures in the GDS and Summit Blue in-house libraries, and a review of measures included in other studies such as the Massachusetts Market Transformation Scoping Study conducted for GasNetworks' companies in 1997[19]

[17] http://www.eia.doe.gov/oiaf/archive/aeo08/supplement/index.html
[18] Energy Information Administration, Energy Outlook 2008, Release Data April 2008.
[19] Energy Information Administration, Natural Gas Consumption by End Use, Massachusetts, Annual.

and more recent studies such as the 2009 study of "Additional Opportunities for Energy Efficiency in New Hampshire." Only measures that are commercially available were considered.

A total of 73 commercial natural gas energy efficiency measures were included in the energy efficiency potential analysis. These measures, which impact water heating, space heating, space conditioning and cooking end uses, are shown below in Table 6-3. Measures are defined as either market driven or retrofit. Market driven measures are assumed to replace existing equipment at the end of its effective useful life. Market-driven measures are generally characterized by incremental measure costs and savings (e.g., the incremental costs and savings of a high-efficiency versus a standard efficiency boiler); whereas retrofit measures are generally characterized by full costs and savings (e.g., the full costs and savings associated with retrofitting ceiling insulation into an existing attic). For this study, energy efficiency measures are further identified as used in existing construction, new construction or both.

Table 6-3
Commercial Energy Efficiency Measures

Measure	Impacted End Use	Measure Type	Construction Type
Water Heating			
High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	Water Heating	Market Driven	Used in Both
Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 Btu)	Water Heating	Market Driven	Used in Both
On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 Btu/h)	Water Heating	Market Driven	Used in Both
On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	Water Heating	Market Driven	Used in Both
On-Demand, Tankless Water Heater (.85 TE) (>200,000 Btu)	Water Heating	Market Driven	Used in Both
Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	Water Heating	Market Driven	Used in Both
Heat Recovery Water Heater	Water Heating	Retrofit	Used in Both
Pipe wrap	Water Heating	Retrofit	Used in Both
Low flow shower head (1.5 GPM)	Water Heating	Retrofit	Used in Both
Faucet aerator	Water Heating	Retrofit	Used in Both
Graywater Heat Exchanger/GFX	Water Heating	Retrofit	Used in Both
Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	Water Heating	Retrofit	Used in Both
Circulation Pump Time Clocks	Water Heating	Retrofit	Used in Both

Table 6-3
Commercial Energy Efficiency Measures

Measure	Impacted End Use	Measure Type	Construction Type
Solar Water Heating w/gas auxiliary tank (SEF=1.5)	Water Heating	Retrofit	Used in Both
Wastewater, Filtration/Reclamation	Water Heating	Retrofit	Used in Both
Ozone Commercial Laundry System (Gas HW)	Water Heating	Retrofit	Used in Both
High Efficiency Clothes Washer	Water Heating	Market Driven	Used in Both
High Efficiency (95%) Gas Pool Water Heater	Water Heating	Market Driven	Used in Both
Pool Cover	Water Heating	Retrofit	Used in Both
Solar pool heater	Water Heating	Retrofit	Used in Both
Space & Water Heating			
Combination Water Heater/Furnace (.86 EF, .90 AFUE)	Space & Water Heating	Market Driven	Used in Both
Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Space & Water Heating	Market Driven	Used in Both
Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Space & Water Heating	Market Driven	Used in Both
Building Envelope			
Double Glazing Low Emissivity Windows	Space Heating	Market Driven	Existing Construction
Triple Glazing Low Emissivity Windows	Space Heating	Market Driven	Existing Construction
Improved Wall Insulation (to R12)	Space Heating	Retrofit	Existing Construction
Improved Roof/Ceiling Insulation (to R32)	Space Heating	Retrofit	Existing Construction
Improved Below-Grade Insulation (to R6)	Space Heating	Retrofit	Existing Construction
Air Sealing	Space Heating	Retrofit	Existing Construction
Integrated Building Design, Envelope Only (30% > code)	Space Heating	Not Applicable	New Construction
HVAC Controls			
EMS install	Space Heating	Retrofit	Used in Both
EMS Optimization	Space Heating	Retrofit	Existing Construction
Zoning	Space Heating	Retrofit	Existing Construction
Retrocommissioning	Space Heating	Retrofit	Existing Construction
Commissioning	Space Heating	Retrofit	New Construction
Programmable Thermostat	Space Heating	Retrofit	Used in Both

Table 6-3
Commercial Energy Efficiency Measures

Measure	Impacted End Use	Measure Type	Construction Type
Space Conditioning			
High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	Space Conditioning	Market Driven	Used in Both
Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	Space Conditioning	Market Driven	Used in Both
Double-Effect Absorption Chiller (1.03 COP)	Space Conditioning	Market Driven	Used in Both
Cooking			
High Efficiency Gas Griddle	Cooking	Market Driven	Used in Both
High Efficiency Gas Combination Oven	Cooking	Market Driven	Used in Both
High Efficiency Gas Convection Oven	Cooking	Market Driven	Used in Both
High Efficiency Gas Conveyer Oven	Cooking	Market Driven	Used in Both
High Efficiency Gas Rack Oven	Cooking	Market Driven	Used in Both
High Efficiency Gas Broiler	Cooking	Market Driven	Used in Both
Power Burner Range	Cooking	Market Driven	Used in Both
High Efficiency Fryer	Cooking	Market Driven	Used in Both
High Efficiency Gas Steamer	Cooking	Market Driven	Used in Both
Space Heating			
High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	Space Heating	Market Driven	Used in Both
High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	Space Heating	Market Driven	Used in Both
Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	Space Heating	Market Driven	Used in Both
High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	Space Heating	Market Driven	Used in Both
High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff. =85%-90%)	Space Heating	Market Driven	Used in Both
Condensing Boiler (>300,000 Btu/h) (Th.eff. =>90%)	Space Heating	Market Driven	Used in Both
High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	Space Heating	Market Driven	Used in Both
Insulate and Seal Ducts (New Aerosol Duct Sealing)	Space Heating	Retrofit	Used in Both
Gas Unit Heater - Condensing (AFUE =93%)	Space Heating	Market Driven	Used in Both
Infrared Heater (low intensity - two stage)	Space Heating	Market Driven	Used in Both
Stack Heat Exchanger (Standard Economizer)	Space Heating	Retrofit	Used in Both
Stack Heat Exchanger (Condensing Economizer)	Space Heating	Retrofit	Used in Both
Heat Recovery from Air to Air	Space Heating	Retrofit	Used in Both
Boiler Heating Pipe Insulation	Space Heating	Retrofit	Used in Both
Boiler Tune-Up	Space Heating	Retrofit	Used in Both

Table 6-3 Commercial Energy Efficiency Measures			
Measure	Impacted End Use	Measure Type	Construction Type
Boiler Reset Controls	Space Heating	Retrofit	Used in Both
Boiler O2 Trim Controls	Space Heating	Retrofit	Used in Both
Boiler Parallel Positioning	Space Heating	Retrofit	Used in Both
Boiler blowdown heat exchanger (steam)	Space Heating	Retrofit	Used in Both
Repair/Replace malfunctioning steam traps	Space Heating	Retrofit	Used in Both
Insulate steam lines/condensate tank	Space Heating	Retrofit	Used in Both
Destratification Fans (HVLS)	Space Heating	Retrofit	Used in Both
Exhaust Hood Makeup Air	Space Heating	Retrofit	Used in Both
Exhaust Hood - Demand Ventilation	Space Heating	Market Driven	Used in Both
Demand Controlled Ventilation	Space Heating	Retrofit	Used in Both

6.4 Characteristics of Commercial Energy Efficiency Measures

GDS collected data and developed estimates of measure savings, cost and effective useful life for each of the commercial natural gas energy efficiency measures. Savings factors for each measure, which represent the percent savings in annual energy use resulting from implementation of the measure, were then applied to the applicable end-use energy. So, for example, water heating measure savings factors were applied to the estimated water heating end-use energy that is associated with equipment that has not yet been converted to the energy efficiency measure and is technically feasible for conversion.

Table 6-4 shows the savings factors, measure cost and effective useful life for each commercial measure.

Table 6-4 Commercial Measure Characteristics				
Measure Name	Savings Factor	Measure Cost	Cost Type: 1=Full 2=Incremental	Effective useful life
Water Heating End Use				
High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	12%	$415	2	13
Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 Btu)	23%	$2,340	2	15
On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 Btu/h)	28%	$1,198	2	20

Table 6-4 Commercial Measure Characteristics				
Measure Name	Savings Factor	Measure Cost	Cost Type: 1=Full 2=Incremental	Effective useful life
On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	38%	$1,373	2	20
On-Demand, Tankless Water Heater (.85 TE) (>200,000 Btu)	13%	$1,522	2	20
Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	28%	$1,175	2	15
Heat Recovery Water Heater	50%	$4,800	1	15
Pipe wrap	2%	$156	1	13
Low flow shower head (1.5 GPM)	40%	$77	1	10
Faucet aerator	32%	$6	1	10
Graywater Heat Exchanger/GFX	40%	$3,364	1	20
Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	47%	$50	1	5
Circulation Pump Time Clocks	5%	$132	1	10
Solar Water Heating w/gas auxiliary tank (SEF=1.5)	61%	$26,400	1	20
Wastewater, Filtration/Reclamation	50%	$150,000	1	20
Ozone Commercial Laundry System (Gas HW)	55%	$26,000	1	15
High Efficiency Clothes Washer	30%	$200	2	11
High Efficiency (95%) Gas Pool Water Heater	28%	$1,300	2	20
Pool Cover	63%	$1,170	1	6
Solar pool heater	100%	$5,500	1	20
Space & Water Heating				
Combination Water Heater/Furnace (.86 EF, .90 AFUE)	15%	$720	2	15
Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	14%	$2,185	2	20
Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	9%	$1,300	2	20
Building Envelope				
Double Glazing Low Emissivity Windows	5%	$7,624	2	20
Triple Glazing Low Emissivity Windows	10%	$12,615	2	20
Improved Wall Insulation (to R12)	7%	$7,833	1	30
Improved Roof/Ceiling Insulation (to R32)	4%	$4,289	1	30
Improved Below-Grade Insulation (to R6)	1%	$2,271	1	30
Air Sealing	13%	$4,200	1	20
Integrated Building Design, Envelope Only (30% > code)	30%	$83,113	2	40

Table 6-4 Commercial Measure Characteristics				
Measure Name	Savings Factor	Measure Cost	Cost Type: 1=Full 2=Incremental	Effective useful life
HVAC Controls				
EMS install	20%	$72,438	1	10
EMS Optimization	5%	$2,608	1	5
Zoning	5%	$1,500	1	15
Retrocommissioning	10%	$3,082	1	7
Commissioning	7%	$15,936	1	7
Programmable Thermostat	19%	$92	1	10
Space Conditioning				
High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	16%	$1,000	2	15
Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	20%	$20,000	2	20
Double-Effect Absorption Chiller (1.03 COP)	38%	$118,400	2	20
Cooking				
High Efficiency Gas Griddle	5%	$1,165	2	12
High Efficiency Gas Combination Oven	26%	$1,300	2	12
High Efficiency Gas Convection Oven	31%	$1,400	2	12
High Efficiency Gas Conveyer Oven	24%	$2,100	2	12
High Efficiency Gas Rack Oven	39%	$4,000	2	12
High Efficiency Gas Broiler	19%	$1,750	2	12
Power Burner Range	34%	$1,400	2	7
High Efficiency Fryer	31%	$1,100	2	10
High Efficiency Gas Steamer	50%	$2,000	2	10
Space Heating				
High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	15%	$696	2	18
High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	6%	$1,012	2	20
Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	16%	$1,627	2	18
High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	9%	$3,552	2	20
High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff. =85%-90%)	10%	$9,110	2	25
Condensing Boiler (>300,000 Btu/h) (Th.eff. =>90%)	13%	$11,019	2	18

Table 6-4
Commercial Measure Characteristics

Measure Name	Savings Factor	Measure Cost	Cost Type: 1=Full 2=Incremental	Effective useful life
High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	5%	$5,352	2	25
Insulate and Seal Ducts (New Aerosol Duct Sealing)	7%	$11,329	1	20
Gas Unit Heater - Condensing (AFUE =93%)	14%	$2,640	2	19
Infrared Heater (low intensity - two stage)	26%	$948	2	17
Stack Heat Exchanger (Standard Economizer)	5%	$1,500	1	20
Stack Heat Exchanger (Condensing Economizer)	10%	$2,120	1	20
Heat Recovery from Air to Air	13%	$8,886	1	20
Boiler Heating Pipe Insulation	2%	$243	1	15
Boiler Tune-Up	2%	$450	1	2
Boiler Reset Controls	5%	$993	1	20
Boiler O2 Trim Controls	2%	$10,000	1	15
Boiler Parallel Positioning	2%	$14,500	1	15
Boiler blowdown heat exchanger (steam)	6%	$60,000	1	20
Repair/Replace malfunctioning steam traps	10%	$219	1	5
Insulate steam lines/condensate tank	2%	$1,302	1	15
Destratification Fans (HVLS)	23%	$20,000	1	12.5
Exhaust Hood Makeup Air	57%	$5,900	1	15
Exhaust Hood - Demand Ventilation	25%	$10,000	2	10
Demand Controlled Ventilation	12%	$3,450	1	15

6.5 Commercial Measure Cost Effectiveness

In the calculation of a measure's cost-effectiveness, all measures are treated *independently*; that is, the savings of each measure are not reduced or otherwise adjusted for overlap between competing or interacting measures. By analyzing measures independently, no assumptions are made about the combinations or order in which they might be installed. This approach evaluates energy-efficient technologies on their own merit, and does not unfairly exclude one measure in favor of another. GDS screened individual commercial natural gas energy efficiency measures to determine their cost effectiveness in accordance with TRC test. Table 6-5 below shows the screening results for each measure. Those measures that did not pass the TRC test (benefit/cost ratio of less than 1.0) were not included in the estimate of economic and achievable economic potential.

Table 6-5 Measure Cost-Effectiveness Screening Results	
Measure Name	TRC B/C Ratio
Water Heating End Use	
Faucet aerator	117.65
Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	54.32
Low flow shower head (1.5 GPM)	20.28
Pool Cover	13.31
Ozone Commercial Laundry System (Gas HW)	8.70
Heat Recovery Water Heater	7.14
High Efficiency (95%) Gas Pool Water Heater	5.78
Solar pool heater	4.81
Circulation Pump Time Clocks	4.16
Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	3.43
High Efficiency Clothes Washer	3.27
Wastewater, Filtration/Reclamation	2.35
Graywater Heat Exchanger/GFX	2.26
Pipe wrap	1.67
On-Demand, Tankless Water Heater (.85 TE) (>200,000 Btu)	1.51
Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 Btu)	1.42
On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	1.19
On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 Btu/h)	1.01
High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	0.84
Solar Water Heating w/gas auxiliary tank (SEF=1.5)	0.44
Space & Water Heating	
Combination Water Heater/Furnace (.86 EF, .90 AFUE)	4.69
Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	1.87
Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	1.74
Building Envelope	
Double Glazing Low Emissivity Windows	0.90
Triple Glazing Low Emissivity Windows	1.01
Improved Wall Insulation (to R12)	1.59
Improved Roof/Ceiling Insulation (to R32)	1.93
Improved Below-Grade Insulation (to R6)	0.59

Table 6-5 Measure Cost-Effectiveness Screening Results	
Measure Name	TRC B/C Ratio
Air Sealing	4.20
Integrated Building Design, Envelope Only (30% > code)	3.27
HVAC Controls	
EMS install	0.72
EMS Optimization	1.76
Zoning	3.09
Retrocommissioning	1.72
Commissioning	0.37
Programmable Thermostat	8.54
Space Conditioning	
High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	3.78
Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	2.85
Double-Effect Absorption Chiller (1.03 COP)	1.83
Cooking	
High Efficiency Gas Griddle	0.54
High Efficiency Gas Combination Oven	3.37
High Efficiency Gas Convection Oven	2.52
High Efficiency Gas Conveyer Oven	4.38
High Efficiency Gas Rack Oven	5.75
High Efficiency Gas Broiler	4.11
Power Burner Range	1.98
High Efficiency Fryer	3.04
High Efficiency Gas Steamer	2.10
Space Heating	
High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	9.97
High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	4.90
Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	7.47
High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	4.18
High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff. =85%-90%)	7.46
Condensing Boiler (>300,000 Btu/h) (Th.eff. =>90%)	5.98
High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	5.85
Insulate and Seal Ducts (New Aerosol Duct Sealing)	0.90

Table 6-5 Measure Cost-Effectiveness Screening Results	
Measure Name	TRC B/C Ratio
Gas Unit Heater - Condensing (AFUE =93%)	3.35
Infrared Heater (low intensity - two stage)	10.53
Stack Heat Exchanger (Standard Economizer)	13.16
Stack Heat Exchanger (Condensing Economizer)	18.62
Heat Recovery from Air to Air	1.95
Boiler Heating Pipe Insulation	10.41
Boiler Tune-Up	2.11
Boiler Reset Controls	6.72
Boiler O2 Trim Controls	1.37
Boiler Parallel Positioning	0.95
Boiler blowdown heat exchanger (steam)	4.42
Repair/Replace malfunctioning steam traps	10.31
Insulate steam lines/condensate tank	10.12
Destratification Fans (HVLS)	1.38
Exhaust Hood Makeup Air	7.34
Exhaust Hood - Demand Ventilation	0.60
Demand Controlled Ventilation	2.49

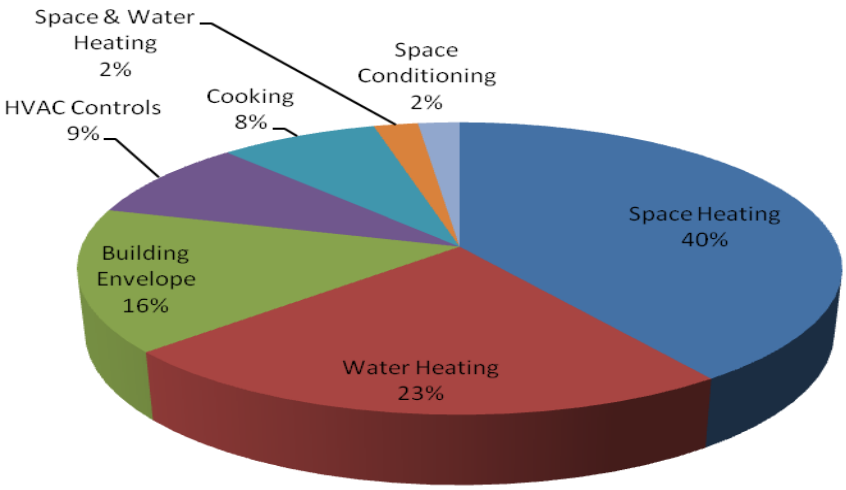
6.6 Commercial Savings Potential

The technical potential for commercial natural gas energy efficiency in Massachusetts is nearly 35% of the projected 2018 commercial natural gas sales. As can be seen in Table 6-6 most of the savings potential is found in existing commercial buildings and slightly more that 90% of the technical potential results from measures that are cost effective (TRC values of at least 1.0).

Table 6-6 Natural Gas Energy Efficiency Potential Commercial Sector		
	Technical Potential (MMBtu)	Economic Potential (MMBTU)
Existing Construction	20,611,543	18,700,268
New Construction	1,168,981	1,063,654
Total	21,780,523	19,763,923
Percent of 2018 Sales	34.74%	31.5%

Figure 6-4, shows a breakdown of commercial sector economic potential. As expected space heating, and measures that impact space heating use (building shell and HVAC controls) together represent a significant portion (65%) of the total economic potential.

Figure 6-4
Commercial Economic Potential
(MMBTU)



It should be noted that HVAC controls refer only to system controls such as programmable thermostats and energy management systems. Controls such as boiler O2 trim, reset and parallel positioning are included under space heating. A more detailed breakdown of commercial sector economic potential by measure category can be found in Figure 6-5 below. The measures included in each category are as follows:

Measure Category	**Measures Included**
Boiler Controls & Maintenance	Boiler Reset and O2 Trim Controls, Circulation Pump Time Clocks, Boiler Tune-Up
Building Insulation & Air Sealing	Improved Wall and Roof/Ceiling Insulation, Air Sealing, Integrated Building Design, Envelope Only (30% > code)
Building Systems Management	Retrocommissioning
Cooking - Broiling/Frying/Steaming	High Efficiency Gas Broilers, Fryers and Steamers
Cooking - Ovens & Ranges	High Efficiency Gas Rack, Convection, Combination and Conveyer Ovens and Power Burner Range
Cross-Cutting HVAC Controls	Programmable Thermostat, Zoning, EMS

Measure Category	Measures Included
	Optimization
Efficient Hot Water Use	Faucet Aerator, Ozone Commercial Laundry System (Gas HW), Wastewater, Filtration/Reclamation, Low flow Shower Head, High Efficiency Clothes Washer, Low Flow Pre-Rinse Spray Nozzle
Energy Efficient Windows	Triple Glazing Low Emissivity Windows
Heat Recovery	Heat Recovery from Air to Air, Boiler Blowdown Heat Exchanger (steam), Stack Heat Exchanger, Heat Recovery Water Heater, Graywater Heat Exchanger/GFX
High Efficiency Boiler, Furnaces & Unit Heaters	High Efficiency Furnaces, Steam Boilers, Hot Water Boilers, Infrared Heaters and Gas Unit Heaters
High Efficiency Gas Air Conditioning	Double-Effect Absorption Chiller, High-Efficiency Gas-Fired Rooftop Unit, Engine-Driven Chiller w/ heat recovery
High Efficiency Water Heaters	High Efficiency Stand Alone, Indirect, On-Demand Tankless and Combination Water Heaters
Hot Water/Steam Pipe Insulation & Maintenance	Boiler and water Heater Pipe Insulation, Steam Trap Replacement
Pool Water Heating	Pool Cover, High Efficient Gas and Solar Pool Heater
Ventilation & Fans	Destratification Fans, Demand Controlled Ventilation and Exhaust Hood Makeup Air

Measures have been grouped in these categories for presentation purpose only and are not intended to represent program groupings in existing or future GasNetworks' programs

Figure 6-5
Commercial Economic Potential
By Measure Category (MMBtu)

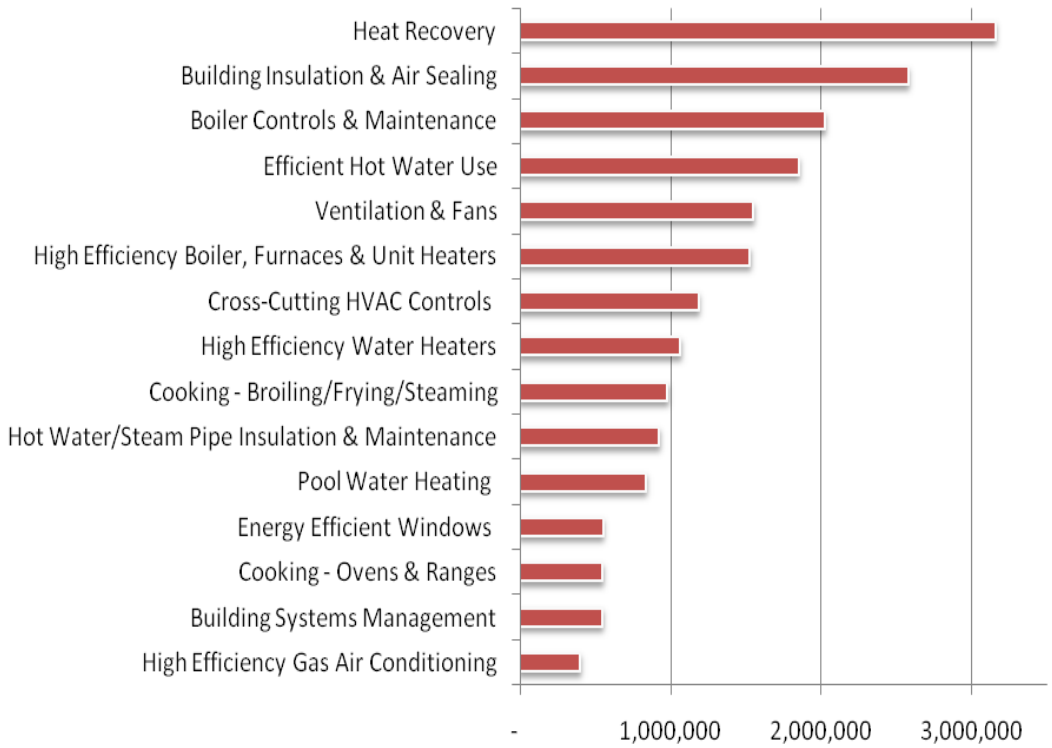
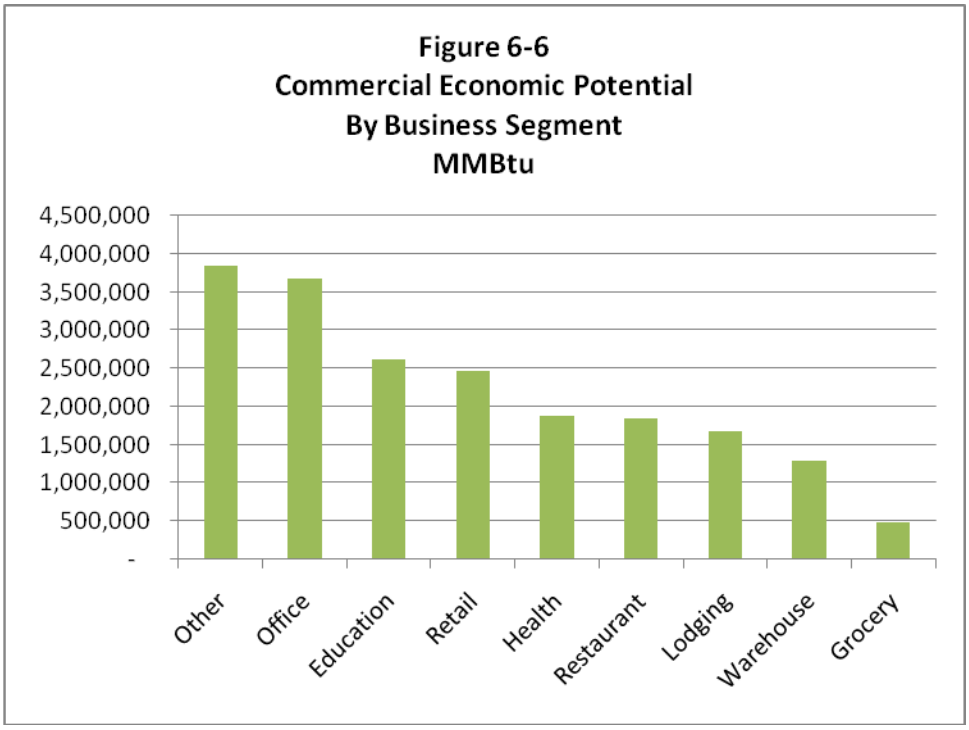


Figure 6-6 below shows that the office and other business segments offer significant potential for energy efficiency savings followed by education and retail. Together these four business sectors represent almost 64% of the total economic potential in the commercial sector.



6.7 Market Penetration Scenario Results

Estimates of achievable economic potential were developed for two scenarios, 80% and 60% maximum measure penetration rates. These scenarios also reflect the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, it was assumed that they would replace existing inefficient equipment at the end of the equipment's effective useful life. For purposes of this study, retrofit measures are limited to the application of low cost or supplemental measures (such as the addition of a low-flow pre-rinse spray nozzle or increased levels of insulation), and do not include the early replacement of high cost operational equipment.

Achievable potential can vary based on energy efficiency program parameters, such as the magnitude of rebates or incentives offered to customers for installing energy efficiency measures and thus, many different scenarios can be modeled. To demonstrate the range of impacts that program parameters can have on achievable economic potential, this report includes savings estimates based on a 60% market penetration scenario and an 80% market penetration scenario.

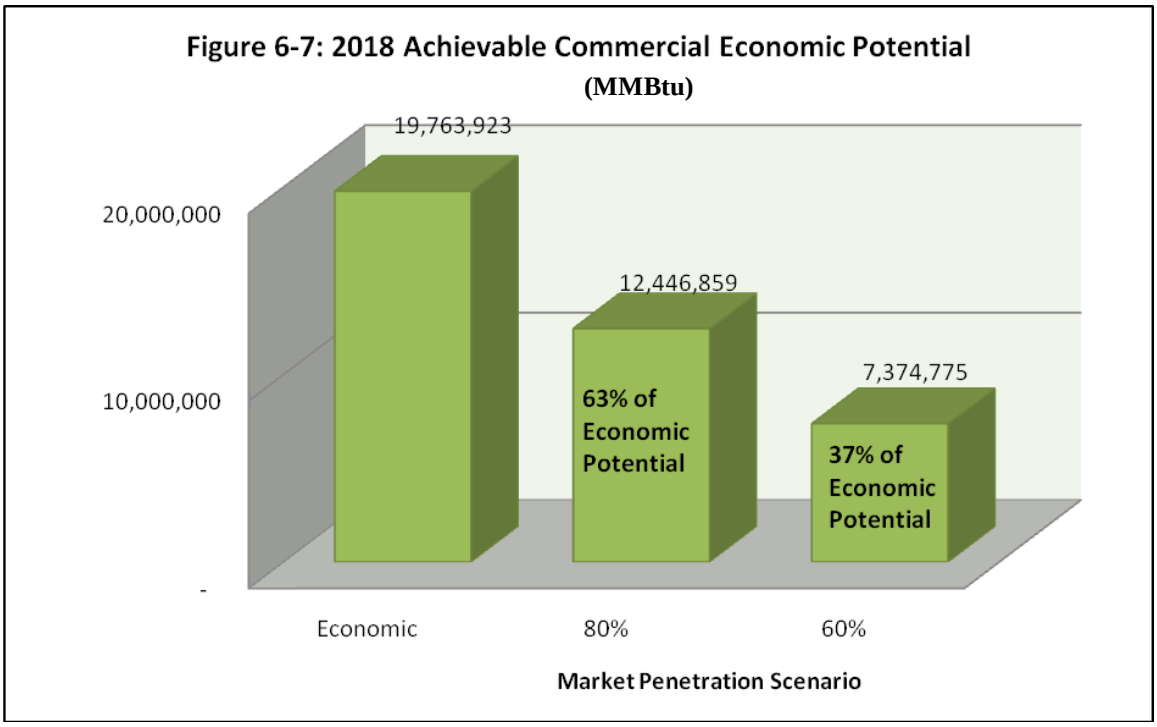


Figure 6-7 shows that the achievable commercial savings potential by 2018 ranges from 37% to 63% of commercial economic potential. The 80% market penetration scenario assumes aggressive program designs that include high incentive levels and strong educational and marketing campaigns. The 60% market penetration scenario assumes a program design that includes smaller incentive levels with less aggressive program promotion targeting consumers already knowledgeable and more willing to make an investment in energy efficient technologies.

7.0 INDUSTRIAL SECTOR ENERGY EFFICIENCY POTENTIAL

7.1 Introduction and Summary of Results

Estimating energy efficiency potential for the industrial sector can be more challenging than it is for the residential and commercial sectors because of the significant differences in the way energy is used across manufacturing segments. How a paper mill uses energy is very different from how a semiconductor manufacturer does. Further, even within a particular industrial segment, energy use is influenced by the particular processes utilized, past investments in energy efficiency, the age of the facility, and the corporate operating philosophy. For example, energy use at a paper mill is dependent on whether the facility produces its own pulp or buys it. Further, the energy requirements of thermo-mechanical pulping are very different from kraft pulping.

Efficiency potential estimates can be developed using either a top-down or a bottom-up approach, depending on data availability. A top-down approach builds an energy profile based on local economic data, national energy consumption surveys and available studies related to conservation potential. A bottom-up approach combines utility sales data, local survey data and facility audits to identify the energy use characteristics of manufacturing segments and the potential for efficiency improvements.

Because industry-level energy consumption and audit data are not available for GasNetworks customers, it was necessary to gather economic data for industrial segments in Massachusetts and then to develop industry-specific energy use estimates using national energy intensities for each industry. The current analysis assumes that industries in the Bay State are similar to those in other jurisdictions. However, industrial processes in Massachusetts are believed to be less energy intensive than those in other regions of the U.S.

Roughly two-thirds of the natural gas used by Massachusetts's industrial sector is consumed by five manufacturing segments: chemicals, paper, fabricated metals, computers & electronics, and food. Process heat accounts for 41% of natural gas use, followed by conventional boiler use at 24% and 14% for cogeneration. Baseline natural gas demand is projected to decline by about 0.6% per annum; falling from 46.2 TBtu (trillion Btu, or billion cubic feet) in 2007 to 43.1TBtu in 2018. (The baseline forecast incorporates natural occurring conservation as projected by the Energy Information Administration).[20]

The technical potential for energy efficiency that could be achieved by 2018 is on the order of 7,360,000 MMBtu, or about 20% of the projected baseline gas usage, excluding cogeneration. According to this analysis, there is still a large potential for natural gas efficiency savings in this sector. Table and Figure 7-1,

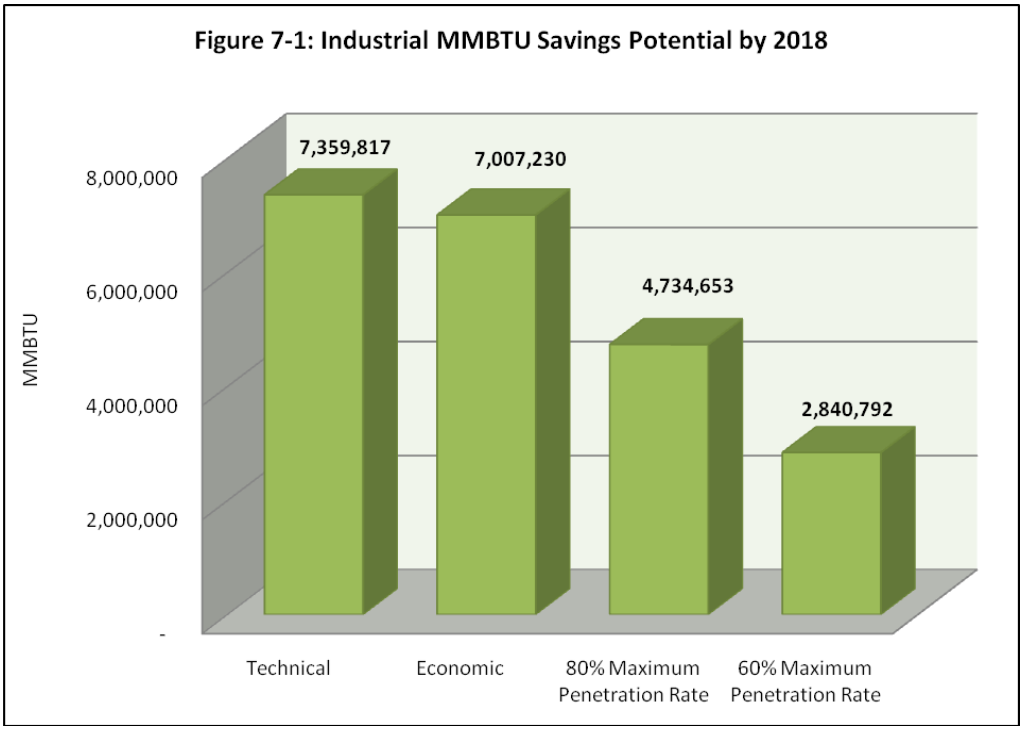
[20] Energy Information Administration, Energy Outlook 2008, Release Data April 2008

below, summarize the technical, economic (based on the TRC test), and achievable economic savings potential by 2018 for the 80% and 60% market measure penetration rate scenarios. These scenarios also reflect the market driven implementation of certain measures that were modeled as non-retrofit measures. In other words, for these measures it was assumed that residential customers would replace existing inefficient equipment at the end of the equipment's effective useful life.

Most of the industrial technical potential is economic and that economic potential represents about 19% of the total 2018 industrial sales. The amount of this economic potential that can be achieved by 2018 ranges from approximately 8% to 13% of projected 2018 industrial natural gas sales assuming a market penetration rate of between 60% and 80% over the next ten years.

Table 7-1
Natural Gas Energy Efficiency Potential
Industrial Sector

			Maximum Achievable Cost Effective Potential (2018)	
	Technical	Economic	80% Maximum Penetration Rate	60% Maximum Penetration Rate
Total MMBtu Savings	7,359,817	7,007,230	4,734,653	2,840,792
Percent of 2018 Sales	20.1%	19.1%	12.9%	7.7%



7.2 Industrial Sector Segmentation & End Use Breakdown

Estimates of energy efficiency potential were developed using a top-down approach, wherein economic data for industrial segments in Massachusetts was used to develop industry-specific energy use estimates based on national energy intensities for each industry.

Gross domestic product (GDP) estimates for manufacturing sectors are available from the Bureau of Economic Analysis (BEA)[21] The following table provides a perspective on the relative importance of different industrial segments to the U.S. and Massachusetts economy. The computer & electronic product manufacturing segment accounts for nearly half of the value of industrial production in the Bay State.

[21] http://www.bea.gov/regional/gsp/

Table 7-2
Economic Perspective on Manufacturing in U.S. and Massachusetts, 2005
Gross Domestic Product (millions of 2000 dollars)

	US	% of Total	MA	% of Total	MA as a % of US
Manufacturing	**1,492,984**	**100.0%**	**36,695**	**100.0%**	**2.5%**
Durable goods	**942,883**	**63.2%**	**28,376**	**77.3%**	**3.0%**
Wood product manufacturing	30,900	2.1%	192	0.5%	0.6%
Nonmetallic mineral product manufacturing	46,109	3.1%	537	1.5%	1.2%
Primary metal manufacturing	45,218	3.0%	363	1.0%	0.8%
Fabricated metal product manufacturing	112,627	7.5%	3,303	9.0%	2.9%
Machinery manufacturing	112,533	7.5%	2,302	6.3%	2.0%
Computer and electronic product manufacturing	301,284	20.2%	17,458	47.6%	5.8%
Electrical equipment and appliance manufacturing	43,836	2.9%	966	2.6%	2.2%
Motor vehicle, body, trailer, and parts manufacturing	129,775	8.7%	250	0.7%	0.2%
Other transportation equipment manufacturing	68,820	4.6%	2,032	5.5%	3.0%
Furniture and related product manufacturing	29,056	1.9%	324	0.9%	1.1%
Miscellaneous manufacturing	66,352	4.4%	2,701	7.4%	4.1%
Nondurable goods	**557,673**	**37.4%**	**8,576**	**23.4%**	**1.5%**
Food product manufacturing	149,790	10.0%	1,483	4.0%	1.0%
Textile and textile product mills	21,571	1.4%	480	1.3%	2.2%
Apparel manufacturing	17,286	1.2%	376	1.0%	2.2%
Paper manufacturing	55,500	3.7%	984	2.7%	1.8%
Printing and related support activities	44,381	3.0%	1,193	3.3%	2.7%
Petroleum and coal products manufacturing	33,991	2.3%	90	0.2%	0.3%
Chemical manufacturing	170,828	11.4%	2,550	6.9%	1.5%
Plastics and rubber products manufacturing	66,076	4.4%	1,460	4.0%	2.2%

U.S. economic data on industrial production was used in conjunction with energy use estimates from the 2002 Manufacturing Energy Consumption Survey[22] which is produced by the Energy Information Administration (EIA), to develop energy intensities by end use and industrial segment. End use energy consumption estimates are calculated for the following end use categories for specific manufacturing segments:

Indirect Uses – Boilers
- Conventional boiler use
- CHP and/or cogeneration

Direct Uses - Process
- Process heating (e.g., kilns, furnaces, ovens, strip heaters)
- Process cooling & refrigeration
- Machine drive
- Electro-chemical processes
- Other direct process use

Direct Uses – Nonprocess
- Facility heating, ventilation and air conditioning
- Facility lighting
- Other facility support (e.g., cooking, water heating, office equipment)
- Conventional electricity generation

Other nonprocess use

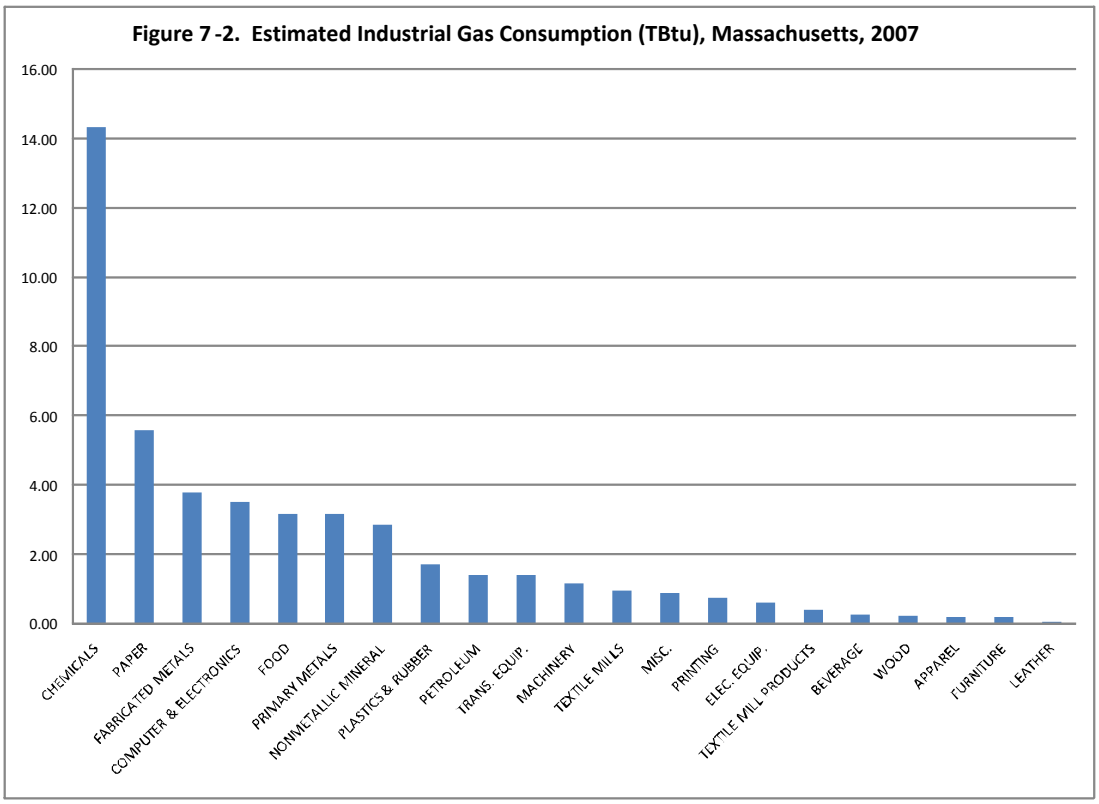
[22] http://www.eia.doe.gov/emeu/mecs/mecs2002/data02/shelltables.html

Nationally, natural gas accounts about 36% of the energy consumed by industrial customers. Twenty nine percent (29%) of the natural gas is consumed in the production of chemical products, and 15% in petroleum manufacturing. With respect to natural gas usage, the most energy intensive industrial sectors are petroleum (27,000 Btu/$ of output), primary metals (15,200), paper (9,900) and chemicals (9,800). The average manufacturing process in the U.S. consumed 4,400 Btu per dollar of output in 2002. Industry-specific end use intensities for the U.S. were calculated for 2002 and used to convert Massachusetts's economic output data to natural gas equivalents in 2005.

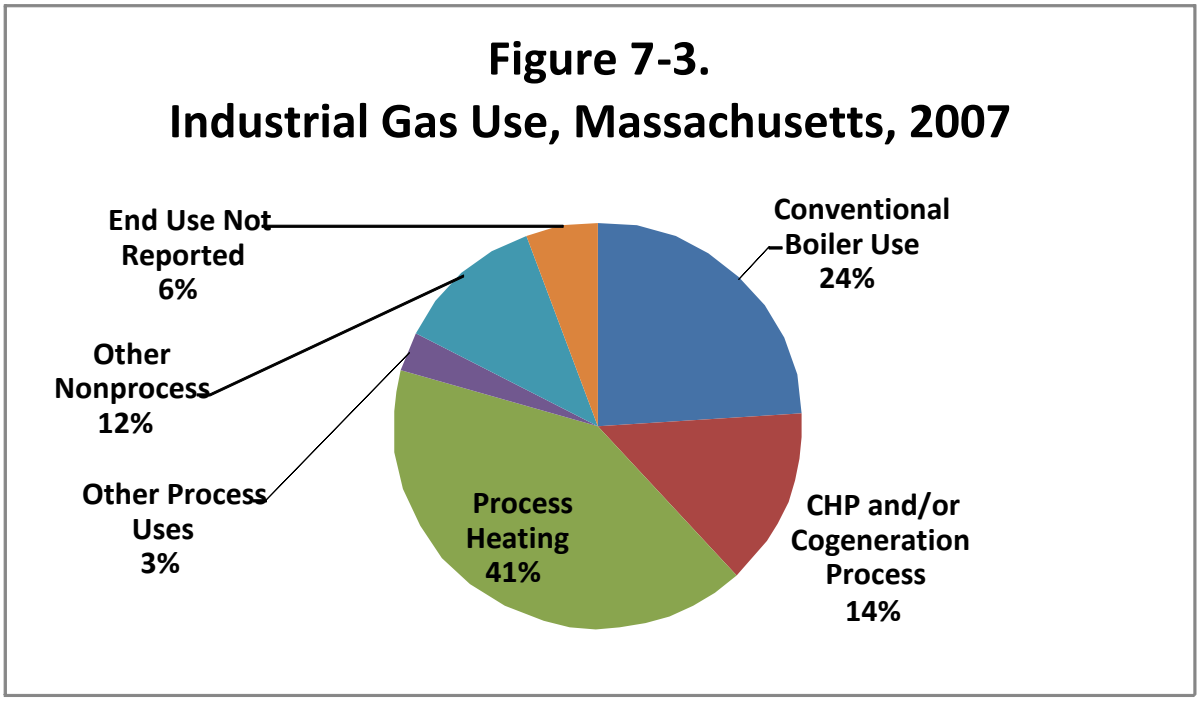
Applying the calculated national gas energy intensities by industrial segment to Massachusetts data on manufacturing GDP results in a total natural gas consumption estimate of 81.0 TBtu for 2005. However, the actual amount of natural gas consumed in Massachusetts by the industrial sector in that year was 48.2 TBtu, based on EIA's State Energy Data System[23] This suggests that Massachusetts's manufacturing sector is considerably less energy intensive than the U.S. Thus, an adjustment factor of 0.595 (i.e., 48.2 / 81.0) is necessary to reflect this difference in energy intensity and adjust the calculated gas consumption estimate to actual consumption data. The average manufacturing process in Massachusetts consumed 1,310 Btu per dollar of output in 2005.

The industry-specific gas consumption estimates for 2005 were later updated to reflect reported gas consumption in 2007; that is, 46.2 TBtu. The following chart shows the calculated breakdown of industrial gas usage by segment for Massachusetts in 2007. The greatest amount of consumption is estimated to be found in the chemicals, paper, fabricated metals and computer industries.

[23] http://www.eia.doe.gov/emeu/states/_seds.html



The estimated usage of natural gas by end use is as follows:



Having established the energy use profile for Massachusetts industries, a baseline projection of natural gas consumption in 2018 was developed. The baseline forecast includes some improvement in energy efficiency, but excludes utility-sponsored conservation efforts. The EIA's June 2008 natural gas demand forecast for New England's industrial sector was used to advance Massachusetts usage to 2018[24] EIA estimates that the demand for natural gas by industrial customers in New England will decline from 88 TBtu in 2007 to 82 TBtu in 2018, or by -0.6% per year.

Table 7-3 shows estimated breakdown of natural gas usage by industrial segment and end use for Massachusetts in 2018.

Table 7-3. Estimated Natural Gas Consumption by Industry and End Use, Massachusetts, 2018

	FOOD	BEVERAGE	TEXTILE MILLS	TEXTILE MILL PRODUCTS	APPAREL	LEATHER	WOOD	PAPER	PRINTING	PETROLEUM	CHEMICALS	PLASTICS & RUBBER	NONMETALLIC MINERAL	PRIMARY METALS	FABRICATED METALS	MACHINERY	COMPUTER & ELECTRONICS	ELECTRICAL EQUIPMENT	TRANSPORTATION EQUIPMENT	FURNITURE	MISCELLANEOUS OTHER
NAICS Code	311	312	313	314	315	316	321	322	323	324	325	326	327	331	332	333	334	335	336	337	339
Total Gas Demand (TBtu)	2.951	0.236	0.884	0.346	0.151	0.038	0.192	5.188	0.671	1.293	13.347	1.581	2.640	2.927	3.517	1.076	3.249	0.557	1.285	0.148	0.815
Conventional Boiler Use	41%	63%	50%	34%	25%	75%	26%	28%	13%	18%	27%	38%	2%	6%	0%	16%	42%	11%	24%	4%	31%
CHP and/or Cogeneration	7%	4%	0%	0%	0%	0%	0%	32%	0%	15%	28%	2%	1%	5%	0%	1%	0%	0%	1%	0%	0%
Process Heating	36%	15%	31%	45%	13%	0%	49%	26%	41%	60%	35%	29%	85%	79%	62%	37%	14%	51%	31%	44%	25%
Process Cooling & Refrigeration	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	1%	1%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Machine Drive	2%	0%	4%	0%	0%	0%	2%	4%	2%	1%	3%	1%	0%	0%	1%	2%	0%	0%	1%	0%	0%
Other Process Use	1%	0%	0%	0%	0%	0%	2%	0%	0%	0%	2%	1%	0%	0%	0%	0%	2%	0%	0%	0%	0%
Facility HVAC	6%	9%	0%	0%	13%	25%	12%	4%	33%	1%	2%	19%	5%	7%	21%	37%	31%	28%	31%	48%	31%
Other Facility Support	0%	0%	0%	0%	13%	0%	0%	0%	2%	0%	0%	1%	0%	1%	0%	1%	2%	0%	1%	0%	0%
Onsite Transportation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Conventional Electricity Generation	0%	0%	1%	0%	0%	0%	0%	2%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Other Nonprocess Use	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	1%	0%	0%	0%	0%	2%	0%	0%	0%	0%
End Use Not Reported	7%	9%	14%	21%	38%	0%	7%	3%	9%	1%	1%	9%	6%	2%	16%	6%	9%	9%	9%	4%	13%

7.3 Industrial Energy Efficiency Measures

Potential energy saving estimates for various industrial measures were identified. Where appropriate, the industrial analysis used the same cost and savings relationships that were utilized in preparing the estimates of commercial sector

[24] http://www.eia.doe.gov/oiaf/archive/aeo08/supplement/index.html

energy efficiency potential. Otherwise, cost and savings estimates were adopted from available studies prepared for New York, California or New Hampshire.

Thirty-seven (37) industrial technologies were adopted for further examination as gas efficiency measures. Preliminary measure data including savings, costs and useful life was also collected for four additional measures (Micro CHP, Gas Drying & Heating Technologies. Desiccant Dehumidification and Gas Fired Air Compression). This data was collected for possible future use in assessing the cost-effectiveness and market potential of these measures, but they were not included in this analysis of natural gas energy efficiency potential.

The measures reviewed in the study were as follows:

Conventional Boiler Use
High Efficiency Hot Water Boiler (<=300,000 Btu/h)
Condensing Boiler (<=300,000 Btu/h)
High Efficiency Steam Boiler (<=300,000 Btu/h)
High Efficiency Hot Water Boiler (>300,000 Btu/h)
Condensing Boiler (>300,000 Btu/h)
High Efficiency Steam Boiler (>300,000 Btu/h)
Boiler Tune-Up
Boiler Pipe Insulation
Boiler Reset Controls
Boiler O2 Trim Controls
Electronic Parallel Positioning Controls
Boiler Blowdown Heat Exchanger (Steam)
Repair Malfunctioning Steam Traps
Insulate Steam Lines / Condensate Tank
Micro CHP

Process Heating
High Efficiency Hot Water Boiler (>300,000 Btu/h)
Condensing Boiler (>300,000 Btu/h)
High Efficiency Steam Boiler (>300,000 Btu/h)
Direct Fired Make-up Air System
Direct Contact Water Heater
Boiler Tune-Up
Boiler Pipe Insulation
Boiler Reset Controls
Boiler O2 Trim Controls
Electronic Parallel Positioning Controls
Waste-Heat Recovery
Gas Drying & Heating Technologies
Regenerative Thermal Oxidizer (replacing a Standard Thermal Oxidizer)
Regenerative Thermal Oxidizer (replacing a Catalytic Thermal Oxidizer)
Infrared Oven
Improved Sensors & Process Controls

Refrigeration Heat Recovery

Facility HVAC
High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)
Gas Unit Heater - Condensing
Infrared Heater (low intensity)
Insulate and Seal Ducts
Stack Heat Exchanger (Standard Economizer)
Stack Heat Exchanger (Condensing Economizer)
Heat Recovery: Air to Air
Desiccant Dehumidification
Direct Fired Make-up Air System

Other Facility Support
Gas Fired Air Compression

GDS collected data and developed estimates of measure savings, cost and useful life for each of the industrial natural gas energy efficiency measures. Savings factors for each measure, which represent the percent savings in annual energy use resulting from implementation of the measure, were then applied to the applicable end-use energy. So, for example, process heating measure savings factors were applied to the estimated process heating end-use energy that is associated with equipment that has not yet been converted to the energy efficiency measure and is technically feasible for conversion All of the industrial measure data and sources can be found in Appendix C,

7.4 Industrial Measure Cost Effectiveness

In the calculation of a measure's cost-effectiveness, all measures are treated *independently*; that is, the savings of each measure are not reduced or otherwise adjusted for overlap between competing or interacting measures. By analyzing measures independently, no assumptions are made about the combinations or order in which they might be installed. This approach evaluates energy-efficient technologies on their own merit, and does not unfairly exclude one measure in favor of another. GDS screened individual commercial natural gas energy efficiency measures to determine their cost effectiveness in accordance with TRC test. Table 7-4 below shows the screening results for each measure. Those measures that did not pass the TRC test (benefit/cost ratio of less than 1.0) were not included in the estimate of economic and achievable economic potential.

Table 7-4. Industrial Natural Gas Measure Screening Results

Industrial Measure	Savings Factor	Cost per MMBtu Saved	Gas Savings - Technical Potential (MMBtu Per Year)	TRC Test Results
Conventional Boiler Use (Boilers)				
High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE = 85%-90%)	6%	$38.34	200	4.90
Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	16%	$22.95	131	7.47
High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	9%	$44.98	290	4.18
High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th. Eff. =85%-90%)	10%	$30.54	13,069	7.46
Condensing Boiler (>300,000 Btu/h) (EF>90%) (Th. Eff. >=90%)	13%	$28.67	443	5.98
High Efficiency Steam Boiler (>300,000 Btu/h) (Th. Eff. >=80%)	5%	$38.95	6,016	5.85
Conventional Boiler Use (Other)				
Boiler Tune-Up	5%	$11.69	156,523	2.11
Boiler Pipe Insulation	2%	$14.05	11,031	10.39
Boiler Reset Controls	5%	$27.95	16,988	6.72
Boiler O2 Trim Controls	2%	$106.36	3,807	1.37
Electronic Parallel Positioning Controls	2%	$154.22	3,807	0.95
Boiler Blowdown Heat Exchanger (Steam)	6%	$42.51	8,895	4.42
Repair Malfunctioning Steam Traps	10%	$5.42	252,781	2.35
Insulate Steam Lines / Condensate Tank	2%	$14.43	3,370	10.12

Table 7-4. Industrial Measure Screening Results (Continued)

Industrial Measure	Savings Factor	Cost per MMBtu Saved	Gas Savings - Technical Potential (MMBtu Per Year)	TRC Test Results
Process Heating (Boilers)				
High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th. Eff. =85%-90%)	10%	$30.54	24,720	7.46
Condensing Boiler (>300,000 Btu/h) (EF>90%) (Th. Eff. >=90%)	13%	$28.67	1,025	5.98
High Efficiency Steam Boiler (>300,000 Btu/h) (Th. Eff. >=80%)	5%	$38.95	11,380	5.85
Direct Fired Make-up Air System	16%	$53.69	19,277	3.50
Direct Contact Water Heater	34%	$22.73	1,664	8.27
Process Heating (Other)				
Boiler Tune-Up	5%	$11.69	289,838	2.11
Boiler Pipe Insulation	2%	$14.05	20,426	10.39
Boiler Reset Controls	5%	$27.95	31,457	2.11
Boiler O2 Trim Controls	2%	$106.36	3,807	1.37
Electronic Parallel Positioning Controls	2%	$154.22	3,807	0.95
Waste-Heat Recovery	6%	$96.21	24,794	6.72
Regenerative Thermal Oxidizer vs. STO	95%	$3.93	12,403	26.06
Regenerative Thermal Oxidizer vs. CTO	69%	$33.28	9,009	3.08
Infrared Oven	23%	$31.20	19,398	4.27
Improved Sensors & Process Controls	5%	$31.20	94,371	4.27
Refrigeration Heat Recovery	50%	$18.56	7,178	3.28

Table 7-4. Industrial Measure Screening Results (Continued)

Industrial Measure	Savings Factor	Cost per MMBtu Saved	Gas Savings - Technical Potential (MMBtu Per Year)	TRC Test Results
Facility HVAC				
High Efficiency Furnace (<=300,000 Btu/h) (AFUE >=92%)	15%	$17.20	14,493	9.97
Gas Unit Heater - Condensing	14%	$53.69	10,102	3.35
Infrared Heater (low intensity - two stage)	26%	$15.49	5,153	10.53
Insulate and Seal Ducts (New Aerosl Duct Sealing)	7%	$245.33	9,482	0.77
Stack Heat Exchanger (Standard Economizer)	5%	$14.29	3,003	13.16
Stack Heat Exchanger (Condensing Economizer)	10%	$10.10	6,007	18.62
Heat Recovery: Air to Air	13%	$96.21	7,809	1.95
Direct Fired Make-up Air System	16%	$53.69	3,493	3.50

7.5 Industrial Energy Efficiency Potential

The technical potential for industrial natural gas energy efficiency in Massachusetts is nearly 20% of the projected 2018 industrial natural gas sales. Almost all of this savings potential is cost-effective according to the TRC test.

Figure 7-4, shows a breakdown of industrial sector economic potential by end use category.

Figure 7.4 Industrial Economic Potential, by End Use Category

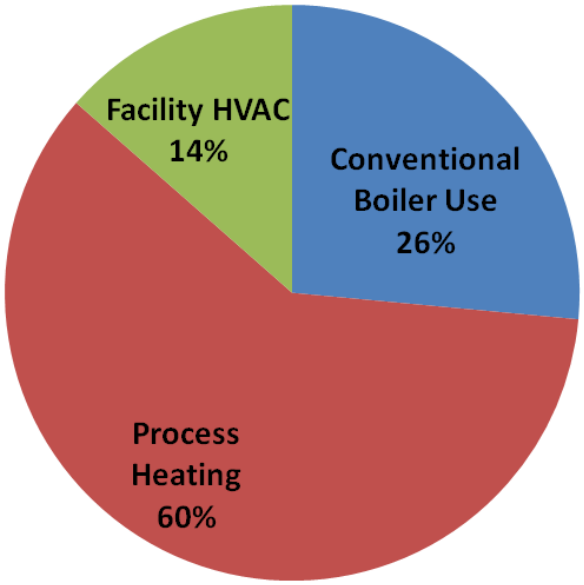
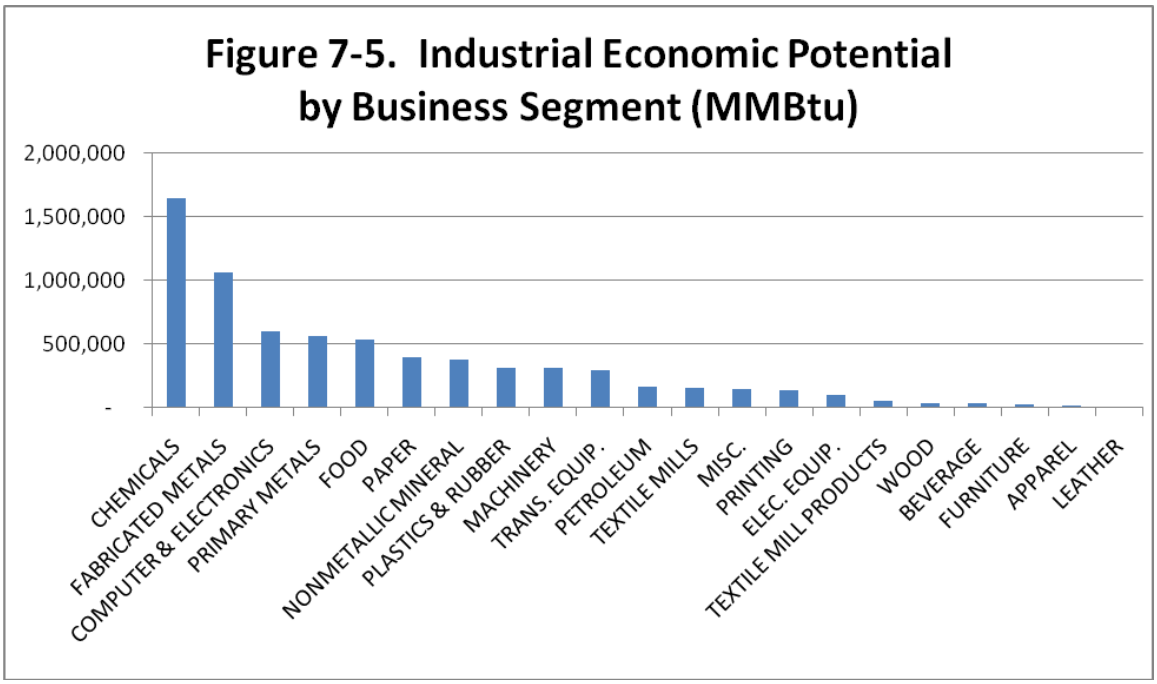


Figure 7-5 below shows that the Chemicals and Fabricated Metals segments offer significant potential for energy efficiency savings followed by Computers & Electronics and Primary Metals. Together these four industrial sectors represent 55% of the total economic potential in the industrial sector.



The economic potential of industrial conservation measures are ranked in Table 7-5 below according to the amount of savings that could be achieved by 2018.

Table 7-5 Industrial Economic Potential by Measure Type

Measure Type	Maximum Achievable Conservation (MMBtu)	Maximum Achievable Conservation (% of Total)
High Efficiency Boilers	1,418,873	20%
Boiler Controls	1,132,207	16%
Boiler Tune-Up	893,142	13%
Boiler Pipe Insulation	472,084	7%
Improved Sensors & Process Controls	472,077	7%
Direct Fired Make-up Air System	455,624	7%
High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	260,993	4%
Repair Malfunctioning Steam Traps	252,900	4%
Waste-Heat Recovery	248,060	4%
Regenerative Thermal Oxidizer	214,223	3%
Infrared Oven	194,066	3%
Gas Unit Heater - Condensing	192,036	3%

Table 7-5 Industrial Economic Potential by Measure Type		
Measure Type	**Maximum Achievable Conservation (MMBtu)**	**Maximum Achievable Conservation (% of Total)**
Stack Heat Exchanger	177,977	3%
Boiler Blowdown Heat Exchanger (Steam)	156,252	2%
Heat Recovery: Air to Air	180,291	3%
Refrigeration Heat Recovery	114,896	2%
Infrared Heater (low intensity)	87,643	1%
Insulate Steam Lines / Condensate Tank	50,580	1%
Direct Contact Water Heater	33,304	0%
Total Maximum Achievable Cost Effective Conservation	7,007,230	

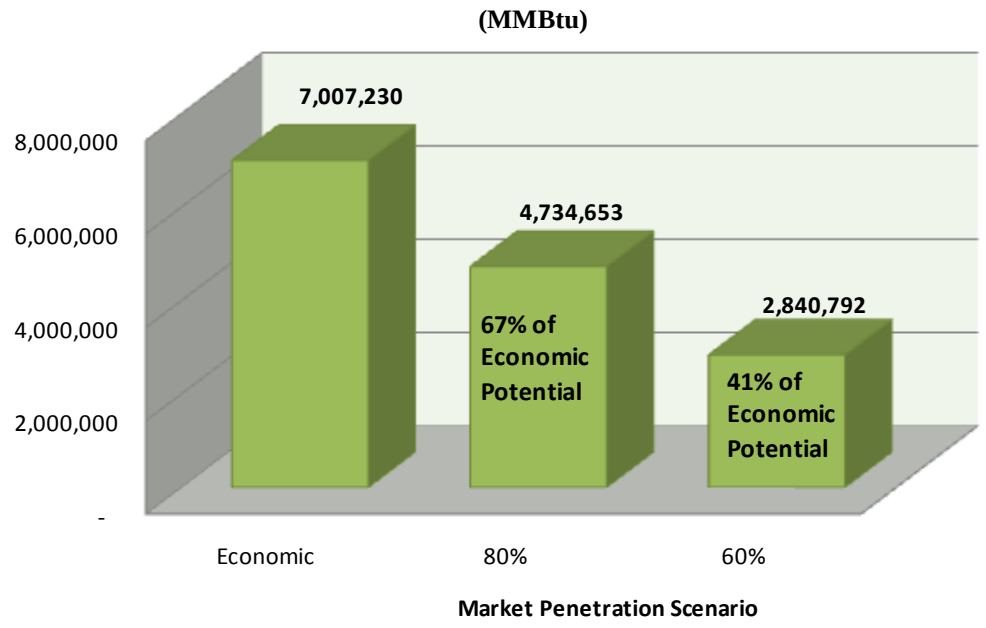
In addition to the natural gas conservation measures that were analyzed, GDS considered the potential energy savings that could be obtained by adopting energy efficient gas technologies as a replacement for electric end uses. Four measures (Micro-cogeneration CHP, Gas Drying & Heating Technologies. Desiccant Dehumidification and Gas Fired Air Compression) were considered. While the adoption of said technologies is very much site and industry specific, Microcogeneration, Gas Drying & Heating Technologies deserve further study as gas technologies that will save energy on net basis (i.e., with increased gas usage being offset by electricity savings). Gas Fired Air Comprehension may also offer the same benefits in certain high use industrial applications.

7.6 Market Penetration Scenario Results

Achievable potential can vary based on energy efficiency program parameters, such as the magnitude of rebates or incentives offered to customers for installing energy efficiency measures and thus, many different scenarios can be modeled. To demonstrate the range of impacts that program parameters can have on achievable economic potential, this report includes savings estimates based on a 60% market penetration scenario and an 80% market penetration scenario.

Figure 7-6 shows that the achievable savings potential by 2018 ranges from 41% to 67% of economic potential. The 80% market penetration scenario assumes aggressive program designs that include high incentive levels and strong educational and marketing campaigns. The 60% market penetration scenario assumes a program design that includes smaller incentive levels with less aggressive program promotion targeting consumers already knowledgeable and more willing to make an investment in energy efficient technologies.

Figure 7-6: 2018 Achievable Economic Potential



APPENDIX A

Residential Sector Data

Appendix A-1

Residential Energy Efficiency Measure Descriptions

Fifty-two (52) residential energy efficiency measures were included in this study of gas efficiency potential in Massachusetts. Appendix A-1 contains brief descriptions of each of these measures by end-use category.

Water heating

Note: SF = Single Family, MF = Multi-Family - SF/MF means that the measure applies to both single family and multi-family housing

R-SF/MF-WatH-1&2 (Market Driven & Retrofit) Condensing Water Heater (0.8 EF)

Condensing water heaters recover energy by using a larger heat exchanger or a second heat exchanger that reduces the flue-gas temperature to the point where this water vapor condenses, releasing even more energy.

R-SF/MF-WatH-3&4 (Market Driven and Retrofit) High Efficiency Stand Alone Water Heater (0.62 EF)

High efficiency water heaters rated at 0.62EF that are not combined with space heating devices.

R-SF/MF-WatH-5&6 (Market Driven & Retrofit) High Efficiency Stand Alone Water Heater (0.67 EF)

High efficiency water heaters rated at 0.67EF that are not combined with space heating devices.

R-SF/MF-WatH-7&8 (Market Driven & Retrofit) On-Demand, Tankless Water Heater (>=.82, <.95 EF)

Efficient on-demand (tankless) water heaters heat water as its passes through a gas-heated water-jacket/heat exchanger.

R-SF/MF-WatH-9&10 (Market Driven & Retrofit) On-Demand, Tankless Water Heater (>=.95 EF)

Efficient on-demand (tankless) water heaters heat water as its passes through a gas-heated water-jacket/heat exchanger.

R-SF/MF-WatH-11 Gravity-Film Exchange (GFX) Waste Water Heat Recovery

System for heat recovery from graywater drainpipe - a coil wrap that heats incoming cold water with waste heat from outgoing hot wastewater (showers and sinks)

R-SF/MF-WatH-12 Low-flow Shower Heads (1.59 GPM)

Shower head with smaller outlets and aerators to reduce water flow and the associated heating/costs.

R-SF/MF-WatH-13 Low Flow Shower Heads (1.59 GPM + ShowerStart technology)

Shower head with smaller outlets and a small in-line heat sensor that shuts-off water flow when hot water begins to flow, reducing hot water loss (and associated costs - $0.03/gal) while waiting for a hot shower.

R-SF/MF-WatH-14 Shower Start Technology Only

A small in-line heat sensor that shuts-off water flow when hot water begins to flow, reducing hot water loss (and associated costs - $0.03/gal) while waiting for a hot shower.

R-SF/MF-WatH-15 Pipe Insulation

Insulation is wrapped around the first 12 feet of either hot/cold pipe to reduce heat loss.

R-SF/MF-WatH-16 Faucet Aerators

Small wire mesh fitting placed over water faucets to reduce total water flow.

R-SF/MF-WatH-17 Solar Water Heating – drain back system/with gas backup

Water heating system that utilizes the sun's solar energy to heat water indirectly (heat exchanger) or directly from a rooftop collector - through large flat roof plates or tubes. A drain back system allows heated water to drain back into a holding tank when sensors indicate that no solar heat gain is possible.

R-SF/MF-WatH-18&19 (Market Driven & Replacement) Indirect Water Heater

Indirect-fired water heater is heated by efficient boiler (EF = 0.68)

Space Heating

R-SF/MF-SpH-1 Insulate and Seal Ducts

Repair and seal leaky and unsealed residential air ducts for heating with sealant products (mastic) to prevent air and heat loss.

R-SF/MF-SpH-2 Insulate Unconditioned Basement/Crawl Space Piping

Insulate piping in basement/crawl areas to reduce heat loss from distribution piping in unconditioned areas.

R-SF/MF-SpH-3&4 (Market Driven & Retrofit) Energy Star Furnace (AFUE=90%)

Space heating gas-fired furnace with an energy star rating and AFUE at 90%

R-SF/MF-SpH-5&6 (Market Driven & Retrofit) CEE Tier 2 Furnace (AFUE=92%)

Space heating gas -fired furnace with a CEE tier 2 rating and AFUE at 92%

R-SF/MF-SpH-7&8 (Market Driven & Retrofit) CEE Tier 3 Furnace (AFUE=94%)

Space heating gas-fired furnace with a CEE tier 3 rating and AFUE at 94%

R-SF/MF-SpH-9&10 (Market Driven & Retrofit) Energy Star Gas Boiler (AFUE=85%)

Gas boiler with an energy star rating and AFUE at 85%

R-SF/MF-SpH-11&12 (Market Driven & Retrofit) Condensing Gas Boiler with Controls(AFUE=90%)

Gas boiler with an energy star rating and AFUE at 90% -a water heating device designed to recover energy normally discharged to the atmosphere through the flue. A heat exchanger cools the exhaust, forcing condensation and thus saving the water vapor (and stored energy) it contains.

R-SF/MF-SpH-13&14 (Market Driven & Retrofit) Condensing Gas Boiler with Controls (AFUE=95%)

Gas boiler with an energy star rating and AFUE at 95% - a water heating device designed to recover energy normally discharged to the atmosphere through the flue. A heat exchanger cools the exhaust, forcing condensation and thus saving the water vapor (and stored energy) it contains.

R-SF/MF-SpH-15&16 (Market Driven & Retrofit) Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)

Heat pumps that works on the principle of the vapor compression cycle. The main components in such a heat pump system are the compressor, the expansion valve and two heat exchangers referred to as evaporator and condenser. When the compressor is driven by a gas engine, heat from the cooling water and exhaust gas is used in addition to the condenser heat.

R-SF/MF-SpH-17&18 (Market Driven & Retrofit) Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)

Absorption heat pumps are thermally driven, which means that heat rather than mechanical energy is supplied to drive the cycle. Absorption heat pumps for space conditioning are often gas-fired

R-SF/MF-SpH-19 Heat Recovery Ventilator

A heat recovery ventilator (HRV) can help make mechanical ventilation more cost effective by reclaiming energy from exhaust airflows. HRVs use heat exchangers to heat or cool incoming fresh air, recapturing 60 to 80 percent of the conditioned temperatures that would otherwise be lost.

R-SF/MF-SpH-20 Energy Star (High Performance Homes)

These homes are at least 15% more energy efficient than homes built to the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20–30% more efficient than standard homes

R-SF/MF-SpH-21 Energy Efficient Steam Boilers (low pressure/single-family)

Low Pressure Steam Boiler is a ready-to-install packaged system featuring a matched and efficient burner/boiler combination. All steam boiler controls and secondary plumbing are in place and pre wired, yet the vessels easily fit through a three foot wide doorway resulting in a very quick start-up. .

Dehumidification

R-SF/MF-DEHUM-1 Desiccant Dehumidification

A desiccant dehumidifier is a device that employs a desiccant material to produce a dehumidification effect. Typically used in residential settings to minimize dampness and mold growth.

Space and Water Heating

R-SF/MF-SpH&WatH-1&2 (Market Driven & Retrofit) Combination Water Heater/Furnace (.86 EF, .90 AFUE)

These systems use one primary heat source shared between conventional pieces of equipment, such as, an air handler and a tank water heater, to serve dual heating purposes.

R-SF/MF-SpH&WatH-3&4 (Market Driven & Retrofit) Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)

A powerful water heater that provides space heating as a supplemental end-use. Heated water passes through a heat exchanger in a central handler to heat air which is then blown into the home's duct system.

R-SF/MF-SpH&WatH-5&6 (Market Driven & Retrofit) Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)

A powerful water heater that provides space heating as a supplemental end-use. Heated water passes through a heat exchanger in a central handler to heat air which is then blown into the home's duct system. 0.86 EF, 0.85 AFUE

Laundry

R-SF/MF-LAUN-1 Energy Star Clothes Washer (vertical and horizontal)

Clothes washing machine with an energy star rating (Minimum Modified Energy Factor (MEF) of 1.72 and a maximum Water Factor (WF) of 8.0.

R-SF/MF-LAUN-2 Clothes Dryer with Moisture Sensor

Moisture sensor shuts-off the dryer when clothes are dry.

Building Envelope

R-SF/MF-ENV-1 Energy Star Windows

Windows with multiple insulated layers to reduce heat/cooling loss -- upgrade to low-e, vinyl frame, u-value = 0.3

R-SF/MF-ENV-2 Improved Wall Insulation

Material used to reduce heat loss through building walls -- upgrade to R-12 whole wall

R-SF/MF-ENV-3 Improved Roof Insulation

Material used to reduce heat loss through the roof of the house -- upgrade to R-32 ceiling

R-SF-ENV-4 Improved Below-Grade Insulation

Improving the insulation in basement areas -- add R-6 insulation to top 4 feet

R-SF-ENV-5 Improved Floor Insulation

Material used to reduce heat loss through the floor. Add R-13 insulation to floor.

R-SF-ENV-6 Storm Windows

Storm windows provide another layer of insulation to your home and can dramatically decrease energy bills, especially in the case of older windows.

R-SF-ENV-7 Air Sealing

Properly air sealing thermal shell air leaks and openings through strategic use and location of airtight materials significantly reduces heating and cooling costs. Cut leakage to 0.5 ACH.

R-SF-ENV-8 Insulated Exterior Door

Door with added insulation hung in the exterior shell of the house to reduce heat loss. R-5 door.

R-SF-ENV-9 Attic Hatch Insulation

R-19 Insulation added to the attic hatch to reduce heat loss through the ceiling/roof

Cooking

R-SF/MF-COOK-1 Convection Ovens

Convection ovens are more energy efficient than standard ovens, since the heat is continuously circulated, reducing temperatures and cooking time by up to 30%.

Controls

R-SF/MF-CTRL-1 Programmable Thermostat

Ability to adjust heating or air-conditioning operating times according to a pre-set schedule to meet occupancy needs and minimize redundant HVAC operation.

R-SF/MF-CTRL-2 Occupancy Controlled Thermostat Retrofit

A control device that detects occupancy levels of various zones to determine zonal air-flow and temperature settings.

R-SF/MF-CTRL-3 Boiler Controls (Non-Condensing Boiler) Retrofit

Controls for boilers that estimate changes in heat demand under part-load conditions and control maximum boiler water temperature, firing time, and/or circulating pump cycling and speed in response

R-SF/MF-CTRL-4 Zoning Retrofit

The zone control system allows a single HVAC unit to have separate temperature zones in the home.

Pool Water Heating

R-SF/MF-POOL-1 Pool Cover (Vinyl)

Large insulating cover to prevent heat loss from a heated pool or water loss through evaporation.

R-SF/MF-POOL-2 Solar Pool Cover (Bubble)

Large insulating cover to prevent heat loss from a heated pool or water loss through evaporation.

R-SF/MF-POOL-3 High Efficiency Gas Pool Heater

High capacity, gas-powered water heater for a swimming pool

R-SF/MF-POOL-4 Temperature Control

Temperature controllers offer advanced operating features to provide differential temperature control, selectable high limit, programmable recirculation freeze protection, solar temperature, nocturnal cooling and optional booster pump control.

R-SF/MF-POOL-5 Outdoor Spa Cover

Outdoor spa covers prevent evaporation and heat loss

R-SF/MF-POOL-6 Solar Pool Heater

Install a solar pool heater that plugs into the existing filtration unit. Some systems include an automatic controller and sensors to open and close a valve, deciding whether to send water back into the pool or through the collectors.

Appendix A-2

Residential Sector Measure Data

Appendix A-2 contains measure data including incremental costs, useful lives, MMBTU savings, electric savings and water savings for all of the residential measures considered in this study.

Appendix A-2 includes the following tables:

a) Water Heating

b) Space Heating

c) Dehumidification

d) Space and Water Heating

e) Laundry

f) Building Envelope

g) Cooking

h) Controls

i) Pool Water Heating

j) *Sources*

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2a

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Water Heating												
R-SF-WatH-1	Condensing Water Heater (0.8 EF)	SF	Market-driven	15	unit	18.00	4.66	-	4.66	25.9%	0	0	$685
R-SF-WatH-2	Condensing Water Heater (0.8 EF)	SF	Retrofit	15	unit	19.44	6.10	-	6.10	31.4%	0	0	$1,285
R-SF-WatH-3	High Efficiency Stand Alone Water Heater (0.62 EF)	SF	Market-driven	10	unit	18.00	0.76	-	0.76	4.2%	0	0	$70
R-SF-WatH-4	High Efficiency Stand Alone Water Heater (0.62 EF)	SF	Retrofit	10	unit	19.44	2.20	-	2.20	11.3%	0	0	$670
R-SF-WatH-5	High Efficiency Stand Alone Water Heater (0.67 EF)	SF	Market-driven	10	unit	18.00	2.05	-	2.05	11.4%	0	0	$400
R-SF-WatH-6	High Efficiency Stand Alone Water Heater (0.67 EF)	SF	Retrofit	10	unit	19.44	3.49	-	3.49	18.0%	0	0	$1,000
R-SF-WatH-7	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	SF	Market-driven	20	unit	18.00	5.92	-	5.92	32.9%	0	0	$900
R-SF-WatH-8	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	SF	Retrofit	20	unit	19.44	7.37	-	7.37	37.9%	0	0	$1,500
R-SF-WatH-9	On-Demand, Tankless Water Heater (>=.95 EF)	SF	Market-driven	20	unit	18.00	6.78	-	6.78	37.7%	0	0	$1,730
R-SF-WatH-10	On-Demand, Tankless Water Heater (>=.95 EF)	SF	Retrofit	20	unit	19.44	8.22	-	8.22	42.3%	0	0	$2,330
R-SF-WatH-11	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	SF	Retrofit	20	unit	19.44	2.81	-	2.81	14.4%	0	0	$800
R-SF-WatH-12	Low-flow Shower Heads (1.59 GPM)	SF	Retrofit	9	unit	19.44	2.74	-	2.74	14.1%	0	4,982	$15
R-SF-WatH-13	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	SF	Retrofit	9	unit	19.44	3.06	-	3.06	15.7%	0	5,369	$40
R-SF-WatH-14	Shower Start Technology Only	SF	Retrofit	9	unit	19.44	0.50	-	0.50	2.6%	0	608	$30
R-SF-WatH-15	Pipe Insulation	SF	Retrofit	13	home	19.44	0.78	-	0.78	4.0%	0	0	$15

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2a

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Water Heating												
R-SF-WatH-16	Faucet Aerators	SF	Retrofit	10	faucet	19.44	1.36	-	1.36	7.0%	0	3,842	$6
R-SF-WatH-17	Solar Water Heating – drain back system/with gas backup	SF	Retrofit	20	home	19.44	11.66	-	11.66	60.0%	0	0	$3,230
R-SF-WatH-18	Indirect Water Heater	SF	Market-driven	20	home	18.00	3.96	-	3.96	22.0%	0	0	$750
R-SF-WatH-19	Indirect Water Heater	SF	Retrofit	20	home	19.44	5.44	-	5.44	28.0%	0	0	$1,350
R-MF-WatH-1	Condensing Water Heater	MF	Market-driven	15	unit	18.00	4.66	-	4.66	25.9%	0	0	$685
R-MF-WatH-2	Condensing Water Heater	MF	Retrofit	15	unit	19.44	6.10	-	6.10	31.4%	0	0	$1,285
R-MF-WatH-3	High Efficiency Stand Alone Water Heater (0.62 EF)	MF	Market-driven	10	unit	18.00	0.76	-	0.76	4.2%	0	0	$70
R-MF-WatH-4	High Efficiency Stand Alone Water Heater (0.62 EF)	MF	Retrofit	10	unit	19.44	2.20	-	2.20	11.3%	0	0	$670
R-MF-WatH-5	High Efficiency Stand Alone Water Heater (0.67 EF)	MF	Market-driven	10	unit	18.00	2.05	-	2.05	11.4%	0	0	$400
R-MF-WatH-6	High Efficiency Stand Alone Water Heater (0.67 EF)	MF	Retrofit	10	unit	19.44	3.49	-	3.49	18.0%	0	0	$1,000
R-MF-WatH-7	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	MF	Market-driven	20	unit	18.00	5.92	-	5.92	32.9%	0	0	$900
R-MF-WatH-8	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	MF	Retrofit	20	unit	19.44	7.37	-	7.37	37.9%	0	0	$1,500
R-MF-WatH-9	On-Demand, Tankless Water Heater (>=.95 EF)	MF	Market-driven	20	unit	18.00	6.78	-	6.78	37.7%	0	0	$1,730
R-MF-WatH-10	On-Demand, Tankless Water Heater (>=.95 EF)	MF	Retrofit	20	unit	19.44	8.22	-	8.22	42.3%	0	0	$2,330
R-MF-WatH-11	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	MF	Retrofit	20	unit	19.44	2.81	-	2.81	14.4%	0	0	$800

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2a

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Water Heating												
R-MF-WatH-12	Low-flow Shower Heads (1.59 GPM)	MF	Retrofit	9	unit	19.44	2.74	-	2.74	14.1%	0	4982	$15
R-MF-WatH-13	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	MF	Retrofit	9	unit	19.44	3.06	-	3.06	15.7%	0	5,369	$40
R-MF-WatH-14	Shower Start Technology Only	MF	Retrofit	9	unit	19.44	0.50	-	0.50	2.6%	0	608	$30
R-MF-WatH-15	Pipe Insulation	MF	Retrofit	13	home	19.44	0.78	-	0.78	4.0%	0	0	$15
R-MF-WatH-16	Faucet Aerators	MF	Retrofit	10	faucet	19.44	1.36	-	1.36	7.0%	0	3,842	$6
R-MF-WatH-17	Solar Water Heating – drain back system/with gas backup	MF	Retrofit	20	home	19.44	11.66	-	11.66	60.0%	0	0	$3,230
R-MF-WatH-18	Indirect Water Heater	MF	Market-driven	20	home	18.00	3.96	-	3.96	22.0%	0	0	$750
R-MF-WatH-19	Indirect Water Heater	MF	Retrofit	20	home	19.44	5.44	-	5.44	28.0%	0	0	$1,350

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2b

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Space Heating													
R-SF-SpH-1	Insulate and Seal Ducts	SF	Retrofit	15	home	2007 Building America Benchmark (duct location depends on number of floors and foundation type)	143.86	3.60	-	3.60	2.5%	0	0	$300
R-SF-SpH-2	Insulate Unconditioned Basement/Crawl Space Piping	SF	Retrofit	15	home	no insulation	143.86	3.45	-	3.45	2.4%	0	0	$568
R-SF-SpH-3	Energy Star Furnace (AFUE=90%)	SF	Market-driven	18	home	78% AFUE	138.33	18.44	-	18.44	13.3%	0	0	$320
R-SF-SpH-4	Energy Star Furnace (AFUE=90%)	SF	Retrofit	18	home	75% AFUE	143.86	23.98	-	23.98	16.7%	0	0	$3,320
R-SF-SpH-5	CEE Tier 2 Furnace (AFUE=92%)	SF	Market-driven	18	home	78% AFUE	138.33	21.05	-	21.05	15.2%	0	0	$520
R-SF-SpH-6	CEE Tier 2 Furnace (AFUE=92%)	SF	Retrofit	18	home	75% AFUE	143.86	26.58	-	26.58	18.5%	0	0	$3,520
R-SF-SpH-7	CEE Tier 3 Furnace (AFUE=94%)	SF	Market-driven	18	home	78% AFUE	138.33	23.55	-	23.55	17.0%	0	0	$688
R-SF-SpH-8	CEE Tier 3 Furnace (AFUE=94%)	SF	Retrofit	18	home	75% AFUE	143.86	29.08	-	29.08	20.2%	0	0	$3,688
R-SF-SpH-9	Energy Star Gas Boiler (AFUE=85%)	SF	Market-driven	20	home	80% AFUE	134.87	8.00	-	8.00	5.9%	0	0	$900
R-SF-SpH-10	Energy Star Gas Boiler (AFUE=85%)	SF	Retrofit	20	home	75% AFUE	143.86	16.99	-	16.99	11.8%	0	0	$3,900
R-SF-SpH-11	Condensing Gas Boiler with Controls(AFUE=90%)	SF	Market-driven	20	home	80% AFUE	134.87	14.99	-	14.99	11.1%	0	0	$1,500
R-SF-SpH-12	Condensing Gas Boiler with Controls(AFUE=90%)	SF	Retrofit	20	home	75% AFUE	143.86	23.98	-	23.98	16.7%	0	0	$4,500
R-SF-SpH-13	Condensing Gas Boiler with Controls (AFUE=95%)	SF	Market-driven	20	home	80% AFUE	134.87	21.30	-	21.30	15.8%	0	0	$2,400
R-SF-SpH-14	Condensing Gas Boiler with Controls (AFUE=95%)	SF	Retrofit	20	home	75% AFUE	143.86	30.29	-	30.29	21.1%	0	0	$5,400
R-SF-SpH-15	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	SF	Market-driven	10	home	78% AFUE furnace	138.33	52.70	3.13	49.57	35.8%	1,053	0	$2,800
R-SF-SpH-16	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	SF	Retrofit	10	home	75% AFUE Furnace, room AC	143.86	58.23	3.13	55.10	38.3%	364	0	$8,800
R-SF-SpH-17	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	SF	Market-driven	20	home	78% AFUE furnace, 13 SEER AC	138.33	67.34	17.14	50.20	36.3%	941	0	$10,000
R-SF-SpH-18	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	SF	Retrofit	20	home	75% AFUE Furnace, room AC	143.86	72.88	17.14	55.73	38.7%	252	0	$16,000
R-SF-SpH-19	Heat Recovery Ventilator	SF	Retrofit	20	home	ASHRAE 62.2-compliant exhaust fan system with no heat recovery (0.01 cfm/sf + 7.5 cfm * (1 + #bedrooms)	87.79	7.68	-	7.68	8.7%	-133	0	$960
R-SF-SpH-20	Energy Star (High Performance Homes)	SF	New Construction	25	home	2004 IRC-compliant home	131.00	37.79	-	37.79	28.8%	0	0	$2,599

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2b

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Space Heating													
R-SF-SpH-21	Energy Efficient Steam Boilers (low pressure/single-family)	SF	Market-driven	25	unit	75%AFUE	143.86	12.28	-	12.28	8.5%	0	0	$2,500
R-MF-SpH-1	Insulate and Seal Ducts	MF	Retrofit	15	home	2007 Building America Benchmark (duct location depends on number of floors and foundation type)	71.93	1.80	-	1.80	2.5%	0	0	$300
R-MF-SpH-2	Insulate Unconditioned Basement/Crawl Space Piping	MF	Retrofit	15	home	no insulation	71.93	1.29	-	1.29	1.8%	0	0	$186
R-MF-SpH-3	Energy Star Furnace (AFUE=90%)	MF	Market-driven	18	home	78% AFUE	68.41	9.12	-	9.12	13.3%	0	0	$320
R-MF-SpH-4	Energy Star Furnace (AFUE=90%)	MF	Retrofit	18	home	75% AFUE	71.15	11.86	-	11.86	16.7%	0	0	$3,320
R-MF-SpH-5	CEE Tier 2 Furnace (AFUE=92%)	MF	Market-driven	18	home	78% AFUE	68.41	10.41	-	10.41	15.2%	0	0	$520
R-MF-SpH-6	CEE Tier 2 Furnace (AFUE=92%)	MF	Retrofit	18	home	75% AFUE	71.15	13.15	-	13.15	18.5%	0	0	$3,520
R-MF-SpH-7	CEE Tier 3 Furnace (AFUE=94%)	MF	Market-driven	18	home	78% AFUE	68.41	11.64	-	11.64	17.0%	0	0	$688
R-MF-SpH-8	CEE Tier 3 Furnace (AFUE=94%)	MF	Retrofit	18	home	75% AFUE	71.15	14.38	-	14.38	20.2%	0	0	$3,688
R-MF-SpH-9	Energy Star Gas Boiler (AFUE=85%)	MF	Market-driven	20	home	80% AFUE	66.70	3.96	-	3.96	5.9%	0	0	$900
R-MF-SpH-10	Energy Star Gas Boiler (AFUE=85%)	MF	Retrofit	20	home	75% AFUE	71.15	8.40	-	8.40	11.8%	0	0	$3,900
R-MF-SpH-11	Condensing Gas Boiler (AFUE=90%)	MF	Market-driven	20	home	80% AFUE	66.70	7.41	-	7.41	11.1%	0	0	$1,500
R-MF-SpH-12	Condensing Gas Boiler (AFUE=90%)	MF	Retrofit	20	home	75% AFUE	71.15	11.86	-	11.86	16.7%	0	0	$4,500
R-MF-SpH-13	Condensing Gas Boiler (AFUE=95%)	MF	Market-driven	20	home	80% AFUE	66.70	10.53	-	10.53	15.8%	0	0	$2,400
R-MF-SpH-14	Condensing Gas Boiler (AFUE=95%)	MF	Retrofit	20	home	75% AFUE	71.15	14.98	-	14.98	21.1%	0	0	$5,400
R-MF-SpH-15	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	MF	Market-driven	10	home	78% AFUE furnace	68.41	26.08	1.56	24.52	35.8%	526	0	$2,800
R-MF-SpH-16	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	MF	Retrofit	10	home	75% AFUE Furnace	71.15	28.81	1.56	27.25	38.3%	182	0	$8,800
R-MF-SpH-17	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	MF	Market-driven	20	home	78% AFUE furnace, 13 SEER AC	68.41	33.40	8.57	24.83	36.3%	471	0	$10,000
R-MF-SpH-18	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	MF	Retrofit	20	home	75% AFUE Furnace, 10 SEER AC	71.15	36.14	8.57	27.56	38.7%	126	0	$16,000
R-MF-SpH-19	Heat Recovery Ventilator	MF	Retrofit	20	home	ASHRAE 62.2-compliant exhaust fan system with no heat recovery (0.01 cfm/sf + 7.5 cfm * (1 + #bedrooms)	43.42	4.38	-	4.38	10.1%	-76	0	$660
R-MF-SpH-20	Energy Star (High Performance Homes)	MF	New Construction	25	home	2004 IRC-compliant home	68.00	19.61	-	19.61	28.8%	0	0	$1,286

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2b

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Space Heating													
R-MF-SpH-21	Energy Efficient Steam Boilers (low pressure/multi-family)	MF	Market-driven	25	unit	80% efficient	404.00	15.83	-	15.83	3.9%	0	0	$5,000

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2c

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Dehumidification													
R-SF-DEHUM-1	Desiccant Dehumidification	SF	Retrofit	15	unit	Standard dehumidifier of 1.30 liters/kWh	143.86	-	(7.05)	(7.05)	-4.9%	1,801	0	$1,875.00
R-MF-DEHUM-1	Desiccant Dehumidification	MF	Retrofit	15	unit	Standard dehumidifier of 1.30 liters/kWh	71.93	-	(3.52)	(3.52)	-4.9%	1,801	0	$1,875.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2d

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)	Notes
	Space and Water Heating														
R-SF-SpH&WatH-1	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	SF	Market-driven	15	unit	78 AFUE furnace and 0.594 EF water heater	156.33	24.01	-	24.01	15.4%	0	0	$720.00	Source Note 1
R-SF-SpH&WatH-2	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	SF	Retrofit	15	unit	75 AFUE furnace and 0.55 EF	163.31	30.99	-	30.99	19.0%	0	0	$4,320.00	Source Note 1
R-SF-SpH&WatH-3	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	SF	Market-driven	20	unit	80 AFUE boiler and 0.594 EF water heater	152.88	21.11	-	21.11	13.8%	0	0	$2,185.00	Source Note 1
R-SF-SpH&WatH-4	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	SF	Retrofit	20	unit	75 AFUE boiler and 0.55 EF	163.31	31.54	-	31.54	19.3%	0	0	$5,785.00	Source Note 1
R-SF-SpH&WatH-5	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	SF	Market-driven	20	unit	80 AFUE boiler and 0.594 EF water heater	152.88	13.50	-	13.50	8.8%	0	0	$1,300.00	Source Note 1
R-SF-SpH&WatH-6	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	SF	Retrofit	20	unit	75 AFUE boiler and 0.55 EF	163.31	23.93	-	23.93	14.7%	0	0	$4,900.00	Source Note 1
R-MF-SpH&WatH-1	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	MF	Market-driven	15	unit	78 AFUE furnace and 0.594 EF water heater	86.48	14.70	-	14.70	17.0%	0	0	$720.00	Source Note 1
R-MF-SpH&WatH-2	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	MF	Retrofit	15	unit	75 AFUE furnace and 0.55 EF	90.65	18.88	-	18.88	20.8%	0	0	$4,320.00	Source Note 1
R-MF-SpH&WatH-3	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	MF	Market-driven	20	unit	80 AFUE boiler and 0.594 EF water heater	84.76	13.54	-	13.54	16.0%	0	0	$2,185.00	Source Note 1
R-MF-SpH&WatH-4	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	MF	Retrofit	20	unit	75 AFUE boiler and 0.55 EF	90.65	19.43	-	19.43	21.4%	0	0	$5,785.00	Source Note 1
R-MF-SpH&WatH-5	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	MF	Market-driven	20	unit	80 AFUE boiler and 0.594 EF water heater	84.76	9.49	-	9.49	11.2%	0	0	$1,300.00	Source Note 1
R-MF-SpH&WatH-6	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	MF	Retrofit	20	unit	75 AFUE boiler and 0.55 EF	90.65	15.39	-	15.39	17.0%	0	0	$4,900.00	Source Note 1

Source Notes

1 Costs and savings add up similar separate equipment from water heating tab and space heating tab. Literature claims combined system equipment costs are higher, installation costs lower compared to separate systems.

2 For water heater, Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements. For boiler, Engineering Judgment -- EPACT 1992 created 80 AFUE minimum. Retrofit, non-ROB, are going to be a mix of post-1992 and pre-1992 units, which had AFUEs in the 65-70 range. 75 AFUE is a reasonable conservative assumption. If only old equipment (>20 years) is being replaced, then a lower AFUE can be justified.

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2e

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Laundry													
R-SF-LAUN-1	Energy Star Clothes Washer (vertical and horizontal)	SF	Market-driven	11	unit	MEF of 1.26 and WF of 9.5, with gas dryer	2.95	0.88	-	0.88	29.8%	26	6,978	$200.00
R-SF-LAUN-2	Clothes Dryer with Moisture Sensor	SF	Market-driven	18	unit	standard clothes dryer	5.88	0.88	-	0.88	15.0%	0	0	$10.00
R-MF-LAUN-1	Energy Star Clothes Washer (vertical and horizontal)	MF	Market-driven	11	unit	MEF of 1.26 and WF of 9.5, with gas dryer	2.95	0.88	-	0.88	29.8%	26	6,978	$200.00
R-MF-LAUN-2	Clothes Dryer with Moisture Sensor	MF	Market-driven	18	unit	standard clothes dryer	5.88	0.88	-	0.88	15.0%	0	0	$10.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2f

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Building Envelope													
R-SF-ENV-1	Energy Star Windows	SF	Retrofit	25	per 10.5 sq ft window	single clear glazing with wood frames	143.86	1.19	-	1.19	14.9%	0	0	$555.00
R-SF-ENV-2	Improved Wall Insulation	SF	Retrofit	25	home	R-9 whole wall	143.86	12.00	-	12.00	8.3%	0	0	$1,864.96
R-SF-ENV-3	Improved Roof Insulation	SF	Retrofit	25	home	R-22 ceiling insulation	143.86	2.33	-	2.33	1.6%	0	0	$850.00
R-SF-ENV-4	Improved Below-Grade Insulation	SF	Retrofit	25	home	no basement insulation	143.86	1.31	-	1.31	0.9%	0	0	$540.80
R-SF-ENV-5	Improved Floor Insulation	SF	Retrofit	25	home	no floor insulation (unvented crawlspace)	143.86	16.85	-	16.85	11.7%	0	0	$1,040.00
R-SF-ENV-6	Storm Windows	SF	Retrofit	25	per 12.5 sq ft window	single clear glazing with wood frames	143.86	0.57	-	0.57	0.4%	0	0	$87.50
R-SF-ENV-7	Air Sealing	SF	Retrofit	20	home	1.0 ACH total	143.86	21.58	-	21.58	15.0%	0	0	$1,000.00
R-SF-ENV-8	Insulated Exterior Door	SF	Retrofit	30	home	uninsulated exterior door (solid wood)	143.86	2.03	-	2.03	1.4%	0	0	$400.00
R-SF-ENV-9	Attic Hatch Insulation	SF	Retrofit	30	home	no hatch insulation	143.86	2.48	-	2.48	1.7%	0	0	$50.00
R-MF-ENV-1	Energy Star Windows	MF	Retrofit	25	per 10.5 sq ft window	single clear glazing with wood frames	71.93	1.19		1.19	14.9%	0	0	$555.00
R-MF-ENV-2	Improved Wall Insulation	MF	Retrofit	25	home	R-9 whole wall	71.93	4.74	-	4.74	6.6%	0	0	$1,052.80

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2f

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Building Envelope													
R-MF-ENV-3	Improved Roof Insulation	MF	Retrofit	25	home	R-22 ceiling insulation	71.93	1.17	-	1.17	1.6%	0	0	$850.00
R-MF-ENV-4	Improved Below-Grade Insulation	MF	Retrofit	25	home	no basement insulation	71.93	0.78	-	0.78	1.1%	0	0	$540.80
R-MF-ENV-5	Improved Floor Insulation	MF	Retrofit	25	home	no floor insulation (unvented crawlspace)	71.93	10.11	-	10.11	14.1%	0	0	$1,040.00
R-MF-ENV-6	Storm Windows	MF	Retrofit	25	per 12.5 sq ft window	single clear glazing with wood frames	71.93	0.57	-	0.57	0.8%	0	0	$87.50
R-MF-ENV-7	Air Sealing	MF	Retrofit	20	home	1.0 ACH total	71.93	10.79	-	10.79	15.0%	0	0	$1,000.00
R-MF-ENV-8	Insulated Exterior Door	MF	Retrofit	30	home	uninsulated exterior door (solid wood)	71.93	2.03	-	2.03	2.8%	0	0	$400.00
R-MF-ENV-9	Attic Hatch Insulation	MF	Retrofit	30	home	no hatch insulation	71.93	2.48	-	2.48	3.5%	0	0	$50.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2g

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Cooking												
R-SF-COOK-1	Convection Ovens	SF	Market-driven	unit	Standard Residential Gas Oven with EF = 0.030; if self-cleaning EF = 0.054	1.50	0.20	-	0.20	13.3%	0	0	$200.00
R-MF-COOK-1	Convection Ovens	MF	Market-driven	unit	Standard Residential Gas Oven with EF = 0.030; if self-cleaning EF = 0.054	1.50	0.20	-	0.20	13.3%	0	0	$200.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2h

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Controls													
R-SF-CTRL-1	Programmable Thermostat	SF	Retrofit	15	Per home	constant temperature setpoint	143.86	7.59	-	7.59	5.3%	0	0	$92.00
R-SF-CTRL-2	Occupancy Controlled Thermostat	SF	Retrofit	15	Per home	constant temperature setpoint	143.86	7.59	-	7.59	5.3%	0	0	$200.00
R-SF-CTRL-3	Boiler Controls (Non-Condensing Boiler)	SF	Retrofit	15	Per home	No boiler controls	143.86	10.07	-	10.07	7.0%	0	0	$575.00
R-SF-CTRL-4	Zoning	SF	Retrofit	30	Per home	single zone control	143.86	6.47	-	6.47	4.5%	0	0	$1,600.00
R-MF-CTRL-1	Programmable Thermostat	MF	Retrofit	15	Per home	constant temperature setpoint	71.93	3.80	-	3.80	5.3%	0	0	$92.00
R-MF-CTRL-2	Occupancy Controlled Thermostat	MF	Retrofit	15	Per home	no occupancy sensors	71.93	3.80	-	3.80	5.3%	0	0	$200.00
R-MF-CTRL-3	Controls (Non-Condensing Boiler)	MF	Retrofit	15	Per home	No boiler controls	71.93	5.04	-	5.04	7.0%	0	0	$575.00
R-MF-CTRL-4	Zoning	MF	Retrofit	30	Per home	single zone control	71.93	0.72	-	0.72	1.0%	0	0	$1,130.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A-2i

Measure #	Residential Measures	SF/MF	Market-driven or Retrofit	Equipment Useful Life (Years)	Units	Baseline Efficiency Assumption	Base Gas (MMBtu)	Gas Savings (MMBtu)	Gas Increase (MMBtu)	Net Gas Savings (MMBtu)	Gas Savings (%)	Electricity Savings (kWh)	Water Savings (gallons)	Cost ($)
	Pool Water Heating													
R-SF-POOL-1	Pool Cover (Vinyl)	SF	Retrofit	6	pool	Gas Heated Pool with no pool cover	141.48	70.74	-	70.74	50.0%	0	0	$350.00
R-SF-POOL-2	Solar Pool Cover (Bubble)	SF	Retrofit	2.5	pool	Gas Heated Pool with no pool cover	141.48	70.74	-	70.74	50.0%	0	0	$150.00
R-SF-POOL-3	High Efficiency Gas Pool Heater	SF	Market-driven	20	pool	standard gas pool heater	29.52	4.18	-	4.18	14.2%	0	0	$585.00
R-SF-POOL-4	Temperature Control	SF	Retrofit	15	pool	no temperature control	This measure was not included in the analysis (Note 1)							
R-SF-POOL-5	Outdoor Spa Cover	SF	Retrofit	6	pool	no spa cover	7.68	5.76	-	5.76	75.0%	0	0	$300.00
R-SF-POOL-6	Solar pool heater	SF	Retrofit	20	pool	Baseline 68% efficient pool heater	29.52	29.52	-	29.52	100.0%	0	0	$4,275.00
R-MF-POOL-1	Pool Cover (Vinyl)	MF	Retrofit	6	pool	Gas Heated Pool with no pool cover	141.48	70.74	-	70.74	50.0%	0	0	$350.00
R-MF-POOL-2	Solar Pool Cover (Bubble)	MF	Retrofit	2.5	pool	Gas Heated Pool with no pool cover	141.48	70.74	-	70.74	50.0%	0	0	$150.00
R-MF-POOL-3	High Efficiency Gas Pool Heater	MF	Market-driven	20	pool	standard gas pool heater	29.52	4.18	-	4.18	14.2%	0	0	$585.00
R-MF-POOL-4	Temperature Control	MF	Retrofit	15	pool	no temperature control	This measure was not included in the analysis (Note 1)							
R-MF-POOL-5	Outdoor Spa Cover	MF	Retrofit	6	pool	no spa cover	7.68	5.76	-	5.76	75.0%	0	0	$300.00
R-MF-POOL-6	Solar pool heater	SF	Retrofit	20	pool	Baseline 68% efficient pool heater	29.52	29.52	-	29.52	100.0%	0	0	$4,275.00

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Water Heating				
R-SF-WatH-1	Condensing Water Heater (0.8 EF)	ES Analysis-ResDWH Tbl 2/GDS	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-SF-WatH-2	Condensing Water Heater (0.8 EF)	ES Analysis-ResDWH Tbl 2/GDS	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-SF-WatH-3	High Efficiency Stand Alone Water Heater (0.62 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-SF-WatH-4	High Efficiency Stand Alone Water Heater (0.62 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-SF-WatH-5	High Efficiency Stand Alone Water Heater (0.67 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-SF-WatH-6	High Efficiency Stand Alone Water Heater (0.67 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-SF-WatH-7	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	See Commercial Measure Data Source	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 8
R-SF-WatH-8	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	See Commercial Measure Data Source	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	VT TRM No. 2008-43, p. 386
R-SF-WatH-9	On-Demand, Tankless Water Heater (>=.95 EF)	See Commercial Measure Data Source	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	+ delta from www.ecoairandwater.com

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Water Heating				
R-SF-WatH-10	On-Demand, Tankless Water Heater (>=.95 EF)	See Commercial Measure Data Source	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-SF-WatH-11	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	Source Note 1	Business as usual	SB calc; SB DHW Analysis Tab	Source note 9
R-SF-WatH-12	Low-flow Shower Heads (1.59 GPM)	VT TRM No. 2006-43, p. 286	Source Note 4	SB calc; SB DHW Analysis Tab	VT TRM No. 2006-43, p. 286
R-SF-WatH-13	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	Source Note 2	Source Note 4	SB calc; SB DHW Analysis Tab	evolveshowerheads.com
R-SF-WatH-14	Shower Start Technology Only	Source Note 2	Business as usual	SB calc; SB DHW Analysis Tab	evolveshowerheads.com
R-SF-WatH-15	Pipe Insulation	VT TRM No. 2006-43, p. 284	Business as usual	2001 DEER Update Study, http://www.calmac.org/publications/2001%20DEER%20Update%20Study.pdf, p. 5–37	VT TRM No. 2006-43, p. 284
R-SF-WatH-16	Faucet Aerators	Source Note 3	Retrofitting Apartment Buildings to Conserve Water: A Guide for Managers, Engineers, and Contractors, p. 9; http://www.huduser.org/Publications/PDF/Book2.pdf	SB calc; SB DHW Analysis Tab	VT TRM No. 2006-43, p. 286
R-SF-WatH-17	Solar Water Heating – drain back system/with gas backup	Source note 5	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Source note 5	Source note 6
R-SF-WatH-18	Indirect Water Heater	ACEEE T6.6	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	VT TRM No. 2008-43 less $600 cost of standard efficiency water heater

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Water Heating				
R-SF-WatH-19	Indirect Water Heater	ACEEE T6.6	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	VT TRM No. 2008-43
R-MF-WatH-1	Condensing Water Heater	ES Analysis-ResDWH Tbl 2/GDS	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-MF-WatH-2	Condensing Water Heater	ES Analysis-ResDWH Tbl 2/GDS	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-MF-WatH-3	High Efficiency Stand Alone Water Heater (0.62 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-MF-WatH-4	High Efficiency Stand Alone Water Heater (0.62 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-MF-WatH-5	High Efficiency Stand Alone Water Heater (0.67 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	Source note 7
R-MF-WatH-6	High Efficiency Stand Alone Water Heater (0.67 EF)	ES Analysis-ResDWH Tbl 2	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-MF-WatH-7	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	Natural Gas Energy Efficiency Resource Development Potential in New York - October 2006 - Appendix A, Table 2B.	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	VT TRM No. 2008-43 less $600 cost of standard efficiency water heater

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Water Heating				
R-MF-WatH-8	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	Natural Gas Energy Efficiency Resource Development Potential in New York - October 2006 - Appendix A, Table 2B.	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	VT TRM No. 2008-43
R-MF-WatH-9	On-Demand, Tankless Water Heater (>=.95 EF)	Set to same as other tankless	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	+ delta from www.ecoairandwater.com
R-MF-WatH-10	On-Demand, Tankless Water Heater (>=.95 EF)	Set to same as other tankless	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	Source note 8
R-MF-WatH-11	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	Source Note 1	Business as usual	SB calc; SB DHW Analysis Tab	Source note 9
R-MF-WatH-12	Low-flow Shower Heads (1.59 GPM)	VT TRM No. 2006-43, p. 286	Source Note 4	SB calc; SB DHW Analysis Tab	VT TRM No. 2006-43, p. 286
R-MF-WatH-13	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	Source Note 2	Source Note 4	SB calc; SB DHW Analysis Tab	evolveshowerheads.com
R-MF-WatH-14	Shower Start Technology Only	Source Note 2	Business as usual	SB calc; SB DHW Analysis Tab	evolveshowerheads.com
R-MF-WatH-15	Pipe Insulation	VT TRM No. 2006-43, p. 284	Business as usual	2001 DEER Update Study, http://www.calmac.org/publications/2001%20DEER%20Update%20Study.pdf, p. 5–37	VT TRM No. 2006-43, p. 284
R-MF-WatH-16	Faucet Aerators	Source Note 3	Retrofitting Apartment Buildings to Conserve Water: A Guide for Managers, Engineers, and Contractors, p. 9; http://www.huduser.org/Publications/PDF/Book2.pdf	SB calc; SB DHW Analysis Tab	VT TRM No. 2006-43, p. 286

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Water Heating				
R-MF-WatH-17	Solar Water Heating – drain back system/with gas backup	Source note 5	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Source note 5	Source note 6
R-MF-WatH-18	Indirect Water Heater	Gas Networks	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater	SB calc; SB DHW Analysis Tab	VT TRM No. 2008-43 less $600 cost of standard efficiency water heater
R-MF-WatH-19	Indirect Water Heater	Gas Networks	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	Above + delta Baseline calc	VT TRM No. 2008-43

Source Notes

1	NATURAL GAS ENERGY EFFICIENCY RESOURCE DEVELOPMENT POTENTIAL IN NEW YORK Final Report Prepared for New York Energy Research and Development Authority October 31, 2006 - Optimal Energy, Inc.
2	New Product, Lifetime is unclear, set to low flow showerhead lifetime
3	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads/Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006
4	DOE, Office of Energy Efficiency and Renewable Energy, 10 CFR Part 430, Energy Conservation Program for Consumer Products: Test Procedures and Certification and Enforcement Requirements for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances; Final Rule., March 18, 1998, section 430.32, p. 13317 of the Federal Register
5	RERC: 'Investing in a Solar Hot Water System' Renewable Energy Resource Center: A Project of the Vermont Energy Investment Corporation. (www.rerc-vt.org/shw_investing.htm)
6	ACEEE T6.6: 'Consumer Guide to Home Energy Savings' 8th ed. ACEEE. 2003. Table 6.6
7	ENERGY STAR® Residential Water Heaters: Final Criteria Analysis (www.energystar.gov). April 2008.-ResDWH Table 2/GDS
8	$600 installed typical base 40 gallon hot water heater assumed, rounded up from $565 in DEER 2008, then added to incremental cost for replacement to get total retrofit cost, or subtracted from retrofit cost to get replacement cost
9	Estimated based on internet cost research, plus a small amount for PEX and installation, See Drainwater Heat Recovery Prices, November 2008.pdf

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space Heating				
R-SF-SpH-1	Insulate and Seal Ducts	Source note 4	Building America Research Benchmark, Updated December 15, 2007, p. 9	SB calc; see source note	Source note 4
R-SF-SpH-2	Insulate Unconditioned Basement/Crawl Space Piping	Energy Star Boiler Savings Calculator	Business as usual	SB calc; SB PipeIns tab	Home Energy Saver - Average Cost (Medford MA)
R-SF-SpH-3	Energy Star Furnace (AFUE=90%)	Source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, EffFurn-cond-90AFUE - EffFurn-cond-81AFUE, 100 kBtuh
R-SF-SpH-4	Energy Star Furnace (AFUE=90%)	Source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace
R-SF-SpH-5	CEE Tier 2 Furnace (AFUE=92%)	Set to Same as source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	VT TRM - No. 2008-51, 4/9/08, p. 441
R-SF-SpH-6	CEE Tier 2 Furnace (AFUE=92%)	Set to Same as source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace
R-SF-SpH-7	CEE Tier 3 Furnace (AFUE=94%)	Set to Same as source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, EffFurn-cond-94AFUE - EffFurn-cond-81AFUE, 100 kBtuh
R-SF-SpH-8	CEE Tier 3 Furnace (AFUE=94%)	Set to Same as source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace
R-SF-SpH-9	Energy Star Gas Boiler (AFUE=85%)	Energy Star Calculator - Furnace	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Energy Star Calculator - Furnace
R-SF-SpH-10	Energy Star Gas Boiler (AFUE=85%)	Energy Star Calculator - Furnace	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)
R-SF-SpH-11	Condensing Gas Boiler with Controls(AFUE=90%)	Conservative estimate based on various sources. 20 years used by 2004-2005 California Database of Energy Efficient Resources.	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	GDS price comparison using RSMeans 2008 data and available pricing information for Weil-McLain, Buderus, and Burnham boilers.
R-SF-SpH-12	Condensing Gas Boiler with Controls(AFUE=90%)	Assumed same measure life as high efficiency steam boiler	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)
R-SF-SpH-13	Condensing Gas Boiler with Controls (AFUE=95%)	Assumed same measure life as high efficiency steam boiler	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Source Note 7
R-SF-SpH-14	Condensing Gas Boiler with Controls (AFUE=95%)	Assumed same measure life as high efficiency steam boiler	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space Heating				
R-SF-SpH-15	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	Source Note 2	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Wisconsin Study: http://www.cee1.org/eval/db_pdf/172.pdf
R-SF-SpH-16	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	Source Note 2	VT TRM No. 2006-43, p. 407	SB calc; SB SH HVAC Analysis Tab	Above + Assumed Cost of Baseline Heat Pump
R-SF-SpH-17	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	Source Note 3	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Conversation with Robur (manufacturer selling in US)
R-SF-SpH-18	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	Source Note 3	VT TRM No. 2006-43, p. 407	SB calc; SB SH HVAC Analysis Tab	Above + Assumed Cost of Baseline Heat Pump
R-SF-SpH-19	Heat Recovery Ventilator	BA Analysis spreadsheet	NH Study (REMRate) derivation. Baseline assumes HRV applied to an energy star home or equivalent (#R-SF-SpH-20). Baseline for Energy Star home:VT TRM No. 2006-43, p. 407 (#R-SF-SpH-3 & R-SF-SpH-9)	SB calc; SB HRV Tab	www.climatedoctors.com www.iaqsouirce.com
R-SF-SpH-20	Energy Star (High Performance Homes)	ACEEE report, "Selecting Targets for Market Transformation Programs, A National Analysis", August 1998.	Combining data from: Nexus Market Research, Inc., Dorothy Conant, Consultant "Evaluation of the Massachusetts New Homes with ENERGY STAR, Findings and Analysis", April 24, 2008 and EIA Census Data 2005.	Combining data from: Nexus Market Research, Inc., Dorothy Conant, Consultant "Evaluation of the Massachusetts New Homes with ENERGY STAR, Findings and Analysis", April 24, 2008 and EIA Census Data 2005.	How Much More Does It Cost to Build an ENERGY STAR® Home? Incremental Cost Estimation Process. Nexus Market Research, 2008.
R-SF-SpH-21	Energy Efficient Steam Boilers (low pressure/single-family)	EVT: Efficiency Vermont Technical Reference User Manual. No. 2007-47. p.199	Source Note 6	SB calc; SB SH HVAC Analysis Tab	www.costhelper.com
R-MF-SpH-1	Insulate and Seal Ducts	Source note 4	Building America Research Benchmark, Updated December 15, 2007, p. 9	EVT: Efficiency Vermont Technical Reference User Manual. No. 2007-47.p. 399	Source note 4
R-MF-SpH-2	Insulate Unconditioned Basement/Crawl Space Piping	Comm Measures (Energy Star Boiler Savings Calculator)	Business as usual	SB calc; SB PipeIns tab	Home Energy Saver - Average Cost (Medford MA) and Thermwell product on NexTag and amazon.com
R-MF-SpH-3	Energy Star Furnace (AFUE=90%)	Source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, EffFurn-cond-90AFUE - EffFurn-cond-81AFUE, 100 kBtuh
R-MF-SpH-4	Energy Star Furnace (AFUE=90%)	Source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace
R-MF-SpH-5	CEE Tier 2 Furnace (AFUE=92%)	Set to Same as source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	VT TRM - No. 2008-51, 4/9/08, p. 441
R-MF-SpH-6	CEE Tier 2 Furnace (AFUE=92%)	Set to Same as source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space Heating				
R-MF-SpH-7	CEE Tier 3 Furnace (AFUE=94%)	Set to Same as source note 5	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, EffFurn-cond-94AFUE - EffFurn-cond-81AFUE, 100 kBtuh
R-MF-SpH-8	CEE Tier 3 Furnace (AFUE=94%)	Set to Same as source note 5	VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Above + Assumed Cost of Baseline 100 kBtuh Furnace
R-MF-SpH-9	Energy Star Gas Boiler (AFUE=85%)	GasNetworks data response to the GDS Associates Team, Section 1, dated February 13, 2004, and updated subsequently	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Energy Star Cost Calculator, pricing information based on 2007 Industry data.
R-MF-SpH-10	Energy Star Gas Boiler (AFUE=85%)	GasNetworks data response to the GDS Associates Team, Section 1, dated February 13, 2004, and updated subsequently	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)
R-MF-SpH-11	Condensing Gas Boiler (AFUE=90%)	DEER	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Estimate based on RSMeans, Appliance and Equipment Standards, and available pricing information
R-MF-SpH-12	Condensing Gas Boiler (AFUE=90%)	DEER	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)
R-MF-SpH-13	Condensing Gas Boiler (AFUE=95%)	Set to same as other condensing boiler	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Source Note 7
R-MF-SpH-14	Condensing Gas Boiler (AFUE=95%)	Set to same as other condensing boiler	Source Note 6	Above + delta Baseline calc	Above + Baseline Gas Boiler Cost (RS Means CostWorks 2008: 23 52 16 0160)
R-MF-SpH-15	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	Source Note 2	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	http://www.cee1.org/eval/db_pdf/172.pdf
R-MF-SpH-16	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	Source Note 2	VT TRM No. 2006-43, p. 407	SB calc; SB SH HVAC Analysis Tab	Above + Assumed Cost of Baseline Heat Pump
R-MF-SpH-17	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	Source Note 3	Federal Code: FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab	Conversation with Robur (manufacturer selling in US)
R-MF-SpH-18	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	Source Note 3	VT TRM No. 2006-43, p. 407	SB calc; SB SH HVAC Analysis Tab	Above + Assumed Cost of Baseline Heat Pump
R-MF-SpH-19	Heat Recovery Ventilator	BA Analysis spreadsheet	2004 IRC derivation. Baseline assumes HRV applied to an energy star apartment unit or equivalent (#R-MF-SpH-20). Baseline for Energy Star apartment: Federal Code: FR66/11/Nov 19, 2007, p. 65137 (#R-MF-SpH-3 & R-MF-SpH-10)	SB calc; SB HRV Tab	www.climatedoctors.com www.iaqsouirce.com

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space Heating				
R-MF-SpH-20	Energy Star (High Performance Homes)	ACEEE report, "Selecting Targets for Market Transformation Programs, A National Analysis", August 1998.	2004 IRC	Combining data from: Nexus Market Research, Inc., Dorothy Conant, Consultant "Evaluation of the Massachusetts New Homes with ENERGY STAR, Findings and	How Much More Does It Cost to Build an ENERGY STAR® Home? Incremental Cost Estimation Process. Nexus Market Research, 2008.
R-MF-SpH-21	Energy Efficient Steam Boilers (low pressure/multi-family)	EVT: Efficiency Vermont Technical Reference User Manual. No. 2007-47. p.199	Federal Code: FR69/203/ Oct 21, 2004 p. 61962	SB calc; SB SH HVAC Analysis Tab	www.costhelper.com

Source Notes

1 Assumes reduction from 9% supply leakage to 3% supply leakage, and return leakage from 8% to 3%, with 20% of ducts in ventilated crawlspace or attic (no savings for sealing basement ducts).
2 Engineering Judgment -- 40,000 hours for engine, 4,000 hours/yr, requires significant annual maintenance
3 Engineering Judgment -- absorption equipment has few moving parts, should last as long as a boiler
4 EVT: Efficiency Vermont Technical Reference User Manual. No. 2007-47.
5 Energy Star Calculation (www.energystar.gov) Energy Star Calculator - Furnace (.xls)
6 Engineering Judgment -- EPACT 1992 created 80 AFUE minimum. Retrofit, non-ROB, are going to be a mix of post-1992 and pre-1992 units, which had AFUEs in the 65-70 range. 75 AFUE is a reasonable conservative assumption. If only old equipment (>20 years) is being replaced, then a lower AFUE can be justified.
7 The Summit Blue Boiler cost estimator uses the equipment-only costs of a large variety of roughly 20 residential boilers ranging from 80 to 95 AFUE and 50 to 200 kBtu to derive a mathematical function for cost as a function of size and AFUE rating. In this case, a 120 kBtu, 95 AFUE furnace was compared to a 120 kBtu, 80 AFUE furnace

Replacement
Avg. Heating Use Furnace -
Avg. Heating Use Boiler -

Retrofit
Avg. Heating Use Furnace -
Avg. Heating Use Boiler -

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Dehumidification				
R-SF-DEHUM-1	Desiccant Dehumidification	Source Note 1	Federal Register / Vol. 73, No. 202 / Friday, October 17, 2008 / Proposed Rules p.62039	SB calc based on typical meteorological year wet bulb temperature bins; SB Dehumid Tab	www.iaqsource.com
R-MF-DEHUM-1	Desiccant Dehumidification	Source Note 1	Federal Register / Vol. 73, No. 202 / Friday, October 17, 2008 / Proposed Rules p.62039	SB calc based on typical meteorological year wet bulb temperature bins; SB Dehumid Tab	www.iaqsource.com

Source Notes

1 Engineering Judgment (some equipment has 10 year warranty, should be comparable to furnace)

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space and Water Heating				
R-SF-SpH&WatH-1	Integrated Water Heater/Furnace (.86 EF, .90 AFUE)	Set to water heater lifetime	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1
R-SF-SpH&WatH-2	Integrated Water Heater/Furnace (.86 EF, .90 AFUE)	Set to water heater lifetime	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements; VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Source Note 1
R-SF-SpH&WatH-3	Integrated Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Set to same as typical boilers	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65138	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1
R-SF-SpH&WatH-4	Integrated Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Set to same as typical boilers	Source Note 2	Above + delta Baseline calc	Source Note 1
R-SF-SpH&WatH-5	Integrated Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Set to same as typical boilers	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65139	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1
R-SF-SpH&WatH-6	Integrated Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Set to same as typical boilers	Source Note 2	Above + delta Baseline calc	Source Note 1
R-MF-SpH&WatH-1	Integrated Water Heater/Furnace (.86 EF, .90 AFUE)	Set to water heater lifetime	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1
R-MF-SpH&WatH-2	Integrated Water Heater/Furnace (.86 EF, .90 AFUE)	Set to water heater lifetime	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements; VT TRM No. 2006-43, p. 407	Above + delta Baseline calc	Source Note 1
R-MF-SpH&WatH-3	Integrated Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Set to same as typical boilers	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65138	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Space and Water Heating				
R-MF-SpH&WatH-4	Integrated Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Set to same as typical boilers	Source Note 2	Above + delta Baseline calc	Source Note 1
R-MF-SpH&WatH-5	Integrated Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Set to same as typical boilers	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65139	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Source Note 1
R-MF-SpH&WatH-6	Integrated Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Set to same as typical boilers	Source Note 2	Above + delta Baseline calc	Source Note 1

Source Notes

1 Costs and savings add up similar separate equipment from water heating tab and space heating tab. Literature claims combined system equipment costs are higher, installation costs lower compared to separate systems.

2 For water heater, Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements. For boiler, Engineering

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Laundry				
R-SF-LAUN-1	Energy Star Clothes Washer (vertical and horizontal)	Source Note 1	Federal Register / Vol. 66, No. 9 / Friday, January 12, 2001 / Rules and Regulations 3333	Source note 1	Source note 1
R-SF-LAUN-2	Clothes Dryer with Moisture Sensor	Source Note 2	Business as usual	SB calc; SB Other Analysis	SB Estimate
R-MF-LAUN-1	Energy Star Clothes Washer (vertical and horizontal)	Source Note 1	Federal Register / Vol. 66, No. 9 / Friday, January 12, 2001 / Rules and Regulations 3333	Source note 1	Source note 1
R-MF-LAUN-2	Clothes Dryer with Moisture Sensor	Source Note 2	Business as usual	SB calc; SB Other Analysis	SB Estimate

Source Notes:

1 ES Calc-ClWashr: Energy Star Calculation (www.energystar.gov) Energy Star Calculator - Residential Clothes Washer Savings (.xls)

2 GDS estimate based on review of various sources including DEER, Best Buy, Planentgreen.discovery.com, http://slv-solar.org/Conservation%20works.htm

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Building Envelope				
R-SF-ENV-1	Energy Star Windows	Source Note 2 & 8 (Used Average)	Source note 3	SB calc; SB Building Envelope Analysis Tab	Home Energy Saver - Average Cost (Medford MA)
R-SF-ENV-2	Improved Wall Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, D08-RB-BS-BlowInIns-R0-R13
R-SF-ENV-3	Improved Roof Insulation	Source Note 1	Final Market Potential Report of MA Owner Occupied 1-4 Unit Dwellings. RLW, July 2006, p. 29	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, ClgIns-AddR11
R-SF-ENV-4	Improved Below-Grade Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 4
R-SF-ENV-5	Improved Floor Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, D08-RB-BS-FlrIns-R0-R19, 1000 sq feet
R-SF-ENV-6	Storm Windows	Set to same as windows	Source note 3	SB calc; SB Building Envelope Analysis Tab	Based on RS Means Costworks 2008, 08 52 69 2600
R-SF-ENV-7	Air Sealing	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 5
R-SF-ENV-8	Insulated Exterior Door	Source Note 7	Source note 3	SB calc; SB Building Envelope Analysis Tab	RS Means Costworks 2008, 08 13 13 0420
R-SF-ENV-9	Attic Hatch Insulation	Source Note 7	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 6
R-MF-ENV-1	Energy Star Windows	Source Note 2 & 8 (Used Average)	Source note 3	SB calc; SB Building Envelope Analysis Tab	Home Energy Saver - Average Cost (Medford MA)
R-MF-ENV-2	Improved Wall Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, D08-RB-BS-BlowInIns-R0-R13
R-MF-ENV-3	Improved Roof Insulation	Source Note 1	Final Market Potential Report of MA Owner Occupied 1-4 Unit Dwellings. RLW, July 2006, p. 29	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, ClgIns-AddR11
R-MF-ENV-4	Improved Below-Grade Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 4
R-MF-ENV-5	Improved Floor Insulation	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, D08-RB-BS-FlrIns-R0-R19, 1000 sq feet
R-MF-ENV-6	Storm Windows	Set to same as windows	Source note 3	SB calc; SB Building Envelope Analysis Tab	Based on RS Means Costworks 2008, 08 52 69 2600

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Building Envelope				
R-MF-ENV-7	Air Sealing	Source Note 1	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 5
R-MF-ENV-8	Insulated Exterior Door	Source Note 7	Source note 3	SB calc; SB Building Envelope Analysis Tab	RS Means Costworks 2008, 08 13 13 0420
R-MF-ENV-9	Attic Hatch Insulation	Source Note 7	Source note 3	SB calc; SB Building Envelope Analysis Tab	Source Note 6

Source Notes

1	Comm Measures (also matched Summit Blue typical assumptions)
2	ACEEE E061: N. Elliott et al. 'Reducing Oil Use Through Energy Efficiency: Opportunities Beyond Cars and Light Trucks.' Report E061. ACEEE. Washington D.C. January 2006, p.17
3	Baselines for building envelope were set using Summit Blue's professional judgment with regard to the likely mix of program participants. In these cases, the baseline is set to be consistent with older homes, generally less efficient than the average home. The actual baseline efficiency levels depend heavily on the program delivery and ultimate participant characteristics.
4	Uses floor insulation values from DEER 2008, http://www.deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip, D08-RB-BS-FlrIns-R0-R19, with 520 square feet assumed
5	Summit Blue Estimate based on average of contractor quotes for sealing house in Minnesota found in: IMPLEMENTATION OF MINNESOTA'S RESIDENTIAL ENERGY CODE. MINN. DEPT. OF ADMINISTRATION. JANUARY 2002.
6	Summit Blue Estimate. The cost could be as low as $15, based on costs of roughly $1/sf for insulating. However, with the very small size of the job, it seems appropriate to tack on some additional labor costs. $50 seems like a good conservative average cost.
7	Summit Blue Estimate. These measures have very long lives and should last as long as the house does. 30 years is a good value for measures of this sort.

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Cooking				
R-SF-COOK-1	Convection Ovens	Engineering judgment	EPACT 2005	Source note 1	SB estimate
R-MF-COOK-1	Convection Ovens	Engineering judgment	EPACT 2005	Source note 1	SB estimate

Source note

1 %Savings = 1 - (60 * (1 - 25%) + 15) / (60 + 15) * (2/3)

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data SOURCES
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Controls				
R-SF-CTRL-1	Programmable Thermostat	Source Note 5, p. 17	Business as usual	Validating the Impact of Programmable Thermostats, by RLW Analytics for GasNetworks, January 2007, p. 2.	Energy Star Programmable Thermostat Savings Calculator: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats
R-SF-CTRL-2	Occupancy Controlled Thermostat	Source Note 3	Business as usual	Validating the Impact of Programmable Thermostats, by RLW Analytics for GasNetworks, January 2007, p. 2.	t-stat control unit SBC estimate installation. http://ourworld.compuserve.com/homepages/rciautomation/p141.htm
R-SF-CTRL-3	Boiler Controls (Non-Condensing Boiler)	Source Note 4, p. 2	Business as usual	Source Note 4, p. 3	Source Note 4, p. 3 (Average for conventional boiler add-on controls)
R-SF-CTRL-4	Zoning	Source Note 1	Business as usual	SBC estimate based on programmable t-stat savings (#R-SF-CTRL-1) and assumptions about zone occupancy and inter-zonal energy transfer analysis.	SBC materials estimate plus & hours labor based on RSMeans zone controls - 2 zones per home
R-MF-CTRL-1	Programmable Thermostat	Source Note 5, p. 17	Business as usual	Validating the Impact of Programmable Thermostats, by RLW Analytics for GasNetworks, January 2007, p. 2.	Energy Star Programmable Thermostat Savings Calculator: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats
R-MF-CTRL-2	Occupancy Controlled Thermostat	Source Note 3	Business as usual	Validating the Impact of Programmable Thermostats, by RLW Analytics for GasNetworks, January 2007, p. 2.	t-stat control unit SBC estimate installation. http://ourworld.compuserve.com/homepages/rciautomation/p141.htm
R-MF-CTRL-3	Controls (Non-Condensing Boiler)	Source Note 4, p. 2	Business as usual	Source Note 4, p. 3	Source Note 4, p. 3 (Average for conventional boiler add-on controls)
R-MF-CTRL-4	Zoning	Source Note 1	Business as usual	SBC estimate based on programmable t-stat savings (#R-SF-CTRL-1) and assumptions about zone occupancy and inter-zonal energy transfer.	SBC materials estimate plus & hours labor based on RSMeans zone controls - 1 zones per apartment

Source Notes

1 Engineering Judgment -- zone control should be retained long term
2 Measure Life Study prepared for the Massachusetts Joint Utilities by ERS Nov 2005
3 Engineering Judgment -- Sensors will need to be replaced
4 ACEEE Emerging Technologies Report, May 2006

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Pool Water Heating				
R-SF-POOL-1	Pool Cover (Vinyl)	Source: William Farrell at Farrell Pools (508-429-5003)	Source Note 1 (Assumes 450 sq. ft pool with a 6/1-8/31 pool heating season.)	Source Note 1	http://www.costhelper.com/cost/home-garden/swimming-pool-cover.html
R-SF-POOL-2	Solar Pool Cover (Bubble)	Source: William Farrell at Farrell Pools (508-429-5003)	Source Note 1 (Assumes 450 sq. ft pool with a 6/1-8/31 pool heating season.)	Source Note 1	William Farrell at Farrell Pools (508-429-5003)
R-SF-POOL-3	High Efficiency Gas Pool Heater	Set to boiler lifetime	Assumes that a pool cover is installed and that heater is used about 40% of the pool season (6/1-8/31)	Source Note 4	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003; RS Means CostWorks 2005, construction cost estimating database for Albuquerque (GDS Gas Potential study for PNM) Used Commercial Incremental cost adjusted for difference in pool size (res. vs. commercial)
R-SF-POOL-4	Temperature Control	This measure was not included in the analysis (Source Note 3)			
R-SF-POOL-5	Outdoor Spa Cover	Source: William Farrell at Farrell Pools (508-429-5003)	Engineering Judgment	Source Note 2	SB estimate based on range of internet prices
R-SF-POOL-6	Solar pool heater	Set to same as solar DHW heater	US DOE - Energy Efficiency And Renewable Energy - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13170	Source Note 5	Researched various supplier internet sites. Costs range from $2k-$10k ($7-$12 per square foot of pool area
R-MF-POOL-1	Pool Cover (Vinyl)	Source: William Farrell at Farrell Pools (508-429-5003)	Source Note 1 (Assumes 450 sq. ft pool with a 6/1-8/31 pool heating season.)	Source Note 1	http://www.costhelper.com/cost/home-garden/swimming-pool-cover.html
R-MF-POOL-2	Solar Pool Cover (Bubble)	Source: William Farrell at Farrell Pools (508-429-5003)	Source Note 1 (Assumes 450 sq. ft pool with a 6/1-8/31 pool heating season.)	Source Note 1	William Farrell at Farrell Pools (508-429-5003)
R-MF-POOL-3	High Efficiency Gas Pool Heater	Set to boiler lifetime	Assumes that a pool cover is installed and that heater is used about 40% of the pool season (6/1-8/31)	Source Note 4	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003; RS Means CostWorks 2005, construction cost estimating database for Albuquerque (GDS Gas Potential study for PNM) Used Commercial Incremental cost adjusted for difference in pool size (res. vs. commercial)
R-MF-POOL-4	Temperature Control	This measure was not included in the analysis (Source Note 3)			
R-MF-POOL-5	Outdoor Spa Cover	Source: William Farrell at Farrell Pools (508-429-5003)	Engineering Judgment	Source Note 2	SB estimate based on range of internet prices
R-MF-POOL-6	Solar pool heater	Set to same as solar DHW heater	US DOE - Energy Efficiency And Renewable Energy - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13170	Source Note 5	Researched various supplier internet sites. Costs range from $2k-$10k ($7-$12 per square foot of pool area

Source Note

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Measure Data
TABLE A2-j

Measure #	Residential Measures	EUL Source	Baseline Source	Savings Source	Cost Source
	Pool Water Heating				
1		EERE Website, Swimming Pool Covers: http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13140 (50% - 70% savings range is estimated. Used conservative 50% savings due to the impact that each pools location on a lot and local weather conditions such as temperature humidity and wind can uncertainty associated with the impact of temperature, wind speed and pool loaction associated with temperature, wind can have on evaporation rates and heat loss.			
2		DOE/EERE WH: Water Heating, "Swimming Pool Heating" (http://www.eere.energy.gov/consumer/your_home/)			

Appendix A-3

Residential Sector Factor Data

Appendix A-3 contain the measure factor data including the base case, remaining and convertible factors for the measures included in the analysis of energy efficiency potential. Factor data is displayed by end-use.

- The **base case factor** is the fraction of the end use energy that is applicable for the efficient technology in a given market segment. For example, for residential water heating, this would be the fraction of all residential customers that have gas water heating in their household.
- The **remaining factor** is the fraction of applicable dwelling units that have not yet been converted to the natural gas energy efficiency measure; that is, one minus the fraction of households that already have the energy-efficiency measure installed.
- The **convertible factor** is the fraction of the applicable dwelling units that is technically feasible for conversion to the efficient technology from an engineering perspective (e.g., it may not be possible to install high efficiency natural on-demand tankless or condensing gas water heaters in every home because of technical/engineering or other limiting factors such as the amount of water use).

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Factor Data
TABLE A3

Measure #	Single- or Multi-family	End Use	Measure Description	Base Case Saturation (% of all homes that contain the end use or the measure)	Remaining Factor (In how many homes can this be installed	Convertible Factor (Accounting for competing technologies)
Water heating - Single Family/Multi Family Homes						
R-SF-WatH-16	SF	Hot Water	Faucet Aerators	47.00%	44.66%	100%
R-SF-WatH-12	SF	Hot Water	Low-flow Shower Heads (1.59 GPM)	47.00%	44.70%	100%
R-SF-WatH-14	SF	Hot Water	Shower Start Technology Only	47.00%	99.00%	100%
R-SF-WatH-13	SF	Hot Water	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	47.00%	44.70%	100%
R-SF-WatH-15	SF	Hot Water	Pipe Insulation	47.00%	84.80%	100%
R-SF-WatH-11	SF	Hot Water	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	47.00%	99.00%	100%
R-SF-WatH-17	SF	Hot Water	Solar Water Heating – drain back system/with gas backup	47.00%	99.00%	34%
R-SF-WatH-3	SF	Hot Water	High Efficiency Stand Alone Water Heater (0.62 EF)	47.00%	78.90%	23%
R-SF-WatH-5	SF	Hot Water	High Efficiency Stand Alone Water Heater (0.67 EF)	47.00%	78.90%	23%
R-SF-WatH-1	SF	Hot Water	Condensing Water Heater	47.00%	78.90%	7%
R-SF-WatH-18	SF	Hot Water	Indirect Water Heater	19.60%	87.00%	23%
R-SF-WatH-7	SF	Hot Water	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	47.00%	94.60%	13%
R-SF-WatH-9	SF	Hot Water	On-Demand, Tankless Water Heater (>=.95 EF)	47.00%	94.60%	13%
R-MF-WatH-16	MF	Hot Water	Faucet Aerators	47.00%	62.20%	100%
R-MF-WatH-12	MF	Hot Water	Low-flow Shower Heads (1.59 GPM)	47.00%	62.20%	100%
R-MF-WatH-14	MF	Hot Water	Shower Start Technology Only	47.00%	99.00%	100%
R-MF-WatH-13	MF	Hot Water	Low Flow Shower Heads (1.59 GPM + ShowerStart technology)	47.00%	62.20%	100%
R-MF-WatH-15	MF	Hot Water	Pipe Insulation	47.00%	84.80%	100%
R-MF-WatH-11	MF	Hot Water	Gravity-Film Exchange (GFX) Waste Water Heat Recovery	47.00%	99.00%	100%
R-MF-WatH-17	MF	Hot Water	Solar Water Heating – drain back system/with gas backup	47.00%	99.00%	34%
R-MF-WatH-3	MF	Hot Water	High Efficiency Stand Alone Water Heater (0.62 EF)	47.00%	78.90%	27%
R-MF-WatH-5	MF	Hot Water	High Efficiency Stand Alone Water Heater (0.67 EF)	47.00%	78.90%	27%
R-MF-WatH-1	MF	Hot Water	Condensing Water Heater	47.00%	78.90%	0%
R-MF-WatH-18	MF	Hot Water	Indirect Water Heater	19.60%	87.00%	27%
R-MF-WatH-7	MF	Hot Water	On-Demand, Tankless Water Heater (>=.82, <.95 EF)	47.00%	94.60%	13%
R-MF-WatH-9	MF	Hot Water	On-Demand, Tankless Water Heater (>=.95 EF)	47.00%	94.60%	13%
Space heating - Single Family/Multi Family Homes						
R-SF-SpH-1	SF	HVAC	Insulate and Seal Ducts	20.00%	50.00%	100%
R-SF-SpH-2	SF	HVAC	Insulate Unconditioned Basement/Crawl Space Piping	44.00%	58.80%	50%
R-SF-SpH-19	SF	HVAC	Heat Recovery Ventilator	44.00%	93.00%	5%
R-SF-SpH-3	SF	HVAC	Energy Star Furnace (AFUE=90%)	13.20%	69.70%	100%
R-SF-SpH-5	SF	HVAC	CEE Tier 2 Furnace (AFUE=92%)	13.20%	69.70%	100%
R-SF-SpH-7	SF	HVAC	CEE Tier 3 Furnace (AFUE=94%)	13.20%	69.70%	100%
R-SF-SpH-9	SF	HVAC	Energy Star Gas Boiler (AFUE=85%)	19.60%	69.70%	100%
R-SF-SpH-11	SF	HVAC	Condensing Gas Boiler (AFUE=90%)	19.60%	69.70%	100%
R-SF-SpH-13	SF	HVAC	Condensing Gas Boiler with Controls (AFUE=95%)	19.60%	69.70%	100%
R-SF-SpH-15	SF	HVAC	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	6.80%	99.00%	50%
R-SF-SpH-17	SF	HVAC	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	6.80%	99.00%	50%
R-SF-SpH-21	SF	HVAC	Energy Efficient Steam Boilers (low pressure/single-family)	4.40%	60.00%	100%
R-SF-SpH-20	SF	HVAC	Energy Star (High Performance Homes)	100.00%	85.00%	100%
R-MF-SpH-2	MF	HVAC	Insulate Unconditioned Basement/Crawl Space Piping	44.00%	58.80%	50%
R-MF-SpH-1	MF	HVAC	Insulate and Seal Ducts	20.00%	50.00%	5%
R-MF-SpH-19	MF	HVAC	Heat Recovery Ventilator	44.00%	93.00%	100%
R-MF-SpH-3	MF	HVAC	Energy Star Furnace (AFUE=90%)	13.20%	87.10%	100%
R-MF-SpH-5	MF	HVAC	CEE Tier 2 Furnace (AFUE=92%)	13.20%	87.10%	100%
R-MF-SpH-7	MF	HVAC	CEE Tier 3 Furnace (AFUE=94%)	13.20%	87.10%	100%
R-MF-SpH-9	MF	HVAC	Energy Star Gas Boiler (AFUE=85%)	19.60%	87.10%	100%
R-MF-SpH-11	MF	HVAC	Condensing Gas Boiler (AFUE=90%)	19.60%	87.10%	100%
R-MF-SpH-13	MF	HVAC	Condensing Gas Boiler with Controls (AFUE=95%)	19.60%	87.10%	100%
R-MF-SpH-15	MF	HVAC	Engine-Driven Heat Pump (126% AFUE, 15.6 SEER)	6.80%	99.00%	50%
R-MF-SpH-17	MF	HVAC	Gas Absorption Heat Pump (1.52 COP heating; .7 COP Cooling)	6.80%	99.00%	50%
R-MF-SpH-21	MF	HVAC	Energy Efficient Steam Boilers (low pressure/multi-family)	4.40%	66.67%	25%
R-MF-SpH-20	MF	HVAC	Energy Star (High Performance Homes)	100.00%	85.00%	100%
Dehumification - Single Family/Multifamily homes						
R-SF-DEHUM-1	SF	HVAC	Desiccant Dehumidification	27.00%	0.00%	100%
R-MF-DEHUM-1	MF	HVAC	Desiccant Dehumidification	27.00%	0.00%	100%
Space Heating and Space Cooling Shell Measures - Single Family Homes						
55	SF	HVAC	Combination WH/Furnace (.86 EF, .90 AFUE)	20.00%	70.75%	100%
56	SF	HVAC	Combination WH/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	19.60%	70.77%	100%

Natural Gas Energy Efficiency Potential in Massachusetts, April 2009
Residential Factor Data
TABLE A3

Measure #	Single- or Multi-family	End Use	Measure Description	Base Case Saturation (% of all homes that contain the end use or the measure)	Remaining Factor (In how many homes can this be installed	Convertible Factor (Accounting for competing technologies)
57	SF	HVAC	Combination WH/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	19.60%	70.77%	100%
58	MF	HVAC	Combination WH/Furnace (.86 EF, .90 AFUE)	20.00%	85.39%	100%
59	MF	HVAC	Combination WH/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	19.60%	85.36%	100%
60	MF	HVAC	Combination WH/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	19.60%	85.36%	100%
Laundry - Single Family/ Multi Family Homes						
R-SF-LAUN-2	SF	Laundry	Clothes Dryer with Moisture Sensor	16.00%	60.41%	100%
R-SF-LAUN-1	SF	Laundry	Energy Star Clothes Washer (vertical and horizontal)	45.50%	60.41%	100%
R-MF-LAUN-2	MF	Laundry	Clothes Dryer with Moisture Sensor	16.00%	73.20%	100%
R-MF-LAUN-1	MF	Laundry	Energy Star Clothes Washer (vertical and horizontal)	35.90%	73.20%	100%
Building Envelope - Single Family/Mulit Family Homes						
R-SF-ENV-9	SF	HVAC Shell	Attic Hatch Insulation	44.00%	60.60%	28%
R-SF-ENV-7	SF	HVAC Shell	Air Sealing	44.00%	50.00%	100%
R-SF-ENV-5	SF	HVAC Shell	Improved Floor Insulation	44.00%	60.60%	100%
R-SF-ENV-6	SF	HVAC Shell	Storm Windows	44.00%	64.00%	100%
R-SF-ENV-2	SF	HVAC Shell	Improved Wall Insulation	44.00%	60.60%	100%
R-SF-ENV-8	SF	HVAC Shell	Insulated Exterior Door	44.00%	64.00%	100%
R-SF-ENV-3	SF	HVAC Shell	Improved Roof Insulation	44.00%	60.60%	100%
R-SF-ENV-4	SF	HVAC Shell	Improved Below-Grade Insulation	44.00%	60.60%	29%
R-SF-ENV-1	SF	HVAC Shell	Energy Star Windows	44.00%	85.30%	100%
R-MF-ENV-9	MF	HVAC Shell	Attic Hatch Insulation	44.00%	85.50%	28%
R-MF-ENV-5	MF	HVAC Shell	Improved Floor Insulation	44.00%	85.50%	100%
R-MF-ENV-7	MF	HVAC Shell	Air Sealing	44.00%	50.00%	100%
R-MF-ENV-6	MF	HVAC Shell	Storm Windows	44.00%	70.10%	100%
R-MF-ENV-8	MF	HVAC Shell	Insulated Exterior Door	44.00%	70.10%	100%
R-MF-ENV-2	MF	HVAC Shell	Improved Wall Insulation	44.00%	85.50%	38%
R-MF-ENV-1	MF	HVAC Shell	Energy Star Windows	44.00%	85.90%	100%
R-MF-ENV-4	MF	HVAC Shell	Improved Below-Grade Insulation	44.00%	85.50%	100%
R-MF-ENV-3	MF	HVAC Shell	Improved Roof Insulation	44.00%	85.50%	100%
Cooking Equipment - Single Family/Multi Family Homes						
R-SF-COOK-1	SF	Cooking	Convection Ovens	27.80%	75.00%	100%
R-MF-COOK-1	MF	Cooking	Convection Ovens	27.80%	75.00%	100%
Pool water heating measures - Single Family/Multi-family homes						
R-SF-POOL-2	SF	Pool	Solar Pool Cover (Bubble)	0.95%	78.90%	90%
R-SF-POOL-1	SF	Pool	Pool Cover (Vinyl)	0.95%	78.90%	10%
R-SF-POOL-3	SF	Pool	High Efficiency Gas Pool Heater	0.95%	78.90%	50%
R-SF-POOL-6	SF	Pool	Solar pool heater	0.95%	78.90%	50%
R-SF-POOL-5	SF	Pool	Outdoor Spa Cover	0.65%	78.90%	100%
R-MF-POOL-2	MF	Pool	Solar Pool Cover (Bubble)	0.95%	78.90%	90%
R-MF-POOL-1	MF	Pool	Pool Cover (Vinyl)	0.95%	78.90%	10%
R-MF-POOL-3	MF	Pool	High Efficiency Gas Pool Heater	0.95%	78.90%	50%
R-MF-POOL-6	MF	Pool	Solar pool heater	0.95%	78.90%	50%
R-MF-POOL-5	MF	Pool	Outdoor Spa Cover	0.65%	78.90%	100%
Controls - Single Family/Multi-family						
R-SF-CTRL-1	SF	HVAC Controls	Programmable Thermostat	44.00%	23.50%	95.00%
R-SF-CTRL-2	SF	HVAC Controls	Occupancy Thermostat	44.00%	23.50%	5.00%
R-SF-CTRL-3	SF	HVAC Controls	Boiler Controls (Non-Condensing Boiler)	19.60%	95.00%	70.00%
R-SF-CTRL-4	SF	HVAC Controls	Zoning	20.00%	68.00%	100.00%
R-MF-CTRL-1	MF	HVAC Controls	Programmable Thermostat	44.00%	56.20%	95%
R-MF-CTRL-2	MF	HVAC Controls	Occupancy Thermostat	44.00%	56.20%	5%
R-MF-CTRL-3	MF	HVAC Controls	Boiler Controls (Non-Condensing Boiler)	19.60%	95.00%	70%
R-MF-CTRL-4	MF	HVAC Controls	Zoning	20.00%	68.00%	100%

APPENDIX B

Commercial Sector Data

Appendix B-1

Commercial Energy Efficiency Measure Descriptions

Eighty-six (86) commercial energy efficiency measures were included in this study of gas efficiency potential in Massachusetts. Appendix B-1 contains brief descriptions of each of these measures by end-use category. Descriptions of additional measures that were not included in the energy efficiency potential analysis are also included. These measures were excluded from the energy efficiency potential analysis because they were: (1) considered to be the baseline such as C-SH-16 - Gas Unit Heater - Power Vented/IID**,** (2) resulted in increased gas use such as C-OSG-1- Micro Turbine or C-SC-6-Double-Effect Absorption Chiller (1.03 COP) replacing an electric chiller, or (3) savings and cost were very site specific and difficult to quantify for typical commercial building types. Savings, costs and useful life data was collected for fuel switching measures (gas replacing electric) for potential future use, but they were not included in this analysis of natural gas energy efficiency potential.

Water heating

C-WH-1&2 (Market Driven and Retrofit) High Efficiency Stand Alone Commercial Water Heater (**0.67 EF <=75000 Btu)**

High efficiency water heaters that are not combined with space heating devices.

C-WH-3&4 (Market Driven & Retrofit) Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency) (>75000 Btu)

Recover energy by using a larger heat exchanger or a second heat exchanger that reduces the flue-gas temperature to the point where this water vapor condenses, releasing even more energy

C-WH-5&6 (Market Driven & Retrofit) On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)

Efficient on-demand (tankless) water heaters heat water as its passes through a gas-heated water-jacket/heat exchanger.

C-WH-7&8 (Market Driven & Retrofit) On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)

Efficient on-demand (tankless) water heaters heat water as its passes through a gas-heated water-jacket/heat exchanger.

C-WH-9&10 (Market Driven & Retrofit) On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)

Efficient on-demand (tankless) water heaters heat water as its passes through a gas-heated water-jacket/heat exchanger.

C-WH-11&12 (Market Driven & Retrofit) Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)

Uses the main boiler to heat a fluid that's circulated through a heat exchanger in the storage tank. The energy stored by the water tank allows the furnace to turn off and on less often, which saves energy.

C-WH-13 Heat Recovery Water Heater

Heat recovery for restaurants, supermarkets, food processors or any business that needs hot water and uses refrigeration or air conditioning. By recovering the heat from your refrigeration or cooling system, you can heat water for free.

C-WH-14 Pipe wrap

Insulation is wrapped around the first 12 feet of hot water line running into and out of the water heater to reduce heat loss.

C-WH-15 Low flow shower head (1.5 GPM)

Current Federal regulation - <= 2.5 gpm at a water pressure of 80 psi. Most common is aerating shower head which mixes air with the water. Low-flow showerheads are more likely to scald. Installing 3/4-inch piping with pressure-balancing valves, thermostatic mixing valves, or anti-scald valves should provide adequate protection.

C-WH-16 Faucet aerator

Small wire mesh fitting placed over faucets to aerate and reduce water flow. EPA's WaterSense Program specification is a max of 1.5 gpm. Only lavatory faucets intended for "private" use (includes hotel guest rooms and hospital rooms) are eligible for WaterSense label. The American Society of Mechanical Engineers specifies a max of 0.5 gpm for lavatory faucets intended for public use.

C-WH-17 Graywater Heat Exchanger/GFX

A coil wrap that heats incoming cold water with waste heat from outgoing hot wastewater (showers and sinks)

C-WH-18 Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)

Use higher water velocity and more effective spray patterns to remove food waste using less water than a standard commercial kitchen faucet.

C-WH-19 Circulation Pump Time Clocks

Use a thermostat or timer to automatically turn on the pump whenever water temperature drops below a set-point, or when the timer reaches a setting.

C-WH-20 Solar Water Heating w/gas auxiliary tank (SEF=1.5)

Utilizes the sun's solar energy to heat water indirectly (heat exchanger) or directly from a rooftop collector - through large flat roof plates or tubes.

Space Heating

C-SH-1&2 (Market Driven & Retrofit) High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)

Install a high efficiency furnace with AFUE >= 92%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air

C-SH-3&4 (Market Driven & Retrofit) High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)

Install a high efficiency boiler with AFUE of 85%-90%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

C-SH-5&6 (Market Driven & Retrofit) Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)

Install a condensing boiler with an AFUE rating >90%. A condensing boiler condenses flue gases in a second heat exchanger for extra efficiency.

C-SH-7&8 (Market Driven & Retrofit) High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)

Install a high efficiency steam boiler with AFUE >= 82%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

C-SH-8&9 (Market Driven & Retrofit) High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)

Install a high efficiency boiler with Th.eff.=85%-90%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

C-SH-10&11 (Market Driven & Retrofit) Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)

Install a condensing boiler with an EF >=90% A condensing boiler condenses flue gases in a second heat exchanger for extra efficiency.

C-SH-12&13 (Market Driven & Retrofit) High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)

Install a high efficiency steam boiler with a Th.eff. >=80%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

C-SH-14 Insulate and Seal Ducts (New Aerosol Duct Sealing)

Repair and seal leaky and unsealed commercial air ducts for heating with aerosol duct sealing to prevent air and heat loss. In addition, insulate ducts that run through spaces that get hot in summer or cold in winter.

C-SH-15 Insulate Unconditioned Basement/Crawl Space Piping (This is covered by water heating and boiler pipe insulation measures)

Insulate piping in basement/crawl areas to reduce heat loss from distribution piping in unconditioned areas.

C-SH-16 Gas Unit Heater - Power Vented/IID –

Eliminating gravity-vented units is already underway, since power vented units had a 45% market share in 2002. (Consider power vented units as the baseline). Power-vented units (w/intermittent ignition device) with a sealed exhaust stack use a fan to pull combustion air through the unit, cutting off-cycle losses. (80% seasonal efficiency)

C-SH-17 Gas Unit Heater - Condensing (AFUE =93%)

Extracts the residual heat by leading the flue gases through a second heat exchanger.

C-SH-18 Infrared Heater (low intensity - two stage)

Low-intensity gas-fired infrared heating systems emulate the true efficiency of the sun by generating radiant heat energy. They consist of three main components: a burner control box, black-coated radiant emitter tubes, and a highly polished reflector assembly. The heaters are typically suspended from the ceiling by chains and are controlled by a thermostat.

C-SH-19 Stack Heat Exchanger (Standard Economizer)

Boiler stack economizers are simply heat exchangers with hot flue gas on one side and water on the other. Or, in direct contact condensing units, the make-up water is in direct contact with the flue gases.

C-SH-20 Stack Heat Exchanger (Condensing Economizer)

In terms of energy performance, an existing boiler system with an added condensing stack economizer becomes, in essence, a condensing boiler. A properly sized economizer will drop the flue gas temperature to 77°C (170°F), condensing the flue gases and transferring absorbed heat into the water flow. The economizer can raise the effective seasonal thermal efficiency of these boilers from below 80 percent to nearly 90 percent.

C-SH-21 Heat Recovery from Air to Air

Transfer heat between the intake ventilation air stream and the HVAC exhaust air stream. During periods when the outside air is colder than the inside air, the heat exchanger transfers heat from the exhaust air to the incoming air reducing heating energy use.

C-SH-22 Ceiling Insulation (to R-24) (Included in Improved Roof/Ceiling Insulation under Building Shell Measures)

Insulation installed in the ceiling cavity to prevent heat or cooling loss

C-SH-23 Boiler Heating Pipe Insulation

Insulating accessible steam or hot water supply pipes in the boiler room is a cost-effective way to save energy. Savings will vary depending on the temperature of the hot water or steam and the ambient temperature.

C-SH-24 Boiler Tune-Up

Can improve average combustion efficiency by 2 to 10 percent. The technician uses an electronic flue-gas analyzer to monitoring stack temperature, oxygen and carbon monoxide. In addition, the technician should determine the boiler's gas input rate (cubic

feet per minute). Some boilers can't be tuned up because there is no way to control the excess air or gas flow.

C-SH-25 Boiler Reset Controls

A Boiler Reset Control is a device that automatically controls the boiler water temperature according to a software program based on outdoor temperature.

C-SH-26 Boiler O2 Trim Controls

An electronic sensor inserted into the boiler flue, connected to a control panel to measure oxygen and transmit signals to a control damper on the burner air supply.

C-SH-27 Electronic Parallel Positioning Controls (linkage-less)

Modern electronic parallel positioning controls (PPC) incorporate end-device positioning signals to ensure accurate placement of fuel and air positioners for specific firing rates

C-SH-28 Boiler blow-down heat exchanger (steam)

Recovery of heat from the periodic/continuous flow of outlet waste water (to prevent sludge buildup) to preheat make-up water

C-SH-29 Repair/Replace malfunctioning steam traps

Under normal operating conditions, the valve and seat area is subjected to hot high-pressure water flow. Water is corrosive and causes surface erosion. With no maintenance, eventually the valve will fail to close properly and the trap will fail to seal and will waste steam.

C-SH-30 Insulate steam lines/condensate tank

Insulation to prevent heat loss from steam lines

C-SH-31 Destratification Fans (HVLS)

High Volume Low-Speed (HVLS) ceiling fans are large (8-ft. to 20-ft. in diameter). They will effectively mix and circulate air within a given space to equalize temperature between ceiling and floor levels.

C-SH-32 Exhaust Hood Makeup Air

Install dedicated make-up air supply for exhaust hoods. Exhaust hoods remove heat and vapor associated with cooking processes. An equal volume of makeup air must replace the air removed through the kitchen exhaust hood.

C-SH-33 Optimizing Kitchen Ventilation (Customized optimization strategies that are site specific - very difficult to quantify typical savings.)

Optimizing the kitchen ventilation system in new construction or major renovation to achieve optimum performance and energy efficiency.

C-SH-34 Exhaust Hood - Demand Ventilation

Varies exhaust fan speed to meet actual need as measured by quantity smoke and heat that needs to be removed

C-SH-35 Demand Controlled Ventilation

CO2 sensors control the amount of ventilation based on the actual number of occupants and related ventilation need. DCV can generate substantial energy savings when the space is occupied below the design level.

C-SH-36 Direct Gas-Fired AHU (92% Efficient)

A direct gas-fired AHU is highly efficient because it has a gas burner installed directly in the outside makeup-air stream. Facilities require less than 20% outside-air makeup are not good candidates. Common applications include high-exhaust/infiltration industrial applications and commercial kitchens. Commercial buildings have seen limited utilization.

Space Conditioning

C-SC-1 Desiccant Dehumidifier/Air Conditioner

Thermally activated cooling system, where moisture is absorbed from air into a liquid desiccant solution and a thermal input supplies the heat of vaporization. When applied as a make-up air pre-cooling unit that removes the latent portion of the load, the interior air cooling system can operate at higher CFM per ton and high EER. With double-effect regeneration, thermal COPs of 1.2 to 1.4 are feasible.

C-SC-2 High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)

The majority of commercial gas-fired rooftop air conditioning units are single-speed non-condensing units with combustion efficiencies in the range of 78-82%. High efficiency systems using condensing heat exchangers or pulse combustion can attain efficiency of 89-97%.

C-SC-3 Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)

Engine-driven systems have variable speed operation, high part load efficiency, high temperature waste heat recovery from the engine, and reduced annual operating costs.

C-SC-4 Engine-Driven Chiller w/ heat recovery

Engine-driven systems have variable speed operation, high part load efficiency, high temperature waste heat recovery from the engine, and reduced annual operating costs.

C-SC-5 Double-Effect Absorption Chiller (1.03 COP)

Double-effect absorption cooling adds a second generator and condenser to increase the refrigerant flow, and therefore the cooling effect, for a fraction of the heat input of a single-effect system.

C-SC-6 Double-Effect Absorption Chiller (1.03 COP)

Double-effect absorption cooling adds a second generator and condenser to increase the refrigerant flow, and therefore the cooling effect, for a fraction of the heat input of a single-effect system.

Space heating and conditioning

C-SHC-1 Packaged Absorption Chiller/Heater w/fan coil

An absorption chiller-heater is a cooling/heating unit using gas or oil as fuel and water as refrigerant.

C-SHC-2 Gas Fired Absorption Heat Pump

A gas fired absorption heat pumps use an ammonia-water absorption cycle to provide heating and cooling. As in a standard heat pump, the refrigerant (in this case, ammonia) is condensed in one coil to release its heat; its pressure is then reduced and the refrigerant is evaporated to absorb heat. Heating - 1.2 COP or greater and a cooling efficiency of 0.7

C-SHC-3 Direct-Fired Absorption Chiller/Heater (double effect)

Direct-fired absorption chillers utilize a burner as the heat input for the absorption cooling cycle. Very high efficiency is achieved through a very high temperature heat input.

On-site generation

C-OSG-1 Micro Turbine

Used for distributed power and CHP. Usually consist of a single stage radial compressor, a single stage radial turbine and a recuperator. Exhaust heat can be used for water heating, space heating, drying processes or absorption chillers. Typical microturbine efficiencies are 25 to 35%. When in a combined heat and power cogeneration system, efficiencies of greater than 80% can be achieved.

C-OSG-2 Micro-CHP

Natural gas driven, liquid cooled, internal combustion engine-generator set that is used to supply heat and power to small commercial buildings

Cooking

C-Ck-1 High Efficiency Gas Griddle

Gas griddle with infrared burners, thermal fluid and solid state controls have resulted in improved cooking efficiencies, production capacities and pre-heat/idle energy consumption rates.

C-Ck-2 High Efficiency Gas Combination Oven

Gas combination ovens utilize pressure-less (atmospheric) steam and forced convection hot air to. A high efficiency gas combustion chamber heats the cooking cavity for even, efficient cooking.

C-Ck-3 High Efficiency Gas Convection Oven

A forced air convection oven uses a motorized fan or blower that forces the heated air to move throughout the oven, stripping away the layer of cooler air next to the food. The result is faster more even cooking.

C-Ck-4 High Efficiency Gas Conveyer Oven

Conveyor ovens are available using 4 different technologies: infrared, natural convection with a ceramic baking hearth, forced convection and a combination infrared/forced convection. Efficiency features include independently controlled cooking zones and air curtains.

C-Ck-5 High Efficiency Gas Rack Oven

Improvements through the use of infrared burners, combustion gas recirculation systems, and solid-state controls have resulted in improved cooking efficiencies, production capacities, and pre-heat/idle energy consumption rates.

C-Ck-6 High Efficiency Gas Broiler

Improvements through the use of infrared burners, combustion gas recirculation systems, and solid-state controls have resulted in improved cooking efficiencies, production capacities, and pre-heat/idle energy consumption rates.

C-Ck-7 Power Burner Range

The power burner range is an improved atmospheric burner. The term "power" means that a blower drives gas and air flow to the burner. Gas and air are mixed in a plenum and the mixture is regulated to achieve more efficient combustion. During combustion, the flame moves sideways from the burner and impinges on a bowl made of low-carbon stainless steel located underneath the burner. This bowl glows bright orange and increases the amount of radiant heat transmitted to the cooking utensil. The power burner can be adjusted from a maximum of 20,000 Btu/hour down to 6 Btu/hour and has a design life expectancy of 7 years. The thermal efficiency of the power burner is 63% compared to 42% for standard atmospheric burners found on conventional cooktop ranges and conventional fryers

C-Ck-8 High Efficiency Fryer

Such cookers yield shorter cook times and higher production rates. In addition, frypot insulation reduces standby losses resulting in a lower idle energy rate.

C-Ck-9 High Efficiency Gas Steamer

Energy-efficient steam cookers offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery system.

Space and Water Heating

C-SWH-1&2 (Market Driven & Retrofit) Combination Water Heater/Furnace (.86 EF, .90 AFUE)

These systems use one primary heat source shared between conventional pieces of equipment, such as, an air handler and a tank water heater, to serve dual heating purposes. 0.86 EF water heating, 0.9 AFUE space heating.

C-SWH-3&4 (Market Driven & Retrofit) Combination Water Heater/Boiler (Condensing) (0.9 EF, 0.9 AFUE)

A powerful water heater that provides space heating as a supplemental end-use. Heated water passes through a heat exchanger in a central handler to heat air which is then blown into the home's duct system. 0.9 EF, 0.9 AFUE

C-SWH-5 Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)

A powerful water heater that provides space heating as a supplemental end-use. Heated water passes through a heat exchanger in a central handler to heat air which is then blown into the home's duct system. 0.86 EF, 0.85 AFUE

Building Envelope

C-BE-1 Double Glazing Low Emissivity Windows

Windows with two sandwiched glass panes for improved insulation

C-BE-2 Triple Glazing Low Emissivity Windows

Windows with three sandwiched glass panes for superior insulation properties

C-BE-3 Improved Wall Insulation (to R12)

Installing fiberglass or cellulose insulation material in wall cavity will reduce heat transfer across these surfaces. (R12)

C-BE-4 Improved Roof/Ceiling Insulation (to R32)

Installing fiberglass or cellulose insulation material in roof cavities will reduce heat transfer across these surfaces.

C-BE-5 Improved Below-Grade Insulation (to R6)

Improving the insulation in basement areas (R6)

C-BE-6 Air Sealing

Properly air sealing thermal shell air leaks and openings through strategic use and location of airtight materials significantly reduces heating and cooling costs.

C-BE-7 Integrated Building Design, Envelope Only (30% > code)

Design for energy efficiency 30% better than 90.1-2001, which is the base LEED level.

HVAC Controls

C-CN-1 EMS Install

A computer system which is designed specifically for the automated control and monitoring of the heating, ventilation and lighting needs of a building or group of buildings can then be used to produce trend analysis and annual consumption forecasts.

C-CN-2 EMS Optimization

Reconfiguration of the EMS system to meet new or changed schedules/usage patterns in the building energy environment to minimize waste.

C-CN-3 Zoning

The zone control system allows a single HVAC unit to have separate temperature zones in the building to eliminate redundant HVAC service.

C-CN-4 Retrocommissioning

A tune-up of a building and its systems. Retro-commissioning is an exhaustive examination of the facility HVAC systems and components.

C-CN-5 Commissioning

Commissioning is a systematic process of verifying and documenting that building energy systems or subsystems perform interactively according to the design intent and the owner's operational needs.

C-CN-6 Programmable Thermostat

Ability to adjust heating or air-conditioning operating times according to a pre-set schedule to meet occupancy needs and minimize redundant HVAC operation.

Laundry

C-L-1 Wastewater, Filtration/Reclamation

Filtering wastewater from commercial applications to a level of quality suitable for reuse in the same commercial application (laundry)

C-L-2 Ozone Commercial Laundry System (Gas HW)

A system that uses an ozone additive to reduce water use, fuel use, chemical use.

C-L-3 High Efficiency Clothes Washer

A high efficiency clothes washer will have a minimum Modified Energy Factor (MEF) of 1.72 (Energy Star). MEF takes into account the amount of dryer energy used to remove the remaining moisture content in washed items, in addition to the machine energy and water heating energy of the washer.

Pool Water Heating

C-PWH-1 High Efficiency (95%) Gas Pool Water Heater

High capacity, gas-powered water heater for a swimming pool

C-PWH-2 Pool Cover

Large insulating cover to prevent heat loss from a heated pool or water loss through evaporation.

C-PWH-3 Solar Pool Heater

Install a solar pool heater that plugs into the existing filtration unit. Some systems include an automatic controller and sensors to open and close a valve, deciding whether to send water back into the pool or through the collectors.

Appendix B-2

Commercial Sector Measure Data

Appendix B-2 contains measure data including incremental costs, useful lives, MMBTU savings, electric savings and water savings for all of the commercial measures considered in this study. This includes data for measures that were not included in the potential analysis, as discussed above on page 1 of Appendix B-1.

Appendix B-2 includes the following tables:

a) Water Heating
b) Space Heating
c) Space Conditioning
d) Space Heating and Conditioning
e) On-site Generation
f) Cooking
g) Space and Water Heating
h) Building Envelope
i) HVAC Controls
j) Laundry
k) Pool Water Heating
l) Sources

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2a

ID	Commercial Measures	Market-driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Life (Years)	Cost Type: 1=Full 2=Inc.	Cost	Cost Unit
	Water Heating										
C-WH-1	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	Market-Driven	Storage tank water heater = 0.59 EF	11.9%	3.0			13	1	$415	Unit
C-WH-2	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	Retrofit	Storage tank water heater = 0.55 EF	17.9%	4.8			13	1	$1,149	Unit
C-WH-3	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 btu)	Market-Driven	Stand alone tank water heater w/ Thermal efficiency = 80%	23.1%	25.0			15	1	$2,340	Unit
C-WH-4	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 Btu)	Retrofit	Stand alone tank water heater w/ Thermal efficiency = 78%	25.3%	28.2			15	1	$6,220	Unit
C-WH-5	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	Market-Driven	Storage tank water heater = 0.59 EF	28.1%	7.1			20	1	$1,198	Unit
C-WH-6	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	Retrofit	Storage tank water heater = 0.55 EF	32.9%	8.92			20	1	$2,013	Unit
C-WH-7	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	Market-Driven	Storage tank water heater = 0.59 EF	37.9%	9.59			20	1	$1,373	Unit
C-WH-8	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	Retrofit	Storage tank water heater = 0.55 EF	42.1%	11.41			20	1	$2,188	Unit
C-WH-9	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	Market-Driven	Storage tank w/ Thermal efficiency = 80%	12.5%	13.5			20	1	$1,522	Unit
C-WH-10	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	Retrofit	Storage tank w/ Thermal efficiency = 78%	15.0%	16.7			20	1	$3,640	Unit
C-WH-11	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	Market-Driven	Storage tank water heater = 0.59 EF	28.1%	30.38			15	1	$1,175	Unit
C-WH-12	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	Retrofit	Storage tank water heater = 0.55 EF	32.9%	36.72			15	1	$2,093	Unit
C-WH-13	Heat Recovery Water Heater	Retrofit	Storage tank water heater = 0.59 EF	50.3%	258.60			15	1	$4,800	Unit
C-WH-14	Pipe wrap	Retrofit	No pipe wrap	2.0%	2.23			13	1	$156	Per 12 lin. Ft.
C-WH-15	Low flow shower head (1.5 GPM)	Retrofit	Standard shower flow = 2.5 gpm,	40% (of shower hot water use)	5.20			10	1	$77	unit
C-WH-16	Faucet aerator	Retrofit	Standard faucet flow = 2.2 gpm	78% (0.5gpm faucet), 32% (1.5 gpm faucet.)	1.70			10	1	$6	unit
C-WH-17	Graywater Heat Exchanger/GFX	Retrofit	No GFX graywater heat exchanger	30%-50%	44.60			20	1	$3,364	unit
C-WH-18	Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	Retrofit	3.0 gpm @ 60 psi	46.7%	53.40			5	1	$50	unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2a

	Commercial Measures	Market-driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Life (Years)	Cost Type: 1=Full 2=Inc.	Cost	Cost Unit
C-WH-19	Circulation Pump Time Clocks	Retrofit	No circulation time pump clocks	5.3%	5.91			10	1	$132	unit
C-WH-20	Solar Water Heating w/gas auxiliary tank (SEF=1.5)	Retrofit	Storage tank water heater = 0.59 EF	60.7%	67.68			20	1	$26,400	unit

Notes:

1 - Source Documentation from Measure Assumption Update Study: Efficiency Vermont Technical Reference Manual, p. 409. April 2008 Edition uses 13 years. Actual field experience suggests that this number may be too high - recommend using 10 year (more conservative) value.

2 - Source Documentation from NYSERDA Study: Measure savings factors are calculated based on individual measure data and assumptions about existing stock efficiency (for retrofit measures), standard practice for construction and purchases (for market-driven measures), and high-efficiency options. Measure-savings characteristics were developed using public and private information sources, including NYSERDA, CBECS, California Energy Commission, Efficiency Vermont, American Council for an Energy Efficient Economy (ACEEE), Lawrence Berkeley Laboratory (LBL), National Fenestration Rating Council (NFRC), various Northeastern U.S. baseline and market assessment studies, recent gas potential studies, and communications with manufacturers and vendors. Measure savings are expressed in % of baseline energy usage.

3 - Source Documentation from NYSERDA Study: Measure lives were developed from various sources including prior potential studies, NYSERDA, DOE, EPA, ACEEE, ASHRAE, Efficiency Vermont, NFRC, equipment manufacturers and professional judgment.

4 - Commercial/Residential MMBtu savings x Residential water savings

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2b

ID#	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
	Space Heating										
C-SH-1	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	Market-Driven	AFUE = 78%	15.2%	40.46			18	1	$696	Unit
C-SH-2	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	Retrofit	AFUE = 75%	18.5%	51.17			18	1	$2,497	Unit
C-SH-3	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	Market-Driven	AFUE = 80%	5.9%	26.40			20	1	$1,012	Unit
C-SH-4	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	Retrofit	AFUE = 75%	11.8%	56.13			20	1	$5,815	Unit
C-SH-5	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	Market-Driven	AFUE = 80%	15.8%	70.9			18	1	$1,627	Unit
C-SH-6	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	Retrofit	AFUE = 75%	21.1%	100.5			18	1	$6,040	Unit
C-SH-7	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	Market-Driven	AFUE = 75%	8.5%	79.0			20	1	$3,552	Unit
C-SH-8	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	Market-Driven	Thermal Efficiency = 78%	10.3%	298.3			25	1	$9,110	Unit
C-SH-9	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	Retrofit	Thermal Efficiency = 75%	13.8%	413.7			25	1	$39,450	Unit
C-SH-10	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	Market-Driven	Thermal Efficiency = 78%	13.3%	384.5			18	1	$11,019	Unit
C-SH-11	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	Retrofit	Thermal Efficiency = 75%	16.7%	500.4			18	1	$41,359	Unit
C-SH-12	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	Market-Driven	Thermal Efficiency = 78%	4.8%	137.4			25	1	$5,352	Unit
C-SH-13	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	Retrofit	Thermal Efficiency = 75%	8.4%	252.8			25	1	$30,562	Unit
C-SH-14	Insulate and Seal Ducts (New Aerosl Duct Sealing)	Retrofit	Leaky, unsealed and uninsulated ducts	6.5%	46.2	850		20	1	$11,329	Typical Building
C-SH-15	Insulate Unconditioned Basement/Crawl Space Piping (This is covered by water heating and boiler pipe insulation measures)										
C-SH-16	Gas Unit Heater - Power Vented/IID - Eliminating gravity-vented units is already underway, since power vented units had a 45% market share in 2002. (consider power vented units as the baseline).										
C-SH-17	Gas Unit Heater - Condensing (AFUE =93%)	Market-Driven	Power Vented Unit (AFUE =80%)	13.98%	49.2			19	1	$2,640	Unit
C-SH-18	Infrared Heater (low intensity - two stage)	Market-Driven	Power Vented Unit (AFUE =80%)	26%	61.2			17	1	$948	Unit
C-SH-19	Stack Heat Exchanger (Standard Economizer)	Retrofit	Boiler without economizer	5.00%	105.0			20	1	$1,500	Unit
C-SH-20	Stack Heat Exchanger (Condensing Economizer)	Retrofit	Boiler without economizer	10.00%	210.0			20	1	$2,120	Unit
C-SH-21	Heat Recovery from Air to Air	Retrofit	No air-to-air heat exchanger	13%	92.4			20	1	$8,886	Unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2b

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
C-SH-22	Ceiling Insulation (to R-24) (Included in Improved Roof/Ceiling Insulation Under Building Shell Measures)										
C-SH-23	Boiler Heating Pipe Insulation	Retrofit	No boiler pipe insulation	2.4%	17.3			15	1	$243	Per 25 Ln. ft.
C-SH-24	Boiler Tune-Up	Retrofit	Boiler that does not routinely receive a high efficiency boiler tune-up	2.0%	38.5			2	1	$450	Per Tune-Up
C-SH-25	Boiler Reset Controls	Retrofit	Boiler without reset controls	5.0%	35.5			20	1	$993	Unit
C-SH-26	Boiler O2 Trim Controls	Retrofit	Boiler without O2 trim controls	2.0%	94.02			15	1	$10,000	Unit
C-SH-27	Electronic Parallel Positioning Controls (linkage less)	Retrofit	Mechanical linkage, jack shaft controls- Standard efficiency	2.0%	94.02			15	1	$14,500	Unit
C-SH-28	Boiler blowdown heat exchanger (steam)	Retrofit	Steam boiler without blowdown heat exchanger	5.6%	1411.5			20	1	$60,000	Unit
C-SH-29	Repair/Replace malfunctioning steam traps	Retrofit	Malfunctioning steam traps	10.0%	40.3			5	1	$219	New Steam Trap
C-SH-30	Insulate steam lines/condensate tank	Retrofit	No insulation	2.0%	90.2			15	1	$1,302	Per 100 ln. ft.
C-SH-31	Destratification Fans (HVLS)	Retrofit	Heated high bay facilities such as warehouses with no destratification fans.	22.5%	220	206.4 (Note 1)		12.5	1	$20,000	2 Fans
C-SH-32	Exhaust Hood Makeup Air	Retrofit	No dedicated make-up air supply	57%	215.38	8,906 (Note 2)		15	1	$5,900	Unit
C-SH-33	Optimizing Kitchen Ventilation (Customized optimization strategies that are site specific - very difficult to quantify typical savings.)	New Construction	No optimization included in new kitchen ventilation design								
C-SH-34	Exhaust Hood - Demand Ventilation	Market-Driven	Exhaust hood without demand ventilation controls	25%	35.9	2,500 (Note 3)		10	1	$10,000	Unit
C-SH-35	Demand Controlled Ventilation	Retrofit	Constant Air Volume (CAV) system	11.5%	58.85			15	1	$3,450	per 6 zones
C-SH-36	Direct Gas-Fired AHU (92% Efficient)	Market-Driven	Indirect Gas Fired AHU (80% Efficient)	13.0%	Savings vary significantly by application				1	$0	

Notes:

1 - Kevin Young, Big Ass Fan Company

2 - 41.35 kWh/MMBtu saved from Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C - kWh saved or increased per dTh saved Table

3 - EStar CFS: Energy Star Best Practices tool for full-service restaurants: 7500 CFM design exhaust rate reduced to an avg. of 5000 CFM.

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data

Table B-2c

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	**Space Conditioning**										
C-SC-1	Desiccant Dehumidifier/Air Conditioner	Market-Driven	7.5 ton Electric AC Baseline per 1000 cfm	Not Applicable	-403.75	24,300		20	1	$184,484	Unit
C-SC-2	High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	Market-Driven	Combustion Efficiency = 80%	15.8%	28.5			15	1	$1,000	Unit
C-SC-3	Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	Market-Driven	Engine-driven chiller without heat recovery	19.6%	334.7			20	1	$20,000	Unit
C-SC-4	Engine-Driven Chiller w/ heat recovery	Market-Driven	Electric Chiller	Uses 101% more MMBTu's than electric chiller	-1372.2	199902		20	1	$142,400	Unit
C-SC-5	Double-Effect Absorption Chiller (1.03 COP)	Market-Driven	Single-Effect Absorption Chiller (COP =.8)	38.4%	1274			20	1	$118,400	Unit
C-SC-6	Double-Effect Absorption Chiller (1.03 COP)	Market-Driven	Electric Chiller	Uses 295% more MMBTu's than electric chiller	-2691.7	199902		20	1	$138,800	Unit

Notes:
1 - 9.0 EER, 729 Full Load Hours

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2d

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	Space Heating-Conditioning										
C-SHC-1	Packaged Absorption Chiller/Heater w/fan coil	Market-Driven	Smaller commercial applications - replacing existing electric HVAC and gas heating	Not Applicable	-155.169	32,400 (Note 1)		20	1	$57,891	Unit
C-SHC-2	Gas Fired Absorption Heat Pump	Market-Driven	Furnaces and Electric AC, primarily in small commercial buildings	Not Applicable	-20	12,384		20	1	$56,891	Unit
C-SHC-3	Direct-Fired Absorption Chiller/Heater (double effect)	Market-Driven	(Electric Chiller and Gas Heat) Large cooling and heating loads with central chiller plants in areas of medium to high electric rates.		-2580.1	199,902		20	1	$138,800	Unit

Notes:
1 - 40 ton Electric HVAC, 10.8 EER, 729 Full Load Cooling Hours
2 - Assumes 6.5% savings - 10 ton unit with baseline efficiency of 8.9 EER and 729 full load cooling hours

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2e

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	On-Site Generation										
C-OSG-1	Micro Turbine	Retrofit	100,00 sq. ft. office building (13.4 kWh/sq. ft., 55% load factor, 28.5 kBtu/sq. ft.)	85% (kWh), 65% (Summer kW Peak), 41% increase in gas consumption	-1177	1138800		15	1	$406,000	Unit
C-OSG-2	Micro-CHP	Retrofit	Existing Furnaces (Assumed AFUE=75%)	0%	0	3338		15	1	$10,000	Unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2f

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	**Cooking**										
C-Ck-1	High Efficiency Gas Griddle	Market-Driven	Standard Efficiency Gas Griddle	5.2%	5.8			12	1	$1,165	Unit
C-Ck-2	High Efficiency Gas Combination Oven	Market-Driven	Standard Efficiency Gas Combination Oven	26.3%	40.3			12	1	$1,300	Unit
C-Ck-3	High Efficiency Gas Convection Oven	Market-Driven	Standard Efficiency Gas Oven	30.8%	32.4			12	1	$1,400	Unit
C-Ck-4	High Efficiency Gas Conveyer Oven	Market-Driven	Standard Efficiency Gas Conveyor Oven	24.1%	84.5			12	1	$2,100	Unit
C-Ck-5	High Efficiency Gas Rack Oven	Market-Driven	Standard Efficiency Gas Rack Oven	38.9%	211.3			12	1	$4,000	Unit
C-Ck-6	High Efficiency Gas Broiler	Market-Driven	Standard Efficiency Gas Broiler	18.7%	66.1			12	1	$1,750	Unit
C-Ck-7	Power Burner Range	Market-Driven	Standard Atmospheric Burner	34.0%	40.8			7	1	$1,400	Unit
C-Ck-8	High Efficiency Fryer	Market-Driven	Standard Efficiency Fryer	30.80%	36			10	1	$1,100	Unit
C-Ck-9	High Efficiency Gas Steamer	Market-Driven	61.2% more efficient than a standard gas steamer	50.00%	45		216.65	10	1	$2,000	Unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2g

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	Space & Water Heating										
C-SWH-1	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	Market-Driven	78 AFUE furnace and 0.594 EF water heater	15.4%	24.01			15	2	$720.00	unit
C-SWH-2	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	Retrofit	75 AFUE furnace and 0.55 EF	19.0%	30.98			15	1	$4,320.00	unit
C-SWH-3	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Market-Driven	80 AFUE boiler and 0.594 EF water heater	16.1%	24.56			20	2	$2,185.00	unit
C-SWH-4	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Retrofit	75 AFUE boiler and 0.55 EF	21.4%	35.00			20	1	$5,785.00	unit
C-SWH-5	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Market-Driven	80 AFUE boiler and 0.594 EF water heater	11.1%	16.96			20	2	$1,300.00	unit
C-SWH-6	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Retrofit	75 AFUE boiler and 0.55 EF	16.8%	27.39			20	1	$4,900.00	unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009

Commercial Measure Data

Table B-2h

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	Building Envelope										
C-BE-1	Double Glazing Low Emissivity Windows	Market-Driven	Single glazed windows with no low-E coating	5.20%	36.9			20	1	$7,624	Typical building
C-BE-2	Triple Glazing Low Emissivity Windows	Market-Driven	Single glazed windows with no low-E coating	9.70%	68.9			20	1	$12,615	Typical Building
C-BE-3	Improved Wall Insulation (to R12)	Retrofit	R-9 whole wall	6.8%	48			30	1	$7,833	Typical Building
C-BE-4	Improved Roof/Ceiling Insulation (to R32)	Retrofit	R-13	4.5%	31.8			30	1	$4,289	Typical Building
C-BE-5	Improved Below-Grade Insulation (to R6)	Retrofit	No basement insulation	0.7%	5.2			30	1	$2,271	Typical Building
C-BE-6	Air Sealing	Retrofit	Leaky thermal shell - no air sealing	13.40%	95.2			20	1	$4,200	Typical Building
C-BE-7	Integrated Building Design, Envelope Only (30% > code)	New Construction	Building Code	30.00%	840.31			40	2	$83,113	Typical Building

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2i

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	HVAC Controls										
C-CN-1	EMS install	Retrofit	HVAC without EMS system	20.0%	227.3	14488		10	1	$72,438	Unit
C-CN-2	EMS Optimization	Retrofit	HVAC with EMS Btu without optimization.	5.0%	56.8	1449		5	1	$2,608	Typical Building
C-CN-3	Zoning	Retrofit	HVAC with no zoning capacity	4.50%	32.0			15	1	$1,500	Typical Building
C-CN-4	Retrocommissioning	Retrofit	HVAC without retrocommissioning service	10%	71.0			7	1	$3,082	Typical Building
C-CN-5	Commissioning	Retrofit	New Construction without commissioning service	7%	79.6			7	1	$15,936	Typical Building
C-CN-6	Programmable Thermostat	Retrofit	HVAC without a programmable thermostat	19.2%	7.7			10	1	$92	Unit

Notes:
1 - Energy Efficiency and Renewable Energy Resource Development Potential in New York State - Final Report, Volume 5 Energy Efficiency Technical Appendices, August 2003. (.5 kwh
2- Assumes an increase in savings of 10%

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2j

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	**Laundry**										
C-L-1	Wastewater, Filtration/Reclamation	Retrofit	No wastewater reclamation system	Up to 50%	1396.0		2,790,000	20	1	$150,000	Unit
C-L-2	Ozone Commercial Laundry System (Gas HW)	Retrofit	No ozone system	55%	1656.2		263005	15	1	$26,000	Unit
C-L-3	High Efficiency Clothes Washer	Market-Driven	The federal standard is 1.26 MEF	29.80%	2.13	62.63	16911	11	1	$200	Unit

GasNetworks, Natural Gas Energy Efficiency Potential In Massachusetts, April 2009
Commercial Measure Data
Table B-2k

	Commercial Measures	Market-Driven or Retrofit	Baseline Efficiency	Savings Factor	Annual Savings MMBtu	Annual Electric Savings kWh	Annual Water Savings Gallons	Measure Life (Years)	Cost Type: 1=Full 2=Inc.	Measure Cost	Cost Unit
Measure ID	**Pool Water Heating**										
C-PWH-1	High Efficiency (95%) Gas Pool Water Heater	Market-Driven	Baseline 68% efficient pool heater	28.4%	44.7			20	1	$1,300	Unit
C-PWH-2	Pool Cover	Retrofit	No pool cover	63%	262.0			6	1	$1,170	Unit
C-PWH-3	Solar pool heater	Retrofit	Baseline 68% efficient pool heater	100%	157.2			20	1	$5,500	Unit

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
ID	**Water Heating**					
C-WH-1	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	GDS Calculation	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 25.3 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (See Note 1 - EVT and most other organization use 13 year measure life); Energy Star uses 13 year life. ACEEE assumes 13 year life - http://www.aceee.org/consumerguide/waterheating.htm; NYSERDA Deemed Savings Database, Rev 09-082006 (13 years)	Used average incremental cost from the following sources - GPVR40-101 (40gal, 40000btu, .67EF), $1023 vs. baseline = Rheem 42V50-40F (40 gallon, 40000btu, 0.59EF), $376.95.at https://keithspecialty.com/k/41-040.htm ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10 ($400 incremental cost) SEGWHAI: Super Efficient Gas Water Heating Appliance Initiative, Transforming Storage Gas Water Heaters Marshall B. Hunt, P. E. 2007 National Symposium on Market Transformation, March 20, 2007p. 5 (incremental cost = $200).
C-WH-2	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	GDS Calculation	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 27.1 MMBTU	See Measure Life Source for C-WH-1	Used Average full cost from the following sources: Baseline = Rheem 42V50-40F (40 gallon, 40000btu, 0.59EF), $376.95.at https://keithspecialty.com/k/41-040.htm+$415 (incremental cost) + $240 installation cost (from Mike Sommer); ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10 ($1265 full cost)
C-WH-3	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 btu)	Direct Final Rule: Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures and Efficiency Standards for Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks, Federal Register, October 21, 2004,	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE)	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE and 250 gal/day) Base Use = 108.3 MMBTU	ACEEE, Emerging technologies and practices, 2004: W1 - pg 46.	Used Average incremental cost from the following sources - Cost = $6319 Polaris(50 gal, 100mbtu, 96%TE) http://www.commercialwaterheatersales.com,vs. Baseline = Rheem G50-98 (50gal, 98000 Btu, 80% therm. Eff.), $3,640 www.simplyplumbing.com; Condensing Water Heaters, By Jessica Rivas, E Source Research Analyst -- Foodservice Equipment and Supplies, 1/1/2008 (Max incremenatl cost =$2000)
C-WH-4	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 Btu)	Previous Proposed Federal Standard, August 9, 2000	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE)	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE and 250 gal/day) Base Use = 111.5 MMBTU	ACEEE, Emerging technologies and practices, 2004: W1 - pg 46.	Baseline = Rheem G50-98 (50gal, 98000 Btu, 80% therm. Eff.), $3,640 www.grainger.com + $2,340 average incremental cost +$240 installation cost (from Mike Sommer)
C-WH-5	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	GDS Calculation (Used .82 EF)	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 25.3 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Used average incremental cost from the following sources: Rheem Tankless Call Center - GT-199PVN-1, 200000 Btu .82EF, $1200, Baseline = Rheem 42VOS-40F (40 gallon, 40000btu, 0.59EF), $376.95.at https://keithspecialty.com/k/41-040.htm. - incremental installation cost $1,000 (http://www.buyerschoiceinspections.com/On-Demand-Water-Heaters); ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10 ($605 - $1635 incremental cost) Esource - http://www.esource.com/BEA/hosted/PNM/PA_29.html ($1,000 - $1,500):Rinnai Savings Calculator- http://www.foreverhotwater.com/index.php ($650 incremental cost);Tankless (Demand) Water Heaters Installation Case Study with Photos, Commentary, and Payback Calculator ($1150)
C-WH-6	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	GDS Calculation (Used .82 EF)	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 27.1 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Use Average Full Cost from the following sources: Baseline = Rheem 42VOS-40F (40 gallon, 40000btu, 0.59EF), $376.95.at https://keithspecialty.com/k/41-040.htm.+ Incremental measure cost + $240 (from Mike Sommer); Esource - http://www.esource.com/BEA/hosted/PNM/PA_29.html ($1,600 - $2,100);ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10 ($1470-$2500 full cost); Tankless (Demand) Water Heaters Installation Case Study with Photos, Commentary, and Payback Calculator ($2,400)

Commercial Measure Data SOURCES
Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-WH-7	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	GDS Calculation (Used .95 EF)	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 25.3 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Economy Plumbing and Heating Supply Co, Mattapan, MA - Navien CR240A, 200000 Btu .95 EF., $1375. This is $175 more expensive than the .82 EF Tankless. This increment is added to the Average Incremental cost for C-WH-5
C-WH-8	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	GDS Calculation (Used .95 EF)	FEMP Calculator for Electric & Gas Water Heaters (Assumes 64 gal/day) Base Use = 27.1 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Economy Plumbing and Heating Supply Co, Mattapan, MA - Navien CR240A, 200000 Btu .95 EF., $1375. This is $175 more expensive than the .82 EF Tankless. This increment is added to the Average full cost for C-WH-6
C-WH-9	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	Direct Final Rule: Energy Efficiency Program for Certain Commercial and Industrial Equipment: Test Procedures and Efficiency Standards for Commercial Water Heaters, Hot Water Supply Boilers and Unfired Hot Water Storage Tanks, Federal Register, October 21, 2004,	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE)	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 108.3 MMBTU	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Cost = Rinnai REU-V3237WC-ASME, 237000 Btu 85%TE, AccuAire in Reading, MA quoted approx. $2400 and $3640 installed. Baseline = 100gallon, 80000btu, 80%TE = Rheem G100-80 , $1878 @ www.simplyplumbing.com.
C-WH-10	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	Previous Proposed Federal Standard, August 9, 2000	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE)	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 111.5 MMBtu	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (15 yrs) Most other sources identify 20 years or more as the measure life. This includes: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis, April 1, 2008, p. 10; http://www.toolbase.org/Technology-Inventory/Plumbing/tankless-water-heaters; DOE -EERE - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12820.	Cost = Rinnai REU-V3237WC-ASME, 237000 Btu 85%TE, AccuAire in Reading, MA quoted approx. $2400 and $3640 installed.
C-WH-11	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	GDS Calculation	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 108.3 MMBTU	Efficiency Vermont Technical Reference Manual, p. 409. April 2008 Edition.	Survey of online sites show costs varying from $879.95 - $1806.13 (Pexsupply.com, simplyplumbing.com, ecomfortusa.com) + $600-$900 installation cost (http://hes.lbl.gov/hes/makingithappen/no_regrets/waterheatercombined.html) Baseline = $677.79 -Rheem 42V50-50F (http://www.standardplumbing.com/catalog.html?wscdet_show=0000000001101310 25#top) + $240 Installation cost (Mike Sommer); Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 ($1,418)

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-WH-12	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements	GDS Calculation	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 111.5 MMBtu	Efficiency Vermont Technical Reference Manual, p. 409. April 2008 Edition.	Survey of online sites show costs varying from $879.95 - $1806.13 (Pexsupply.com, simplyplumbing.com, ecomfortusa.com) + $600-$900 installation cost (http://hes.lbl.gov/hes/makingithappen/no_regrets/waterheater combined.html) Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 ($2796)
C-WH-13	Heat Recovery Water Heater	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	Therma-Stor Return on Investment calculation Form	Therma-Stor Return on Investment calculation Form - Restaurant with 80 gal/hr hot water use and 3 tons of refrigeration	REBUILDING FOR EFFICIENCY: Improving the Energy Use of Reconstructed Residences in South Florida; Danny Parker, Philip Fairey, Ross McCluney, Chris Gueymard, Ted Stedman, and Janet McIlvaine; Florida Solar Energy Center (FSEC), FSEC-CR-562-92 http://www.fsec.ucf.edu/en/publications/html/FSEC-CR-562-92/	Therma-Stor Return on Investment calculation Form
C-WH-14	Pipe wrap	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (See Note 2) Appendix C - RET ENERGY SAVINGS FRACTIONS	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE and 250 gal/day) Base Use = 111.5 MMBTU	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (See Note 3) Appendix C p 26(pdf)	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) Average Installed of 1" and 2" over 2"pipe ($6.51 per ln. ft.)
C-WH-15	Low flow shower head (1.5 GPM)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- FEMP: Energy Cost Calculator for Faucets & Shower Heads; Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (See Note 3) Appendix B p 27.	Prices for institutional/commercial low flow shower heads vary significantly depending on quality, featues and intended application (e.g. college dorm versus high end hotel One supplier's prices range from $24.95 to $99.95 -http://www.jet-streamshowerhead.net/products.html (Average price for all 1.5 gpm shower heads offered by this supplier =$60); Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) - Installation Cost = $16.74
C-WH-16	Faucet aerator	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Faucets & Shower Heads	US DOE- FEMP: Energy Cost Calculator for Faucets & Shower Heads; Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (See Note 3) Appendix B p 27	http://www.energyfederation.org/consumer/default.php/cPath/27_52_266
C-WH-17	Graywater Heat Exchanger/GFX	Business as usual	US DOE- Federal Energy Management Program (FEMP): Heat Recovery from Wastewater Using a Gravity-Film Heat Exchanger	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .96 TE and 250 gal/day) Base Use = 111.5 MMBTU	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (See Note 3)Appendix C p 26	'Assessment of Energy and Capacity Savings Potential in Iowa', Prepared for The Iowa Utility Association February 15, 2008. In Collaboration with Summit Blue Consulting, Nexant, Inc., A-TEC Energy Corporation, and Britt/Makela Group; Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix B p 40-44
C-WH-18	Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	US DOE- Federal Energy Management Program (FEMP): "How To Buy a Low Flow Pre-Rinse Spray Valve"	Food Service Technology Center, Pre-Rinse Spray Valve/Water Cost Calculator	Food Service Technology Center, Pre-Rinse Spray Valve/Water Cost Calculator	CEE Commercial Kitchens Initiative, Program Guidance on Pre-Rinse Spray Valves	http://www.webstaurantstore.com/t-s-b-0108-jetspray-pre-rinse-spray-valve/510B0108.html
C-WH-19	Circulation Pump Time Clocks	Business as usual	Energy Efficiency Potential of Gas-Fired Commercial Hot Water Heating Systems in Restaurants, An Emerging Technology Field Monitoring Study, FSTC Report 5011.07.04, Food Service Technology Center, April 2007, p1.	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 111.5 MMBtu	NYSERDA Deemed Savings Database, Rev 09-082006.	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) (assumed twice material cost to cover labor)

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-WH-20	Solar Water Heating w/gas auxiliary tank (SEF=1.5)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	US DOE - Energy Efficiency And Renewable Energy - Estimating a Solar Water Heater System's Cost	Gas Fired water Heater Screening Tool Esource - http://www.esource.com/BEA/demo/PDF/P_PA_41.pdf (Used .85 TE and 250 gal/day) Base use = 111.5 MMBtu	Energy Star, FEMP and EERE websites	Equipment Cost = $12,028 (Helio Pak Pro: 6 - 4x10 collectors - http://shop.solardirect.com/index.php?cPath=22_74_77_118_227%20(Helio%20Pak%20Pro%2012-15%20people, Serves 15 18 people or approximately 250 gal/day -RETScreen Energy Model) - Installed Cost $90-$120 per sq. ft of collector area: Solar Water Heating by Andy Walker, National Renewable Energy Laboratory, http://www.wbdg.org/resources/swheating.php, Last updated: 05-23-2008
ID	**Space Heating**					
C-SH-1	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	Energy Star Furnace Savings Calculator	GDS Calculation (Used .92 AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, measure efficiency difference, 92% vs. 90% and size 120,00 Btu vs. 80,000 Btu) Base Use = 266.2 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007, Appendix C pC-4.	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SH-2	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	SB estimate	GDS Calculation (Used .92 AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, measure efficiency difference, 92% vs. 90% and size 120,00 Btu vs. 80,000 Btu) Base Use = 276.9 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007, Appendix C pC-4.	Full cost ($1493) - Comfort Aire GLUA120E5B from www.grainger.com catalog. Full cost ($1735.20), Labor cost ($7.36/kbtuh) - Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008): Used Average Equipment Cost + Labor
C-SH-3	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	Energy Star Boiler Savings Calculator	GDS Calculation (used 85% AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston and size 210,000 Btu vs. 100,000 Btu) Base Use = 447.5 MMBtu	Conservative estimate based on various sources. 20 years used by Energy Star website. www.energystar.gov	Cost = Solaia SL6150 with Riallo burner 210mbtu 85.1%AFUE, $3000; Baseline = $1950 Carrier BW1AA 000210 (210mbtu, 80%) - JD Supply. NYSERDA Deemed Savings Database, Rev 09-082006 ($1,231), Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) ($756) - Used Average Incremental cost
C-SH-4	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	SB estimate	GDS Calculation (used 85% AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, Baseline efficiency difference (75% vs. 80%), and size 210,000 Btu vs. 100,000 Btu) Base Use =477.3 MMBtu	Conservative estimate based on various sources. 20 years used by Energy Star website. www.energystar.gov	Cost = Solaia SL6150 with Riallo burner 210mbtu 85.1%AFUE, $3000; Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) ($$4429)Installation Cost = $2100 - SB estimate - Used Average Full Equipment Cost
C-SH-5	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	Energy Star Boiler Savings Calculator	GDS Calculation (Used 95% AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, Baseline measure efficiency difference (95% vs. 85%), and size 210,000 Btu vs. 100,000 Btu) Base Use = 447.5 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007.	Cost = $3940 - http://www.pexsupply.com/product_dtl.asp?pID=11346&brand=Burnham&cID=1589, Burnham ALP210 (210000 Btu, AFUE 95%); Baseline = $2313 Hydrotherm R-210 210000 btu AFUE 80%.
C-SH-6	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	SB estimate	GDS Calculation (Used 95%)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, Baseline measure efficiency difference (95% vs. 85%), baseline efficiency difference (75% vs. 80%) and size 210,000 Btu vs. 100,000 Btu) Base Use =477.3 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007.	Cost = $3940 - http://www.pexsupply.com/product_dtl.asp?pID=11346&brand=Burnham&cID=1589, Burnham ALP210 (210000 Btu, AFUE 95%); Installation Cost = $2100 - SB estimate
C-SH-7	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	65136 Federal Register / Vol. 72, No. 222 / Monday, November 19, 2007 / Rules and Regulations	GDS Calculation (Used 82% AFUE)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for location -- Used Boston, assumed baseline and size 250 kBtu vs. 130 kBtu) Base Use = 925 MMBtu	Conservative estimate based on various sources. 20 years used by 2004-2005 California Database of Energy Efficient Resources.	Cost= Weil McLein EG65SPDN-S 250kbtu 82%AFUE, $3582; Baseline = Slant/Fin Model SE-210EDP 81.8% AFUE (Sentinel series) High Efficiency Hot Water Boiler 210000 BTU Natural Gas, AFUE 80%, $2553 (could not find a 75% AFUE steam boiler - Non listed in GAMA Product directory); NYSERDA Deemed Savings Database, Rev 09-082006 ($3,551.60);

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-SH-8	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR COMMERCIAL AND INDUSTRIAL EQUIPMENT: EFFICIENCY STANDARDS FOR COMMERCIAL HEATING, AIR CONDITIONING, AND WATER HEATING EQUIPMENT, 7/9/2008, U.S. DOE, Office of Energy Efficiency and Renewable Energy Building Technologies Program -Appliances and Commercial Equipment Standards	GDS Calculation (Used 87% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 2884.6 MMBtu	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Cost = $25500 - Raypak H7-1503 (87% Therm.Eff., 1500 mbtu), Baseline = PB Heat 211A-08 (78%Therm Eff, 1470 mbtu) $16390
C-SH-9	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	GDS Calculation (Used 87% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 3000 MMBtu	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Cost = $25500 - Raypak H7-1503 (87% Therm.Eff., 1500 mbtu), Baseline = PB Heat 211A-08 (78%Therm Eff, 1470 mbtu) $16390, Installation Cost = $9.30/kBtuh - Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SH-10	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR COMMERCIAL AND INDUSTRIAL EQUIPMENT: EFFICIENCY STANDARDS FOR COMMERCIAL HEATING, AIR CONDITIONING, AND WATER HEATING EQUIPMENT, 7/9/2008, U.S. DOE, Office of Energy Efficiency and Renewable Energy Building Technologies Program -Appliances and Commercial Equipment Standards	GDS Calculation (Used 90% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 2884.6 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007.	Cost = $27409 - Laars Model RHHH1600 (90% Combustion Efficiency - There is very little difference in combustion and thermal efficiency for this size boiler) - Baseline = PB Heat 211A-08 (78%Therm Eff, 1470 mbtu) $16390
C-SH-11	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	GDS Calculation (Used 90% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 3000 MMBtu	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007.	Cost = $27409 - Laars Model RHHH1600 (90% Combustion Efficiency - There is very little difference in combustion and thermal efficiency for this size boiler); Installation Cost = $9.30/kBtuh - Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SH-12	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	GAMA	FEMP - Energy Cost Calculator for Commercial Boilers (81.9% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 2884.6 MMBtu	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	NYSERDA Deemed Savings Database, Rev 09-082006, adjusted for boiler size.
C-SH-13	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	GDS Calculation (Used 81.9% TE)	FEMP - Energy Cost Calculator for Commercial Boilers (1500 mbtu) Base Use = 3000 MMBtu	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Full Cost = $15697 - Smith 28HE S/W 05 (1500mbtu, 81.9% Therm.Eff). Installation Cost = $9.91/kBtu - Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SH-14	Insulate and Seal Ducts (New Aerosl Duct Sealing)	Business as usual	Improved Duct Sealing, ASHRAE Journal, May 2003	GDS Calculation (Assumes 710.46 MMBTU base use)	NYSERDA Deemed Savings Database, Rev 09-082006.	Large Building Duct Sealing, Mark Modera, Carrier Aerosol, August 6, 2007 ($.625/sq. ft.)
C-SH-15	Insulate Unconditioned Basement/Crawl Space Piping (This is covered by water heating and boiler pipe insulation measures)					
C-SH-16	Gas Unit Heater - Power Vented/IID - Eliminating gravity-vented units is already underway, since power vented units had a 45% market share in 2002. (consider power vented units as the baseline).					
C-SH-17	Gas Unit Heater - Condensing (AFUE =93%)	DOE - FY 2005 Technical Support Document, Appendix A - http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/fy05_priority_setting_app_a.pdf, p. 13-2	DOE - Savings Analysis Spreadsheet - www1.eere.energy.gov/buildings/appliance_standards/commercial/docs/doe_heaters.xls-	GDS Calculation assuming 220kBtu, 80% AFUE unit with 14.6% dusty cycle - Base Use =351.7 MMBtu	Unit Heaters Deserve Attention for Commercial Programs, Harvey Sachs, April 2003, Report # A031, ACEEE: http://www.aceee.org/pubs/a031full.pdf	NYSERDA Deemed Savings Database, Rev 09-082006. $12000 per million Btu applied to unit size of 220 MMBtu
C-SH-18	Infrared Heater (low intensity - two stage)	DOE - FY 2005 Technical Support Document, Appendix A - http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/fy05_priority_setting_app_a.pdf, p. 13-2	http://www.buildings.com/articles/detail.aspx?contentID=6218,What Gas-Fired Infrared Heating Has to Offer, July 2008	GDS Associates, GasNetworks Measure Assumptions Update, 2008 (Base Use = 239.8 MMBtu, assuming 150kBtu, 80% AFUE unit with 14.6% dusty cycle)	Massachusetts Market Transformation Scoping Study, Arthur D. Little, 1997. Table 3-5b	NYSERDA Deemed Savings Database 2006, Based on incremental cost of $6,320/Million Btuh and assumed 150 MBtuh heater.
C-SH-19	Stack Heat Exchanger (Standard Economizer)	Business as usual	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Economizers.asp	105 MMBtu per million Btu/hr of the boiler size adjusted to account for HDD difference (NYSERDA Deemed Savings Database, Rev 09-082006)	NYSERDA Deemed Savings Database, Rev 09-082006.	NYSERDA Deemed Savings Database, Rev 09-082006. ($1,500 per MMBTu of boiler size)

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-SH-20	Stack Heat Exchanger (Condensing Economizer)	Business as usual	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Flue_Condensers.asp	GDS Calculation	NYSERDA Deemed Savings Database, Rev 09-082006.	http://www.federalcorp.com/tech/economizer.PDF ($2120/MMBtu)
C-SH-21	Heat Recovery from Air to Air	Business as usual	GDS Energy-10 simulation	GDS Calculation (Base Use = 710.4MMBtu)	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Establishing Benchmarks for DOE Commercial Building R&D and Program Evaluation, M. Deru, B. Griffith, and P. Torcellini, ACEEE Summer Study, August 14−18, Conference Paper, NREL/CP 550-39834, Jun-06 (.105 CFM/ft2)/Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) ($4.68 per Supply CFM)
C-SH-22	Ceiling Insulation (to R-24) (Included in Improved Roof/Ceiling Insulation Under Building Shell Measures)					
C-SH-23	Boiler Heating Pipe Insulation	Business as usual	GDS Calculation (Assumes 710.46 MMBTU base use)	NYSERDA Deemed Savings Database, Rev 09-082006 (assumes .691 MMBtu per lin. Ft. of pipe and 25' of pipe)	NYSERDA Deemed Savings Database, Rev 09-082006.	NYSERDA Deemed Savings Database, Rev 09-082006, $9.71/lin. Ft. (Assume 25 ft.)
C-SH-24	Boiler Tune-Up	Business as usual	GasNetworks estimate provided by Mike Pace, NGRID	Natural Gas Efficiency and Conservation Measure Resource Assessment for the Residential and Commercial Sectors, Prepared for the Energy Trust of Oregon by Ecotope, Inc, August 2003 (.02 therms/sf/yr assuming average 19,253 sq. ft)	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003 Appendix D.	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003; Questar 2006 DSM Market Characterization Report, Nexant, Appendix D (sqft) & E (cost/sqft).
C-SH-25	Boiler Reset Controls	Business as usual	http://www.energysolutionscenter.org/BoilerBurner/Eff_Improve/Efficiency/Boiler_Reset_Control.asp	GDS Calculation (Assumes 710.46 MMBTU base use)	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SH-26	Boiler O2 Trim Controls	Business as usual	Natural Gas Boiler/Burner Consortium - http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for HDD difference) Base use = 4701 MMBTU	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	NYSERDA Deemed Savings Database, Rev 09-082006
C-SH-27	Electronic Parallel Positioning Controls (linkage less)	Business as usual	Natural Gas Boiler/Burner Consortium - http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for HDD difference) Base use = 4701 MMBTU	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	Knauf, Regional Sales Manager for Preferred Instruments (Lenox, MA)
C-SH-28	Boiler blowdown heat exchanger (steam)	Business as usual	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers - (baseline calculation assuming 11,700 MBtu/h)	NYSERDA Deemed Savings Database, Rev 09-082006 (NYSERDA data adjusted to account for HDD difference)	NYSERDA Deemed Savings Database, Rev 09-082006.	NYSERDA Deemed Savings Database, Rev 09-082006
C-SH-29	Repair/Replace malfunctioning steam traps	Business as usual	Found a wide range (4% - 16%) of savings estimates based on literature review Used a mid-range savings estimate factor of 10%	NYSERDA Deemed Savings Database, Rev 09-082006 (Pipe insulation savings = .691/ln. ft)	East Coast Industries, Inc. Steam Trap Testing / Airborne UT, http://www.eci-ndt.com/airborne-ut-steam-trap-testing.html	Cost of the most common type of steam trap (Inverted bucket trap) according to Grainger catalog ranges from $100 - $137, plus one hour of labor @ $100/hr.
C-SH-30	Insulate steam lines/condensate tank	Business as usual	5% - 10% improvement in energy associated with losses (Optimizing Steam Systems: Saving Energy and Money in Mexican Hotels, by David Jaber, Alliance to Save Energy) GDS estimates that poor insulation represents 15%- 20% of total gas input	Represents savings associated with insulating 100' of 2" steam pipe @15psig and condensate tank	NYSERDA Deemed Savings Database, Rev 09-082006.	100 ln. feet @ $8.02/ln. ft installed - Installed cost from Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) Plus condensate tank insulation $500(www.engr.udayton.edu/udiac/Documents/ProcHeat_Insulation.doc)

Commercial Measure Data SOURCES
Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-SH-31	Destratification Fans (HVLS)	Business as usual	Review of various internet sites including SMUD Energy Library, Big Ass Fan Company and Energy Wales (savings range 15%-30%)	Correspondence with Big Ass Fans - Calculation based on warehouse average square footage (23,431), 80% heating efficiency, U-value of 0.2, 15 degrees F delta T, and annual heating hours of 2500 as per ARI Unitary Directory, 1992	Measure Life Report, New England State Program Working Group (SPWG) Reference Document for the ISO Forward Capacity Market (FCM), GDS Associates, June 2007/Oregon State Energy Efficiency Design Program, Guidelines for Oregon Administrative Rules, Chapter 330, Division 130, 1/2006	Installed cost of 2 fan based on discussion with Kevin Young, Big Ass Fans (5-8k cost of fan plus 3-4k per fan installation.
C-SH-32	Exhaust Hood Makeup Air	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 - Appendix C -MD ENERGY SAVINGS FRACTIONS	Gas Solutions for the Foodservice Industry, http://www.gfen.info/pdf/cookinggas0107.pdf	Commercial UI/CL&P C&LM Program Savings Documentation -2007 Table 1.4 C&I Lifetimes, Pg 222-224	Greenheck sales representative cost and measure life information on 5,000 CFM model. ($4,500 materials, $1,000 labor, and $400 crane rental (to lift onto roof))
C-SH-33	Optimizing Kitchen Ventilation (Customized optimization strategies that are site specific - very difficult to quantify typical savings.)					
C-SH-34	Exhaust Hood - Demand Ventilation	Business as usual	Flex Your Power, Demand Ventilation Control Reduces Kitchen Fan Energy Consumption by 50% to 70% and makeup air heating energy by 25%: http://www.fypower.org/news/?p=682	GDS Calculation (based of 7500 cfm, 70% make-up air rate)	http://www.melinkcorp.com/products.html	CFS: Energy Star Best Practices tool for full-service restaurants http://www.energystar.gov/index.cfm?c=commercial_food_service.commercial_food_service
C-SH-35	Demand Controlled Ventilation	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C - RET ENERGY SAVINGS FRACTIONS. (Average across all building types - varies significantly based on occupancy and ventilation requirements)	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p 102. (assumes 50,000 sq. ft. office building with 6 control points) - National Estimate Adjusted by GDS to be Northeast specific	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004, p 102.	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 (6 zones at $575 per zone) p 102.
C-SH-36	Direct Gas-Fired AHU (92% Efficient)	HPAC Engineering, Direct Gas-Fired Air-Handling Units, Sep 23, 2008, By Vincent A. Sakraida, PE, LEED AP	HPAC Engineering, Direct Gas-Fired Air-Handling Units, Sep 23, 2008, By Vincent A. Sakraida, PE, LEED AP			Direct Gas-Fired Air-Handling Units Sep 1, 2008 12:00 PM, By VINCENT A. SAKRAIDA, PE, LEED AP Jacobs Global Building Denver, Colo. Smaller (less than 5,000 cfm) direct gas-fired AHUs have equipment costs similar to those of indirect gas-fired AHUs. As their sizes increase, direct gas-fired AHUs become progressively cheaper. AHU equipment costs are lower for units with electric heat, hot-water heat, and steam because they do not have burner-management systems. Regarding auxiliary support equipment and required infrastructure, direct and indirect gas-fired AHUs only require gas piping. Steam systems require steam boilers, condensate-return systems, makeup-water systems, chemical-treatment systems, steam-distribution systems, combustion-air systems, flues, and gas piping. Hot-water heating systems require hot-water boilers, hot-water distribution piping and pumps, makeup-water systems, chemical-treatment systems, flues, and gas piping. Electric systems need only electrical service. Taking an AHU and all of its associated auxiliary equipment into account, a direct gas-fired AHU has one of the lowest installation costs.
ID	**Space Conditioning**					

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-SC-1	Desiccant Dehumidifier/Air Conditioner	Mike Bell, United Engineering	Not Applicable	Mike Bell, United Engineering (1.3 COP 72,000 BTU per 1000 cfm Desiccant System). Would also need 5 ton AC unit = 3.75kW of additional cooling.	User Guide for Desiccant User Guide for Desiccant Dehumidification Technology By Thomas E. Durbin and Michael A. Caponegro U.S. Army Construction Engineering Research Laboratories Champaign, IL 61826-9005	Desiccant dehumidifiers = 10000cfm @ $10 cfm (unit only) = $100000, @$20/cfm installed = $200000 (Inotes: 3 air changes/hr): source: Mike Bell - United Engineering. He suggested that they probably wouldn't be used in a commercial setting for comfort conditions due to the massive amounts of heat they produce. Electric AC costs (9 EER) = $469.28 (Material) + $151.37 (Labor) per ton - Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008)
C-SC-2	High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	Emerging Technologies and Practices, 2004, ACEEE	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 - 10 ton unit	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p 62.	http://www.aceee.org/pubs/a042_h16.pdf
C-SC-3	Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	Business as usual	http://www.gasairconditioning.org/payback_calculator.htm	http://www.gasairconditioning.org/payback_calculator.htm (400 tons, 729 Full Load Cooling Hours)	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008, p6.	http://www.gasairconditioning.org/payback_calculator.htm
C-SC-4	Engine-Driven Chiller w/ heat recovery	Business as usual	http://www.gasairconditioning.org/payback_calculator.htm	http://www.gasairconditioning.org/payback_calculator.htm (400 tons, 729 Full Load Cooling Hours)	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008 p 6.	http://www.gasairconditioning.org/payback_calculator.htm
C-SC-5	Double-Effect Absorption Chiller (1.03 COP)	http://www.gasairconditioning.org/payback_calculator.htm	http://www.gasairconditioning.org/payback_calculator.htm	http://www.gasairconditioning.org/payback_calculator.htm (400 tons, 729 Full Load Cooling Hours)	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008 p 6.	http://www.gasairconditioning.org/payback_calculator.htm
C-SC-6	Double-Effect Absorption Chiller (1.03 COP)	Business as usual	http://www.gasairconditioning.org/payback_calculator.htm	http://www.gasairconditioning.org/payback_calculator.htm (400 tons, 729 Full Load Cooling Hours)	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008, p 6.	http://www.gasairconditioning.org/payback_calculator.htm
ID	**Space Heating-Conditioning**					
C-SHC-1	Packaged Absorption Chiller/Heater w/fan coil	Business as usual		ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 - savings per 10 ton unit p 92.	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008 p 6.	Clover Corp. ,MA, Brian Cullinane (40 ton unit, $81000) - Installation cost of $201.26/ton from Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008); Electric HVAC cost from DEER 2008 $626.93(material), $152.05 (labor) per ton
C-SHC-2	Gas Fired Absorption Heat Pump	Business as usual		ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 (Scaled up Residential 5 ton unit estimates) p.92.	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p 92.	Clover Corp. ,MA, Brian Cullinane (40 ton unit, $80000) - Installation cost of $201.26/ton from Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008); Electric HVAC cost from DEER 2008 $626.93(material), $152.05 (labor) per ton
C-SHC-3	Direct-Fired Absorption Chiller/Heater (double effect)	Business as usual	15.7% more efficient heating (assumes increase in TE from .78 to .925)	http://www.gasairconditioning.org/payback_calculator.htm (400 tons, 729 Full Load Cooling Hours)	REPORT TO BALTIMORE GAS & ELECTRIC DEMAND-SIDE MANAGEMENT PROGRAM REVISED BENEFIT/COST ANALYSIS, Summit Blue Consulting, January 2008, p 6.	http://www.gasairconditioning.org/payback_calculator.htm
ID	**On-Site Generation**					
C-OSG-1	Micro Turbine	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p144.	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p144.	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004, p 144. - for 100, 000 sq. ft office building	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004 p144.	Emerging Technologies and Practices, 2004,p 144. ACEEE - 200 kW Micro-Turbine at $1750/kw (2003$) inflated to 2009$ - Report also indiactes that there are additional maintenance and overhaul costs of $30,784 (2003 $)
C-OSG-2	Micro-CHP	Freewatt Demonstration Program Report (2006-2007 Home Heating Seson), pp. 9-10 (Effeciency of replaced equipment in demonstration project was not identified in the report)	Freewatt Demonstarion Program Report (2006-2007 Home Heating Seson), p. 10	Freewatt Demonstarion Program Report (2006-2007 Home Heating Seson), p. 10 (kWh savings from p.8)	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004, p 144.	EPA Technical Adoption Plan - Residential Cogeneration, Market Barriers Section
ID	**Cooking**					
C-Ck-1	High Efficiency Gas Griddle	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Energy Star - Commercial Food Services Equipment Best Practices Tool (http://www.energystar.gov/index.cfm?c=commercial_food_service.commercial_food_service)
C-Ck-2	High Efficiency Gas Combination Oven	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	NYSERDA Deemed Savings Database, Rev 09-082006.
C-Ck-3	High Efficiency Gas Convection Oven	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	NYSERDA Deemed Savings Database, Rev 09-082006.

Commercial Measure Data SOURCES
Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-Ck-4	High Efficiency Gas Conveyer Oven	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Questar 2006 DSM Market Characterization Report, Nexant, Appendix E
C-Ck-5	High Efficiency Gas Rack Oven	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	GDS Estimate based on typical $2000 incentive and assumption that this represents 50% of incremental cost
C-Ck-6	High Efficiency Gas Broiler	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	Food Service Technology Center - Life Cycle Cost Calculator	NYSERDA Deemed Savings Database, Rev 09-082006.
C-Ck-7	Power Burner Range	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003	http://www.fishnick.com/equipment/techassessment/5_range_tops.pdf	http://www.fishnick.com/equipment/techassessment/5_range_tops.pdf (Applied Savings factor to median annual use of 120 MMBtu for 6 burner range top)	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003	NYSERDA Deemed Savings Database, Rev 09-082006.
C-Ck-8	High Efficiency Fryer	Food Service Technology Center - Life Cycle Cost Calculator	burners found on conventional cooktop ranges and conventional fryers.	Food Service Technology Center - Life Cycle Cost Calculator	GDS Associates, GasNetworks Measure Assumptions Update, 2008	Energy Star - Commercial Food Services Equipment Best Practices Tool (http://www.energystar.gov/index.cfm?c=commercial_food_service.commercial_food_service)
C-Ck-9	High Efficiency Gas Steamer	Food Service Technology Center - Life Cycle Cost Calculator	Energy Star:http://www.energystar.gov/index.cfm?c=steamcookers.pr_steamcookers	Energy Star:http://www.energystar.gov/index.cfm?c=steamcookers.pr_steamcookers	Food Service Technology Center - Life Cycle Cost Calculator	NYSERDA Deemed Savings Database, Rev 09-082006.
ID	**Space & Water Heating**					
C-SWH-1	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65137	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Set to water heater lifetime	Costs and savings add up similar separate equipment from water heating tab and space heating tab. Literature claims combined system equipment costs are higher, installation costs lower compared to separate systems.
C-SWH-2	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	For water heater, Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater under previous (1991) code requirements. For boiler, Engineering Judgment -- EPACT 1992 created 80 AFUE minimum. Retrofit, non-ROB, are going to be a mix of post-1992 and pre-1992 units, which had AFUEs in the 65-70 range. 75 AFUE is a reasonable conservative assumption. If only old equipment (>20 years) is being replaced, then a lower AFUE can be justified.	Above + delta Baseline calc	Above + delta Baseline calc	Set to water heater lifetime	See Cost Source for C-SWH-1
C-SWH-3	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65138	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Set to same as typical boilers	See Cost Source for C-SWH-1
C-SWH-4	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	See Baseline Source for C-SWH-2	Above + delta Baseline calc	Above + delta Baseline calc	Set to same as typical boilers	See Cost Source for C-SWH-1
C-SWH-5	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	Federal Code: FR66/11/Jan 17, 2001, p 4497, based on 40 gallon gas storage water heater,FR66/11/Nov 19, 2007, p. 65139	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	SB calc; SB SH HVAC Analysis Tab and SB DHW Analysis Tab	Set to same as typical boilers	See Cost Source for C-SWH-1
C-SWH-6	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	See Baseline Source for C-SWH-2	Above + delta Baseline calc	Above + delta Baseline calc	Set to same as typical boilers	See Cost Source for C-SWH-1
ID	**Building Envelope**					
C-BE-1	Double Glazing Low Emissivity Windows	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C - MD ENERGY SAVINGS FRACTIONS	GDS Calculation (Assumes 710.46 MMBTU base use)	NYSERDA Deemed Savings Database, Rev 09-082006.	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) - Incremental cost ($3.04 sq. ft of window area) Assumes 8360 sq. ft of exterior wall area that is approximately 30% window area)

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-BE-2	Triple Glazing Low Emissivity Windows	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C - MD ENERGY SAVINGS FRACTIONS	GDS Calculation (Assumes 710.46 MMBTU base use)	NYSERDA Deemed Savings Database, Rev 09-082006.	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) - Incremental cost ($ 5.03sq. ft of window area) Assumes 8360 sq. ft of exterior wall area that is approximately 30% window area)
C-BE-3	Improved Wall Insulation (to R12)	SB Estimate	GDS Calculation (Assumes 710.46 MMBTU base use)	GDS Calculation (Assumes 8360 sq, ft of exterior wall area)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf)	Assumes that improved wall area is 4.2 times that of SF Home
C-BE-4	Improved Roof/Ceiling Insulation (to R32)	SB Estimate	GDS Calculation (Assumes 710.46 MMBTU base use)	GDS Calculation (Assumes 4214 sq, ft of roof/ceiling improved)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf)	Revised DEER Measure Cost Summary (05_30_2008) Revised (06_02_2008) - $1.04 sq. ft.
C-BE-5	Improved Below-Grade Insulation (to R6)	Business as usual	GDS Calculation (Assumes 710.46 MMBTU base use)	GDS Calculation (Assumes 2191 sq, ft of below grade area is improved)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf)	Assumes that improved below grade insulation area is 4.2 times that of SF Home
C-BE-6	Air Sealing	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C - RET ENERGY SAVINGS FRACTIONS	GDS Calculation (Assumes 710.46 MMBTU base use)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf)	Assumes that area sealed is 4.2 times that of SF Home
C-BE-7	Integrated Building Design, Envelope Only (30% > code)	Business as usual	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004
ID	**HVAC Controls**					
C-CN-1	EMS install	Business as usual	Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential, TIAX LLC, July 2002 (26% - Office Heating)p.A-22, GDS Estimates (18.6% - Weighted Avg. All Buildings) - Used 20%	GDS Calculation (Assumes 1136.7 MMBTU base use)	Keyspan Energy, 2004. Program data provided via email.	Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential, TIAX LLC, July 2002, pA-22. $1 - $4 per sq. ft - Assumed building that is 60% larger than average building
C-CN-2	EMS Optimization	Business as usual	Many existing System exhibit subpar performance. very site and system dependent. Energy Consumption Characteristics of Commercial Building HVAC Systems Volume III: Energy Savings Potential, TIAX LLC, July 2002 (design savings total =5%-15%, 5% more realistic for unoptimized system), GDS Estimates from PNM Study (5.2% - Weighted Avg. All Buildings) - Used 5%	GDS Calculation (Assumes 1136.7 MMBTU base use)	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003 Appendix D.	$.06/sq. ft * 28975 sq. ft. (approximately 60% larger than weighted average building size) - Energy Efficiency and Renewable Energy Resource Development Potential in New York State - Final Report, Volume 5 Energy Efficiency Technical Appendices, August 2003. GDS Estimate = .$.12/sq. ft. (actual cost is highly site and system dependent) Used $.09/sq. ft.
C-CN-3	Zoning	Business as usual	SBC Estimate	GDS Calculation (Assumes 710.46 MMBTU base use)	Natural Gas Efficiency and Conservation Measure Resource Assessment for the Residential and Commercial Sectors, Prepared for the Energy Trust of Oregon by Ecotope, Inc, August 2003 p19 & 75.	http://www.toolbase.org/Technology-Inventory/HVAC/hvac-smart-zoning-controls

Commercial Measure Data SOURCES

Table B-2L

	Commercial Measures	Baseline Source	Savings Factor Source	Annual Savings Source	Measure Life Source	Cost Source
C-CN-4	Retrocommissioning	Business as usual	ACEE, Emerging Energy Saving Technologies & Practices for the Buildings Sector, 2004, p156.	GDS Calculation (Assumes 710.46 MMBTU base use)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf)	$.17/sq. ft. Quantum Consulting - Pilot program experience from Oakland CA per email communication from Mike Rufo on 2/3/04; American Council for an Energy Efficient Economy (ACEEE), Selecting Targets for Market Transformation Programs: A National Analysis, 1998 http://www.aceee.org/pubs/u981.htm
C-CN-5	Commissioning	Business as usual	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Appendix C MD ENERGY SAVINGS FRACTIONS	GDS Calculation (Assumes 1136.7 MMBTU base use)	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix C p 26(pdf).	$.55/sq. ft. * 28,975 sq. ft. (approximately 60% larger than weighted average building size) - The Costs and Benefits of LEED-NC in Colorado, Prepared for the Governor's Office of Energy Management and Conservation by Enermodal Engineering, Inc., October 25, 2006
C-CN-6	Programmable Thermostat	Business as usual	Energy Star Furnace Savings Calculator/Energy Star Boiler Savings Calculator	GasNetworks Aug08update - "Validating the Impacts of Programmable Thermostats." GasNetworks, January 2007. Figure in report is 7.5 ccf per installed thermostat. Converting this to MMBtu yields 7.7.	The New England State Program Working Group Residential and Commercial/Industrial Measure Life Report for the ISO forward capacity market, June 2007. Appendix C pC-5.	GasNetworks Aug08update - Energy Star Cost Calculator, Energy Star Website, www.energystar.gov. Based on Industry data for 2008.
ID	**Laundry**					
C-L-1	Wastewater, Filtration/Reclamation		http://www.aquarecycle.com/laundry-water-energy-savings.php	Gene Dedick - East Coast VP Sales - AquaRecycle - ph: 210-325-9258: 1,248,000 lbs/yr = 30 gpm washer-extractor system with lint shaker.	Commercial Laundry Conservation Technologies - Bill Hoffman, James Riesenberger	Gene Dedick - East Coast VP Sales - AquaRecycle - ph: 210-325-9258: 1,248,000 lbs/yr = 30 gpm washer-extractor system with lint shaker.
C-L-2	Ozone Commercial Laundry System (Gas HW)		Commercial Laundry Conservation Technologies, Bill Hoffman, James Riesenberger	Trevor Brown Southeastern Laundry/Commercial Laundry Conservation Technologies - Bill Hoffman, James Riesenberger	Commercial Laundry Conservation Technologies, Bill Hoffman, James Riesenberger	Trveor Brown Southeastern Laundry/Commercial Laundry Conservation Technologies - Bill Hoffman, James Riesenberger
C-L-3	High Efficiency Clothes Washer	http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers	Energy Star Commercial Clothes Washer Savings Calculator	Energy Star Commercial Washer Savings Calculator	Energy Star Commercial Washer Savings Calculator	Energy Star Commercial Washer Savings Calculator
ID	**Pool Water Heating**					
C-PWH-1	High Efficiency (95%) Gas Pool Water Heater	US DOE - Energy Efficiency And Renewable Energy - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13170	http://www.rlmartin.com/rspec/factsheets/heaters.htm - GDS Calculation	US DOE, EERE website, Gas Swimming Pool Heaters - Boston location with pool cover	Set to Boiler Lifetime	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003 Appendix D (sqft) & E (cost/sqft); RS Means CostWorks 2005, construction cost estimating database for Albequerque (GDS Gas Potential study for PNM)
C-PWH-2	Pool Cover	Business as usual	US DOE, EERE website, Gas Swimming Pool Covers	http://www.covers4pools.co.uk/acatalog/commercial_pools.html; http://www.pooltechnics.com/Upload/ENGELS/Openbare%20baden/AfdekkingenEng.pdf	CA-NGStudy: California Statewide Commercial Sector Natural Gas Energy Efficiency Potential Study, Vol. 2, pgs. C.1-1, C.4-6.	AmeriMerc.com, commercial pool supplies (1000 sq. ft pool)
C-PWH-3	Solar pool heater	US DOE - Energy Efficiency And Renewable Energy - http://apps1.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=13170		GDS Calculation - assumes pool with pool cover	ES Analysis-ResDWH: ENERGY STAR® Residential Water Heaters: Final Criteria Analysis (www.energystar.gov). April 2008.	Actual average project cost provided by NGRID for NY projects

Appendix B-3

Commercial Sector Factor Data

The tables in Appendix B-3 contain the measure factor data including the base case, remaining and convertible factors for the measures included in the analysis of energy efficiency potential. Factor data is shown by end-use and measure for 9 commercial business types: warehouse, retail, grocery, office, lodging, health, restaurant, education and other.

- The **base-case factor** is the fraction of the end use gas energy that is applicable for the efficient technology in a given market segment.
- The **remaining factor** is the fraction of applicable dwelling units that have not yet been converted to the gas efficiency measure, i.e. one minus the fraction of households that already have the high-efficiency measure installed.
- The **convertible factor** is the fraction of the applicable dwelling units that is technically feasible for conversion to the efficient technology from an engineering perspective.

Appendix B-3 includes the following tables:

Table B-3a: Commercial Sector – Base Case Factors

Table B-3b: Commercial Sector – Remaining Factors

Table B-3c: Commercial Sector – Convertible Factors

Table B-3a

GasNetworks Energy Efficiency Potential Study - Commercial Sector: Base Case Factor

Base Case Factor is the fraction of the end use energy that is applicable for the efficient technology in a given market segment. For example, for a faucet aerator, this would be the fraction of all water heating use that is associated with faucets.

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Notes
100		**Water Heating End Use**										
C-WH-1	Water Heating	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	10%	10%	10%	10%	10%	10%	10%	10%	10%	Water heating load is split 50/50 between small and large water heaters and then spilt equally between competing measures.
C-WH-3	Water Heating	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 but)	17%	17%	17%	17%	17%	17%	17%	17%	17%	
C-WH-5	Water Heating	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
C-WH-7	Water Heating	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
C-WH-9	Water Heating	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	17%	17%	17%	17%	17%	17%	17%	17%	17%	
C-WH-11	Water Heating	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	17%	17%	17%	17%	17%	17%	17%	17%	17%	
C-WH-13	Water Heating	Heat Recovery Water Heater	15%	0%	100%	0%	20%	0%	50%	0%	0%	All factors except Warehouse: Source is GDS estimate. Refrigerated warehouse represent about 15% of the industry (Hoovers website, Industry Overview, Warehousing & Storage)
C-WH-14	Water Heating	Pipe wrap	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-WH-15	Water Heating	Low flow shower head (1.5 GPM)	0%	0%	0%	0%	20%	2%	0%	33%	13%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table
C-WH-16	Water Heating	Faucet aerator	60%	60%	5%	50%	5%	15%	5%	15%	26%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table
C-WH-17	Water Heating	Graywater Heat Exchanger/GFX	2%	0%	0%	2%	20%	2%	50%	33%	13%	
C-WH-18	Water Heating	Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	0%	0%	10%	0%	2%	2%	15%	2%	0%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table
C-WH-19	Water Heating	Circulation Pump Time Clocks	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-WH-20	Water Heating	Solar Water Heating w/gas auxiliary tank (SEF=1.5)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
C-L-1	Water Heating	Wastewater, Filtration/Reclamation	0%	0%	0%	0%	17%	8%	0%	0%	8%	
C-L-2	Water Heating	Ozone Commercial Laundry System (Gas HW)	0%	0%	0%	0%	17%	8%	0%	0%	8%	
C-L-3	Water Heating	Energy Star Clothes Washer	0%	0%	0%	0%	17%	8%	0%	0%	8%	
C-PWH-1	Water Heating	High Efficiency (95%) Gas Pool Water Heater	0%	0%	0%	0%	17%	10%	0%	35%	0%	
C-PWH-2	Water Heating	Pool Cover	0%	0%	0%	0%	6%	8%	0%	18%	0%	EIA CBECS data percent distrubuted water heating systens by building activity
C-PWH-3	Water Heating	Solar pool heater	0%	0%	0%	0%	17%	10%	0%	35%	0%	
200		Space & Water Heating			**Space & Water Heating**							
C-SWH-1	Space & Water Heating	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	10%	10%	10%	10%	10%	10%	10%	10%	10%	Water heating load is split 50/50 between small and large water heaters and then spilt equally between competing measures.
C-SWH-3	Space & Water Heating	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
C-SWH-5	Space & Water Heating	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
300		**Building Envelope**										
C-BE-1	Building Envelope	Double Glazing Low Emissivity Windows	50%	50%	50%	50%	50%	50%	50%	50%	50%	
C-BE-2	Building Envelope	Triple Glazing Low Emissivity Windows	50%	50%	50%	50%	50%	50%	50%	50%	50%	
C-BE-3	Building Envelope	Improved Wall Insulation (to R12)	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-BE-4	Building Envelope	Improved Roof/Ceiling Insulation (to R32)	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-BE-5	Building Envelope	Improved Below-Grade Insulation (to R6)	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-BE-6	Building Envelope	Air Sealing	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-BE-7	Building Envelope	Integrated Building Design, Envelope Only (30% > code)	100%	100%	100%	100%	100%	100%	100%	100%	100%	
600		**HVAC Controls**										
C-CN-1	HVAC Controls	EMS install	36%	36%	36%	36%	36%	36%	36%	36%	36%	GDS Estimate - NH Study
C-CN-2	HVAC Controls	EMS Optimization	7%	7%	7%	7%	7%	7%	7%	7%	7%	GDS Estimate - NH Study
C-CN-3	HVAC Controls	Zoning	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-CN-4	HVAC Controls	Retrocommissioning	42%	42%	42%	42%	42%	42%	42%	42%	42%	EIA, 2003 CBECS, Table C31A, Northeast NG Consumption in Buildings! >100k sq. ft.
C-CN-5	HVAC Controls	Commissioning	42%	42%	42%	42%	42%	42%	42%	42%	42%	EIA, 2003 CBECS, Table C31A, Northeast NG Consumption in Buildings! >100k sq. ft.
C-CN-6	HVAC Controls	Programmable Thermostat	14%	24%	61%	23%	6%	5%	60%	12%	20%	Small Commercial Only (<=10,000 sq. ft.) based on EIA CBECS gas consumption and sq, ft data by building size and activity
700		**Space Conditioning**										
C-SC-1	Space Conditioning	Desiccant Dehumidifier/Air Conditioner	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-SC-2	Space Conditioning	High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	54%	54%	54%	54%	54%	54%	54%	54%	54%	
C-SC-3	Space Conditioning	Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	23%	23%	23%	23%	23%	23%	23%	23%	23%	
C-SC-4	Space Conditioning	Engine-Driven Chiller w/ heat recovery	100%	100%	100%	100%	100%	100%	100%	100%	100%	
C-SC-5	Space Conditioning	Double-Effect Absorption Chiller (1.03 COP)	23%	23%	23%	23%	23%	23%	23%	23%	23%	
800		**Cooking**										
C-Ck-1	Cooking	High Efficiency Gas Griddle	18%	18%	18%	18%	18%	18%	18%	18%	18%	Split between cooking measures bases on NH Study
C-Ck-2	Cooking	High Efficiency Gas Combination Oven	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-3	Cooking	High Efficiency Gas Convection Oven	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-4	Cooking	High Efficiency Gas Conveyer Oven	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-5	Cooking	High Efficiency Gas Rack Oven	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-6	Cooking	High Efficiency Gas Broiler	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-7	Cooking	Power Burner Range	6%	6%	6%	6%	6%	6%	6%	6%	6%	
C-Ck-8	Cooking	High Efficiency Fryer	28%	28%	28%	28%	28%	28%	28%	28%	28%	
C-Ck-9	Cooking	High Efficiency Gas Steamer	18%	18%	18%	18%	18%	18%	18%	18%	18%	
900		Space Heating										

Table B-3a

GasNetworks Energy Efficiency Potential Study - Commercial Sector: Base Case Factor

Base Case Factor is the fraction of the end use energy that is applicable for the efficient technology in a given market segment. For example, for a faucet aerator, this would be the fraction of all water heating use that is associated with faucets.

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Notes
C-SH-1	Space Heating	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	17%	17%	17%	17%	17%	17%	17%	17%	17%	22% of heating load is non -boiler. This includes furnaces, unit heater s and infrared heaters. (EIA, 2003 CBECS, Table C27, New England, Total NG Consumption)
C-SH-3	Space Heating	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	9%	9%	9%	9%	9%	9%	9%	9%	9%	78% of heating load is boiler load. 38% of that load is small boilers, 58% of which is hot water. Split equally between competing measures. (EIA, 2003 CBECS, Table C27, New England, Total NG Consumption and US DOE Technical Support Doc. Energy Efficiency Program For C&I Equipment: Efficiency Stds. for Commercial Heating, AC and Water Heating Equipment, July 9, 2008, p. 2-33, Table2.3.1)
C-SH-5	Space Heating	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	9%	9%	9%	9%	9%	9%	9%	9%	9%	
C-SH-7	Space Heating	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	12%	12%	12%	12%	12%	12%	12%	12%	12%	78% of heating load is boiler load. 38% of that load is small boilers, 42% of which is steam. (EIA, 2003 CBECS, Table C27, New England, Total NG Consumption and US DOE Technical Support Doc. Energy Efficiency Program For C&I Equipment: Efficiency Stds. for Commercial Heating, AC and Water Heating Equipment, July 9, 2008, p. 2-33, Table2.3.1)
C-SH-8	Space Heating	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	10%	10%	10%	10%	10%	10%	10%	10%	10%	78% of heating load is boiler load. 62% of that load is large boilers, 41% of which is hot water. Split Equally between competing measures. (EIA, 2003 CBECS, Table C27, New England, Total NG Consumption and US DOE Technical Support Doc. Energy Efficiency Program For C&I Equipment: Efficiency Stds. for Commercial Heating, AC and Water Heating Equipment, July 9, 2008, p. 2-33, Table2.3.1)
C-SH-10	Space Heating	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	10%	10%	10%	10%	10%	10%	10%	10%	10%	
C-SH-12	Space Heating	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	29%	29%	29%	29%	29%	29%	29%	29%	29%	78% of heating load is boiler load. 62% of that load is large boilers, 59% of which is steam. (EIA, 2003 CBECS, Table C27, New England, Total NG Consumption and US DOE Technical Support Doc. Energy Efficiency Program For C&I Equipment: Efficiency Stds. for Commercial Heating, AC and Water Heating Equipment, July 9, 2008, p. 2-33, Table2.3.1)
C-SH-14	Space Heating	Insulate and Seal Ducts (New Aerosol Duct Sealing)	17%	17%	17%	17%	17%	17%	17%	17%	17%	
C-SH-17	Space Heating	Gas Unit Heater - Condensing (AFUE =93%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	
C-SH-18	Space Heating	Infrared Heater (low intensity - two stage)	3%	3%	3%	3%	3%	3%	3%	3%	3%	
C-SH-19	Space Heating	Stack Heat Exchanger (Standard Economizer)	48%	48%	48%	48%	48%	48%	48%	48%	48%	Applied to 100% of Heating Use less Unit and Infrared Heater use. Split equally between standard and condensing economizer.
C-SH-20	Space Heating	Stack Heat Exchanger (Condensing Economizer)	48%	48%	48%	48%	48%	48%	48%	48%	48%	
C-SH-21	Space Heating	Heat Recovery from Air to Air	74%	74%	74%	74%	74%	74%	74%	74%	74%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table
C-SH-23	Space Heating	Boiler Heating Pipe Insulation	37%	37%	37%	37%	37%	37%	37%	37%	37%	Total Boiler Base Case Factor less Steam Boiler Base Case Factor
C-SH-24	Space Heating	Boiler Tune-Up	78%	78%	78%	78%	78%	78%	78%	78%	78%	
C-SH-25	Space Heating	Boiler Reset Controls	78%	78%	78%	78%	78%	78%	78%	78%	78%	
C-SH-26	Space Heating	Boiler O2 Trim Controls (This measure should be replaced by Boiler parallel positioning control, which is the most common method of O2 Trim Control)	78%	78%	78%	78%	78%	78%	78%	0%	0%	
C-SH-27	Space Heating	Boiler Parallel Positioning O2 Trim Control	78%	78%	78%	78%	78%	78%	78%	78%	78%	
C-SH-28	Space Heating	Boiler blowdown heat exchanger (steam)	41%	41%	41%	41%	41%	41%	41%	41%	41%	Sum of steam heating base factors for steam boiler measure #907 & 912
C-SH-29	Space Heating	Repair/Replace malfunctioning steam traps	41%	41%	41%	41%	41%	41%	41%	41%	41%	
C-SH-30	Space Heating	Insulate steam lines/condensate tank	41%	41%	41%	41%	41%	41%	41%	41%	41%	
C-SH-31	Space Heating	Destratification Fans (HVLS)	100%	0%	0%	0%	0%	0%	0%	0%	0%	
C-SH-32	Space Heating	Exhaust Hood Makeup Air	3%	0%	1%	1%	20%	3%	1%	3%	1%	
C-SH-34	Space Heating	Exhaust Hood - Demand Ventilation	3%	0%	1%	1%	20%	3%	1%	3%	1%	GDS Estimate and Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table
C-SH-35	Space Heating	Demand Controlled Ventilation	100%	10%	10%	0%	0%	100%	10%	100%	10%	Most Applicable to buildings with large swings in occupancy levels. GDS Estimate and Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Applicability Table

Table B-3b

GasNetworks Energy Efficiency Potential Study - Remaining Factor

Remaining Factor is the fraction of therm sales that are associated with equipment that has not yet been converted to the energy efficiency measure; that is, one minus the fraction of the market segment that already have the energy-efficiency measure installed.

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Source
100		Water Heating End Use										
C-WH-1	Water Heating	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	5%	5%	5%	5%	5%	5%	5%	5%	5%	NH Study -GDS Commercial Survey
C-WH-3	Water Heating	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 but)	95%	95%	95%	95%	95%	95%	95%	95%	95%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, RET_NOT Complete Table
C-WH-5	Water Heating	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	98%	98%	98%	97%	99%	98%	98%	99%	98%	NH Study -GDS Commercial Survey
C-WH-7	Water Heating	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	100%	100%	100%	100%	100%	100%	100%	100%	100%	NH Study - GDS Associates Estimate/Calculation
C-WH-9	Water Heating	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	98%	98%	98%	97%	99%	98%	98%	99%	98%	NH Study -GDS Commercial Survey
C-WH-11	Water Heating	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	58%	58%	58%	92%	29%	58%	58%	72%	31%	NH Study -GDS Commercial Survey
C-WH-13	Water Heating	Heat Recovery Water Heater	90%	90%	90%	90%	90%	90%	90%	90%	90%	NH Study - GDS Associates Estimate/Calculation
C-WH-14	Water Heating	Pipe wrap	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study -GDS Commercial Survey
C-WH-15	Water Heating	Low flow shower head (1.5 GPM)	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study - GDS Associates Estimate/Calculation
C-WH-16	Water Heating	Faucet aerator	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study - GDS Associates Estimate/Calculation
C-WH-17	Water Heating	Graywater Heat Exchanger/GFX	99%	99%	99%	99%	99%	99%	99%	99%	99%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, RET_NOT Complete Table
C-WH-18	Water Heating	Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study - GDS Associates Estimate/Calculation
C-WH-19	Water Heating	Circulation Pump Time Clocks	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-WH-20	Water Heating	Solar Water Heating w/gas auxiliary tank (SEF=1.5)	100%	100%	100%	100%	100%	100%	100%	100%	100%	Water Heating, DHW Generation and Storage Equipment
C-L-1	Water Heating	Wastewater, Filtration/Reclamation	98%	98%	98%	98%	98%	98%	98%	98%	98%	NH Study - GDS Associates Estimate/Calculation
C-L-2	Water Heating	Ozone Commercial Laundry System (Gas HW)	98%	98%	98%	98%	98%	98%	98%	98%	98%	NH Study - GDS Associates Estimate
C-L-3	Water Heating	Energy Star Clothes Washer	80%	80%	80%	80%	80%	80%	80%	80%	80%	Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, GDS Associates, June 2004
C-PWH-1	Water Heating	High Efficiency (95%) Gas Pool Water Heater	80%	80%	80%	80%	80%	80%	80%	80%	80%	NH Study - GDS Associates Estimate/Calculation
C-PWH-2	Water Heating	Pool Cover	89%	89%	89%	89%	89%	89%	89%	89%	89%	NH Study -GDS Commercial Survey
C-PWH-3	Water Heating	Solar pool heater	100%	100%	100%	100%	100%	100%	100%	100%	100%	NH Study - GDS Associates Estimate/Calculation
200		Space & Water Heating										
C-SWH-1	Space & Water Heating	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	5%	5%	5%	5%	5%	5%	5%	5%	5%	Set to smallest remaining percentage of either small water heater or furnace
C-SWH-3	Space & Water Heating	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	90%	90%	90%	90%	90%	90%	90%	90%	90%	Set to smallest remaining percentage of either small condensing water heater or boiler
C-SWH-5	Space & Water Heating	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	5%	5%	5%	5%	5%	5%	5%	5%	5%	Set to smallest remaining percentage of either small water heater or boiler
300		Building Envelope										
C-BE-1	Building Envelope	Double Glazing Low Emissivity Windows	30%	30%	30%	30%	30%	30%	30%	30%	30%	NH Study - GDS Associates Estimate/Calculation
C-BE-2	Building Envelope	Triple Glazing Low Emissivity Windows	70%	70%	70%	70%	70%	70%	70%	70%	70%	NH Study - GDS Associates Estimate/Calculation
C-BE-3	Building Envelope	Improved Wall Insulation (to R12)	59%	59%	59%	59%	59%	59%	59%	59%	59%	NH Study -GDS Commercial Survey
C-BE-4	Building Envelope	Improved Roof/Ceiling Insulation (to R32)	55%	55%	55%	55%	55%	55%	55%	55%	55%	NH Study -GDS Commercial Survey
C-BE-5	Building Envelope	Improved Below-Grade Insulation (to R6)	55%	55%	55%	55%	55%	55%	55%	55%	55%	NH Study - GDS Associates Estimate/Calculation
C-BE-6	Building Envelope	Air Sealing	59%	59%	59%	59%	59%	59%	59%	59%	59%	NH Study - GDS Associates Estimate/Calculation
C-BE-7	Building Envelope	Integrated Building Design, Envelope Only (30% > code)	100%	100%	100%	100%	100%	100%	100%	100%	100%	NH Study - GDS Associates Estimate/Calculation
600		HVAC Controls										
C-CN-1	HVAC Controls	EMS install	62%	62%	62%	62%	62%	62%	62%	62%	62%	NH Study -GDS Commercial Survey
C-CN-2	HVAC Controls	EMS Optimization	86%	86%	86%	86%	86%	86%	86%	86%	86%	EIA, 2003 CBECS, New England, Non Mall saturation, square footage
C-CN-3	HVAC Controls	Zoning	44%	44%	44%	44%	44%	44%	44%	44%	44%	GDS Associates Estimate/Calculation
C-CN-4	HVAC Controls	Retrocommissioning	100%	100%	100%	100%	100%	100%	100%	100%	100%	The Maximum Achievable Cost Effective Potential for Natural Gas Energy Efficiency In the Service Territory of PNM, GDS Associates, May 2005
C-CN-5	HVAC Controls	Commissioning	100%	100%	100%	100%	100%	100%	100%	100%	100%	The Maximum Achievable Cost Effective Potential for Natural Gas Energy Efficiency In the Service Territory of PNM, GDS Associates, May 2005
C-CN-6	HVAC Controls	Programmable Thermostat	44%	44%	44%	44%	44%	44%	44%	44%	44%	NH Study -GDS Commercial Survey
700		Space Conditioning										
C-SC-2	Space Conditioning	High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Associates Estimate/Calculation
C-SC-4	Space Conditioning	Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Associates Estimate/Calculation
C-SC-6	Space Conditioning	Double-Effect Absorption Chiller (1.03 COP)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Associates Estimate/Calculation
800		Cooking										
C-Ck-1	Cooking	High Efficiency Gas Griddle	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-2	Cooking	High Efficiency Gas Combination Oven	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-3	Cooking	High Efficiency Gas Convection Oven	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-4	Cooking	High Efficiency Gas Conveyer Oven	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-5	Cooking	High Efficiency Gas Rack Oven	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-6	Cooking	High Efficiency Gas Broiler	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-7	Cooking	Power Burner Range	97%	97%	97%	97%	97%	97%	97%	97%	97%	NH Study -GDS Commercial Survey

Table B-3b

GasNetworks Energy Efficiency Potential Study - Remaining Factor

Remaining Factor is the fraction of therm sales that are associated with equipment that has not yet been converted to the energy efficiency measure; that is, one minus the fraction of the market segment that already have the energy-efficiency measure installed.

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Source
C-Ck-8	Cooking	High Efficiency Fryer	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
C-Ck-9	Cooking	High Efficiency Gas Steamer	60%	60%	60%	60%	60%	60%	60%	60%	60%	NH Study - GDS Associates Estimate/Calculation
900		Space Heating										
C-SH-1	Space Heating	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	65%	65%	65%	65%	65%	65%	65%	65%	65%	NH Study -GDS Commercial Survey
C-SH-3	Space Heating	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study -GDS Commercial Survey
C-SH-5	Space Heating	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	50%	90%	90%	90%	90%	90%	90%	90%	90%	http://www.cee1.org/gas/gs-blrs/Boiler_assess.pdf
C-SH-7	Space Heating	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	51%	51%	51%	51%	51%	51%	51%	51%	51%	NH Study -GDS Commercial Survey
C-SH-8	Space Heating	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study -GDS Commercial Survey
C-SH-10	Space Heating	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	90%	90%	90%	90%	90%	90%	90%	90%	90%	http://www.cee1.org/gas/gs-blrs/Boiler_assess.pdf
C-SH-12	Space Heating	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	51%	51%	51%	51%	51%	51%	51%	51%	51%	NH Study -GDS Commercial Survey
C-SH-14	Space Heating	Insulate and Seal Ducts (New Aerosol Duct Sealing)	80%	80%	80%	80%	80%	80%	80%	80%	80%	NH Study - GDS Associates Estimate/Calculation
C-SH-17	Space Heating	Gas Unit Heater - Condensing (AFUE =93%)	90%	90%	90%	90%	90%	90%	90%	90%	90%	NH Study - GDS Associates Estimate/Calculation
C-SH-18	Space Heating	Infrared Heater (low intensity - two stage)	90%	90%	90%	90%	90%	90%	90%	90%	90%	NH Study - GDS Associates Estimate/Calculation
C-SH-19	Space Heating	Stack Heat Exchanger (Standard Economizer)	98%	98%	98%	98%	98%	98%	98%	98%	98%	NH Study - GDS Associates Estimate/Calculation
C-SH-20	Space Heating	Stack Heat Exchanger (Condensing Economizer)	98%	98%	98%	98%	98%	98%	98%	98%	98%	NH Study - GDS Associates Estimate/Calculation
C-SH-21	Space Heating	Heat Recovery from Air to Air	69%	90%	76%	90%	62%	90%	78%	74%	50%	NH Study - GDS Commercial Survey
C-SH-23	Space Heating	Boiler Heating Pipe Insulation	80%	80%	80%	80%	80%	80%	80%	80%	80%	NH Study - GDS Associates Estimate/Calculation
C-SH-24	Space Heating	Boiler Tune-Up	50%	50%	50%	50%	50%	50%	50%	50%	50%	NH Study - GDS Associates Estimate/Calculation
C-SH-25	Space Heating	Boiler Reset Controls	80%	80%	80%	80%	80%	80%	80%	80%	80%	NH Study - GDS Associates Estimate/Calculation
C-SH-26	Space Heating	Boiler O2 Trim Controls (This measure should be replaced by Boiler parallel positioning control, which is the most common method of O2 Trim Control)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Associates Estimate/Calculation
C-SH-27	Space Heating	Boiler Parallel Positioning O2 Trim Control	85%	85%	85%	85%	85%	85%	85%	85%	85%	NH Study - GDS Associates Estimate/Calculation
C-SH-28	Space Heating	Boiler blowdown heat exchanger (steam)	90%	90%	90%	90%	90%	90%	90%	90%	90%	NH Study - GDS Associates Estimate/Calculation
C-SH-29	Space Heating	Repair/Replace malfunctioning steam traps	30%	30%	30%	30%	30%	30%	30%	30%	30%	http://www.energysolutionscenter.org/BoilerBurner/Eff_Improve/Steam_Distribution/Steam_Trap_Leaks.asp
C-SH-30	Space Heating	Insulate steam lines/condensate tank	70%	70%	70%	70%	70%	70%	70%	70%	70%	http://www.energysolutionscenter.org/BoilerBurner/Eff_Improve/Steam_Distribution/Steam_Trap_Leaks.asp
C-SH-31	Space Heating	Destratification Fans (HVLS)	93%	93%	93%	93%	93%	93%	93%	93%	93%	http://www.airius.us/pdf/d1hughes.pdf
C-SH-32	Space Heating	Exhaust Hood Makeup Air	70%	70%	70%	70%	70%	70%	70%	70%	70%	NH Study - GDS Associates Estimate/Calculation
C-SH-34	Space Heating	Exhaust Hood - Demand Ventilation	98%	98%	98%	98%	98%	98%	98%	98%	98%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, RET_NOT Complete Table
C-SH-35	Space Heating	Demand Controlled Ventilation	90%	90%	90%	90%	90%	90%	90%	90%	90%	NH Study - GDS Associates Estimate/Calculation

TABLE B-3c

GasNetworks Energy Efficiency Potential Study - Convertible Factor

Convertible Factor Is the fraction of the equipment or practice that is technically feasible for conversion to the efficient technology from an engineering perspective. (e.g., Solar water heating may not be technically feasible to install in all potential applications because of positioning of the building or limited space for solar panels)

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Source
100		Water Heating End Use										
C-WH-1	Water Heating	High Efficiency Stand Alone Commercial Water Heater (0.67 EF <=75000 Btu)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-WH-3	Water Heating	Condensing Stand Alone Commercial Water Heater (>=95% Thermal efficiency)(>75000 but)	56%	56%	56%	56%	56%	56%	56%	56%	56%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-5	Water Heating	On-Demand, Tankless Water Heater (>=.82, <.95 EF) (<=200,000 BTU/h)	10%	10%	0%	10%	0%	10%	0%	10%	10%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-7	Water Heating	On-Demand, Tankless Water Heater (>=.95 EF) (<=200,000 Btu/h)	10%	10%	0%	10%	0%	10%	0%	10%	10%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-9	Water Heating	On-Demand, Tankless Water Heater (.85 TE) (>200,000 BTU)	10%	10%	0%	10%	0%	10%	0%	10%	10%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-11	Water Heating	Indirect Water Heater - Combined appliance efficiency rating (CAE)>=85% (EF=.82)	39%	39%	39%	39%	39%	39%	39%	39%	39%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-13	Water Heating	Heat Recovery Water Heater	10%	5%	80%	10%	20%	80%	80%	15%	5%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-14	Water Heating	Pipe wrap	50%	50%	50%	50%	50%	50%	50%	50%	50%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-15	Water Heating	Low flow shower head (1.5 GPM)	95%	95%	95%	95%	95%	95%	95%	95%	95%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-16	Water Heating	Faucet aerator	95%	95%	25%	95%	50%	25%	25%	50%	75%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-17	Water Heating	Graywater Heat Exchanger/GFX	50%	50%	50%	50%	50%	50%	50%	50%	50%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-WH-18	Water Heating	Low Flow Pre-Rinse Spray Nozzle (1.6 gpm)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-WH-19	Water Heating	Circulation Pump Time Clocks	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-WH-20	Water Heating	Solar Water Heating w/gas auxiliary tank (SEF=1.5)	34%	34%	34%	34%	34%	34%	34%	34%	34%	GDS Estimate - Used Residential Applicability Factor
C-L-1	Water Heating	Wastewater, Filtration/Reclamation	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-L-2	Water Heating	Ozone Commercial Laundry System (Gas HW)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-L-3	Water Heating	Energy Star Clothes Washer	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-PWH-1	Water Heating	High Efficiency (95%) Gas Pool Water Heater	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-PWH-2	Water Heating	Pool Cover	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-PWH-3	Water Heating	Solar pool heater	34%	34%	34%	34%	34%	34%	34%	34%	34%	GDS Estimate - Used Residential Applicability Factor
200		Space & Water Heating			Space & Water Heating							
C-SWH-1	Space & Water Heating	Combination Water Heater/Furnace (.86 EF, .90 AFUE)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SWH-3	Space & Water Heating	Combination Water Heater/Boiler (Condensing)(0.9 EF, 0.9 AFUE)	56%	56%	56%	56%	56%	56%	56%	56%	56%	Used Condensing Water Heater Factor
C-SWH-5	Space & Water Heating	Combination Water Heater/Boiler (Non-Condensing) (0.86 EF, 85 AFUE)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
300		Building Envelope										
C-BE-1	Building Envelope	Double Glazing Low Emissivity Windows	75%	75%	75%	75%	75%	75%	75%	75%	75%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-BE-2	Building Envelope	Triple Glazing Low Emissivity Windows	75%	75%	75%	75%	75%	75%	75%	75%	75%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-BE-3	Building Envelope	Improved Wall Insulation (to R12)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-BE-4	Building Envelope	Improved Roof/Ceiling Insulation (to R32)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-BE-5	Building Envelope	Improved Below-Grade Insulation (to R6)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-BE-6	Building Envelope	Air Sealing	33%	33%	33%	33%	33%	33%	33%	33%	33%	GDS Estimate
C-BE-7	Building Envelope	Integrated Building Design, Envelope Only (30% > code)	80%	80%	80%	80%	80%	50%	50%	80%	80%	GDS Estimate
600		HVAC Controls										
C-CN-1	HVAC Controls	EMS install	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-CN-2	HVAC Controls	EMS Optimization	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate

TABLE B-3c

GasNetworks Energy Efficiency Potential Study - Convertible Factor

Convertible Factor Is the fraction of the equipment or practice that is technically feasible for conversion to the efficient technology from an engineering perspective. (e.g., Solar water heating may not be technically feasible to install in all potential applications because of positioning of the building or limited space for solar panels)

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Source
C-CN-3	HVAC Controls	Zoning	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-CN-4	HVAC Controls	Retrocommissioning	54%	54%	54%	54%	54%	54%	54%	54%	54%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-CN-5	HVAC Controls	Commissioning	71%	71%	71%	71%	71%	71%	71%	71%	71%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-CN-6	HVAC Controls	Programmable Thermostat	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
700		**Space Conditioning**										
C-SC-1	Space Conditioning	Desiccant Dehumidifier/Air Conditioner	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SC-2	Space Conditioning	High-Efficiency Gas-Fired Rooftop Unit (95% combustion efficiency)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SC-3	Space Conditioning	Packaged Absorption Chiller (included in Space Heating/Conditioning)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SC-4	Space Conditioning	Engine-Driven Chiller w/ heat recovery (replacing no heat recovery unit)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SC-5	Space Conditioning	Engine-Driven Chiller w/ heat recovery	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SC-6	Space Conditioning	Double-Effect Absorption Chiller (1.03 COP)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
800		**Cooking**										
C-Ck-1	Cooking	High Efficiency Gas Griddle	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-2	Cooking	High Efficiency Gas Combination Oven	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-3	Cooking	High Efficiency Gas Convection Oven	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-4	Cooking	High Efficiency Gas Conveyer Oven	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-5	Cooking	High Efficiency Gas Rack Oven	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-6	Cooking	High Efficiency Gas Broiler	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-7	Cooking	Power Burner Range	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-8	Cooking	High Efficiency Fryer	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-Ck-9	Cooking	High Efficiency Gas Steamer	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
900		**Space Heating**										
C-SH-1	Space Heating	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-3	Space Heating	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-5	Space Heating	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	22%	22%	22%	22%	22%	22%	22%	22%	22%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-SH-7	Space Heating	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-8	Space Heating	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th.eff.=85%-90%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-10	Space Heating	Condensing Boiler (>300,000 Btu/h) (Th.eff.=>90%)	22%	22%	22%	22%	22%	22%	22%	22%	22%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-SH-12	Space Heating	High Efficiency Steam Boiler (>300,000 Btu/h) (Th.Eff.>=80%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-14	Space Heating	Insulate and Seal Ducts (New Aerosol Duct Sealing)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-17	Space Heating	Gas Unit Heater - Condensing (AFUE =93%)	100%	0%	65%	0%	0%	0%	0%	0%	35%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-SH-18	Space Heating	Infrared Heater (low intensity - two stage)	100%	0%	65%	0%	0%	0%	0%	0%	35%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-SH-19	Space Heating	Stack Heat Exchanger (Standard Economizer)	32%	32%	32%	32%	32%	32%	32%	32%	32%	Limited to large boilers with high stack temps and either high make-up water needs or significant hot water need (32% based on percent of 2007 boiler shipments that are large boilers from AHRI)
C-SH-20	Space Heating	Stack Heat Exchanger (Condensing Economizer)	32%	32%	32%	32%	32%	32%	32%	32%	32%	Limited to large boilers with high stack temps and either high make-up water needs or significant hot water need (32% based on percent of 2007 boiler shipments that are large boilers from AHRI)
C-SH-21	Space Heating	Heat Recovery from Air to Air	50%	50%	50%	50%	50%	50%	50%	50%	50%	GDS Estimate
C-SH-23	Space Heating	Boiler Heating Pipe Insulation	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-24	Space Heating	Boiler Tune-Up	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-25	Space Heating	Boiler Reset Controls	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-26	Space Heating	Boiler O2 Trim Controls (This measure should be replaced by Boiler parallel positioning control, which is the most common method of O2 Trim Control)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-27	Space Heating	Boiler Parallel Positioning O2 Trim Control	42%	42%	42%	42%	42%	42%	42%	42%	42%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006, Commercial Analysis Appendix, Feasibility Table
C-SH-28	Space Heating	Boiler blowdown heat exchanger (steam)	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-29	Space Heating	Repair/Replace malfunctioning steam traps	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate

TABLE B-3c

GasNetworks Energy Efficiency Potential Study - Convertible Factor

Convertible Factor Is the fraction of the equipment or practice that is technically feasible for conversion to the efficient technology from an engineering perspective. (e.g., Solar water heating may not be technically feasible to install in all potential applications because of positioning of the building or limited space for solar panels)

#	End Use	Measure Name	Warehouse	Retail	Grocery	Office	Lodging	Health	Restaurant	Education	Other	Source
C-SH-30	Space Heating	Insulate steam lines/condensate tank	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-31	Space Heating	Destratification Fans (HVLS)	67%	67%	67%	67%	67%	67%	67%	67%	67%	Most applicable in large high ceiling facilities
C-SH-32	Space Heating	Exhaust Hood Makeup Air	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-34	Space Heating	Exhaust Hood - Demand Ventilation	100%	100%	100%	100%	100%	100%	100%	100%	100%	GDS Estimate
C-SH-35	Space Heating	Demand Controlled Ventilation	67%	67%	67%	67%	67%	67%	67%	67%	67%	GDS Estimate

APPENDIX C

Industrial Sector Data

Appendix C-1

Industrial Energy Efficiency Measure Descriptions

Thirty-s-even (37) industrial energy efficiency measures were included in this study of gas efficiency potential in Massachusetts. Appendix C-1 contains brief descriptions of each of these measures by end-use category. Descriptions of four additional measures (Micro CHP, Gas Drying & Heating Technologies, Desiccant Dehumidification and Gas Fired Air Compression) are also included. Savings, costs and useful life data was collected for these measures for potential use in a future study, but they were not included in this analysis of natural gas energy efficiency potential.

Conventional Boiler Use

I-CBU-1 High Efficiency Hot Water Boiler (<=300,000 Btu/h)
Install a high efficiency boiler with AFUE of 85%-90%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-CBU-2 Condensing Boiler (<=300,000 Btu/h)
Install a condensing boiler with an AFUE rating >90%. A condensing boiler condenses flue gases in a second heat exchanger for extra efficiency.

I-CBU-3 High Efficiency Steam Boiler (<=300,000 Btu/h)
Install a high efficiency steam boiler with AFUE >= 82%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-CBU-4 High Efficiency Hot Water Boiler (>300,000 Btu/h)
Install a high efficiency boiler with EF=85%-90%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-CBU-5 Condensing Boiler (>300,000 Btu/h)
Install a condensing boiler with an EF >=90%. A condensing boiler condenses flue gases in a second heat exchanger for extra efficiency.

I-CBU-6 High Efficiency Steam Boiler (>300,000 Btu/h)
Install a high efficiency steam boiler with an EF >=80%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-CBU-7 Boiler Tune-Up

A high-efficiency boiler tune-up performed by a properly trained technician can improve average combustion efficiency by 2 to 10 percent. To ensure that the boiler tune-up is a success, the tune-up technician should use an electronic flue-gas analyzer that is capable of continuously monitoring stack temperature, oxygen (O2 in percent), and carbon monoxide (CO in ppm). In addition, the technician should determine the boiler's actual gas input rate (cubic feet per minute). Some boilers can't be tuned up because there is no way to control the excess air or gas flow. Before examining this measure the technician or auditor must determine if the boiler is tunable.

I-CBU-8 Boiler Pipe Insulation

Insulating accessible steam or hot water supply pipes in the boiler room is a cost-effective way to save energy. Savings will vary depending on the temperature of the hot water or steam and the ambient temperature.

I-CBU-9 Boiler Reset Controls

A boiler reset control is a device that automatically controls the boiler water temperature according to a software program based on outdoor temperature.

I-CBU-10 Boiler O2 Trim Controls

An electronic sensor is inserted into the boiler flue and is connected to a control panel to measure oxygen and transmit signals to a control damper on the burner air supply.

I-CBU-11 Electronic Parallel Positioning Controls

Modern electronic parallel positioning controls (PPC) incorporate end-device positioning signals to ensure accurate placement of fuel and air positioners for specific firing rates.

I-CBU-12 Boiler Blowdown Heat Exchanger (Steam)

Recovery of heat from the periodic/continuous flow of outlet waste water (to prevent sludge buildup) to preheat make-up water.

I-CBU-13 Repair Malfunctioning Steam Traps

Under normal operating conditions, the valve and seat area is subjected to hot high-pressure water flow. Water is corrosive and causes surface erosion. With no maintenance, eventually the valve will fail to close properly and the trap will fail to seal and will waste steam.

I-CBU-14 Insulate Steam Lines / Condensate Tank

Insulation to prevent heat loss from steam lines and condensate tank.

I-CBU-15 Micro CHP

Microturbines are used for distributed power and combined heat and power applications. Microturbine designs usually consist of a single stage radial compressor, a single stage radial turbine and a recuperator. Exhaust heat can be used for water heating, space heating, drying processes or absorption chillers, which create cold for air

conditioning from heat energy instead of electric energy. Typical microturbine efficiencies are 25 to 35%. When in a combined heat and power cogeneration system, efficiencies of greater than 80% are commonly achieved.

Process Heating

I-PH-1 High Efficiency Hot Water Boiler (>300,000 Btu/h)

Install a high efficiency boiler with EF=85%-90%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-PH-2 Condensing Boiler (>300,000 Btu/h)

Install a condensing boiler with an EF >=90%. A condensing boiler condenses flue gases in a second heat exchanger for extra efficiency.

I-PH-3 High Efficiency Steam Boiler (>300,000 Btu/h)

Install a high efficiency steam boiler with an EF >=80%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-PH-4 Direct Fired Make-up Air System

Heating of make-up air with direct contact with combustion flame in spaces that require high ventilation rates.

I-PH-5 Direct Contact Water Heater

Incoming water flows downward through a vertical column filled with stainless steel packing rings. As cold water comes into Direct Contact with rising hot combustion air from a gas burner, a very rapid heat transfer occurs, absorbing 99% of the heat energy into the water. Pure, heated water then accumulates in the storage tank for "On Demand" use, and clean CO2 and H20 combustion gas leaves the stack at near ambient temperature.

I-PH-6 Boiler Tune-Up

A high-efficiency boiler tune-up performed by a properly trained technician can improve average combustion efficiency by 2 to 10 percent. To ensure that the boiler tune-up is a success, the tune-up technician should use an electronic flue-gas analyzer that is capable of continuously monitoring stack temperature, oxygen (O2 in percent), and carbon monoxide (CO in ppm). In addition, the technician should determine the boiler's actual gas input rate (cubic feet per minute). Some boilers can't be tuned up because there is no way to control the excess air or gas flow. Before examining this measure the technician or auditor must determine if the boiler is tunable.

I-PH-7 Boiler Pipe Insulation

Insulating accessible steam or hot water supply pipes in the boiler room is a cost-effective way to save energy. Savings will vary depending on the temperature of the hot water or steam and the ambient temperature.

I-PH-8 Boiler Reset Controls

A boiler reset control is a device that automatically controls the boiler water temperature according to a software program based on outdoor temperature.

I-PH-9 Boiler O2 Trim Controls

An electronic sensor is inserted into the boiler flue and is connected to a control panel to measure oxygen and transmit signals to a control damper on the burner air supply.

I-PH-10 Electronic Parallel Positioning Controls

Modern electronic parallel positioning controls (PPC) incorporate end-device positioning signals to ensure accurate placement of fuel and air positioners for specific firing rates.

I-PH-10 Waste-Heat Recovery

Recovery of process waste heat for reuse.

I-PH-11 Gas Drying & Heating Technologies

In certain applications, improved dryer and furnace designs can be successfully substituted for electric technologies.

I-PH-12 Regenerative Thermal Oxidizer (replacing a Standard Thermal Oxidizer)

Regenerative thermal oxidizers (RTO) offer superior heat recovery characteristics versus any other oxidation system. Thermal Oxidizers use recovered energy to pre-heat incoming process air to oxidation temperatures. This significantly lowers overall operating costs. A regenerative thermal oxidizer is particularly effective for process streams with low solvent loading.

I-PH-13 Regenerative Thermal Oxidizer (replacing a Catalytic Thermal Oxidizer)

Regenerative thermal oxidizers (RTO) offer superior heat recovery characteristics versus any other oxidation system. Thermal Oxidizers use recovered energy to pre-heat incoming process air to oxidation temperatures. This significantly lowers overall operating costs. A regenerative thermal oxidizer is particularly effective for process streams with low solvent loading.

I-PH-14 Infrared Oven
The use of gas fired infrared heat in industrial process heating. Infrared heating with natural gas can optimize the operation of industrial ovens and dryers used in plastics, processing paper, food, textiles, and painted products.

I-PH-15 Improved Sensors & Process Controls
Sensor and automation technologies are vital, yet often unseen, components of virtually every industrial process. They allow processes to be monitored and systems adjusted to minimize energy consumption. Perhaps more importantly from the consumer's perspective, these systems allow better control of the process that can improve product quality and reduce scrap rates. Since most scrap and waste generating events occur towards the end of the production process when the imbedded energy content is greatest, the resulting waste reduction can reduce in significant net energy savings, as well as other productivity and cost benefits. This measure is poorly understood by the customer but has the benefit of being vendor-driven.

I-PH-16 Refrigeration Heat Recovery
Recovering waste heat from refrigeration systems for water heating.

Facility HVAC

I-HVAC-1 High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)
Install a high efficiency furnace with AFUE >= 92%. High efficiency furnaces/boilers use technological advances such as electronic ignition, controlled air/fuel mixing using outside air and pulse combustion to significantly increase efficiency.

I-HVAC-2 Gas Unit Heater – Condensing
Extracts the residual heat by leading the flue gases through a second heat exchanger. (seasonal efficiency >90%).

I-HVAC-3 Infrared Heater (low intensity)
Low-intensity gas-fired infrared heating systems emulate the true efficiency of the sun by generating radiant heat energy. They consist of three main components: a burner control box, black-coated radiant emitter tubes, and a highly polished reflector assembly. The heaters are typically suspended from the ceiling by chains and are controlled by a thermostat.

I-HVAC-4 Insulate and Seal Ducts
Repair and seal leaky and unsealed commercial air ducts for heating with aerosol duct sealing to prevent air and heat loss. In addition, insulate ducts that run through spaces that get hot in summer or cold in winter.

I-HVAC-5 Stack Heat Exchanger (Standard Economizer)

Boiler stack economizers are simply heat exchangers with hot flue gas on one side and water on the other. Or, in direct contact condensing units, the make-up water is in direct contact with the flue gases.

I-HVAC-6 Stack Heat Exchanger (Condensing Economizer)

In terms of energy performance, an existing boiler system with an added condensing stack economizer becomes, in essence, a condensing boiler. A properly sized economizer will drop the flue gas temperature to 77°C (170°F), condensing the flue gases and transferring absorbed heat into the water flow. The economizer can raise the effective seasonal thermal efficiency of these boilers from below 80 percent to nearly 90 percent.

I-HVAC-7 Heat Recovery: Air to Air

Air-to-air heat exchangers can be used to transfer heat between the intake ventilation air stream and the HVAC exhaust air stream. During periods when the outside air is colder than the inside air, the heat exchanger transfers heat from the exhaust air to the incoming air reducing heating energy use. I installing an air-to-air heat exchanger will cause a slight increase in fan energy due to increased air flow resistance through the heat exchanger. The increase in fan energy is more than compensated for by energy savings in buildings with high outdoor air ventilation requirements. Air-to-air heat exchangers are most cost-effective in buildings having high outdoor air ventilation rates such as hospitals, hotels (kitchens), and restaurants.

I-HVAC-8 Desiccant Dehumidification

Conventional air conditioners drop the relative humidity down to about 45% at best. However, spaces that tend to be cooler to begin with, such as supermarkets, ice arenas, and water treatment plants, need to have a lower relative humidity as moisture will condense on the cool surfaces of the building or its contents. The desiccant system uses special materials that "adsorb" the water vapor, rather than condensing it. The desiccant is then heated and vented to drive off the moisture and the adsorbent process is repeated. With these types of systems, very low (as low as 5%) relative humidity can be achieved.

I-HVAC-9 Direct Fired Make-up Air System

Heating of make-up air with direct contact with combustion flame in spaces that require high ventilation rates.

Other Facility Support

I-OM-1 Gas Fired Air Compression

Substitution of natural gas fueled engine driven air compressors for electric motor driven compressors to reduce peak electrical demand.

Appendix C-2

Industrial Energy Efficiency Measure Data

GDS applied energy efficiency measure savings to applicable end uses for each industry type using eligibility factors to determine the measure specific technical potential. That is,

Technical Potential(naics,eu,2018) = Baseline Energy Use(naics,eu,2018) *

Base Factor(naics,eu,2018) * Remaining Factor(naics,eu,2018) *

Convertible Factor((naics,eu,2018) * Specific Savings Factor(naics,eu,2018)

where,

Technical Potential *= The potential reduction in energy consumption (TBtu) resulting from the application of the efficient technology*

Baseline Energy Use *= Estimated gas usage by industrial segment and end use (TBtu) in 2018, based on EIA forecast for New England 2007-2018 and breakdown of Massachusetts usage by segment and end use in 2007*

Base Factor *= The fraction of end use energy in a given industrial segment for which the efficient technology under consideration is applicable*

Remaining Factor *= The fraction of the applicable end use energy that could be converted to efficiency measure*

Convertible Factor *= The fraction of the equipment or practice that is technically feasible for conversion to the efficient technology*

Specific Savings Factor *= The percentage reduction in gas consumption resulting from the application of the efficient technology*

naics *= Industrial segment based on NAICS classification*

eu *= End use.*

Each of the identified factors is discussed below.

Industrial Energy Efficiency Base Factor

The base factor estimates are shown in Table C-2a. The industrial energy efficiency base factor is the fraction of end use energy in a given industrial segment for which the efficient technology under consideration is applicable. In the majority of cases, the base factor equals 100%. In other cases, the base factor is an estimate of the saturation of a particular energy-using device or process. For example, within the conventional boiler use category, the saturation of small (less than 300,000 Btu/hour) boilers is estimated to be 3% and the saturation of large (greater than 300,000 Btu/hour) boilers is 97%. This assumption is based on Energy and Environmental Analysis, Inc., Characterization of the U.S. Industrial/Commercial Boiler Population, May 2005, pp. 2-1 and 2-2. About 5% of the large boilers are assumed Condensing Boilers, and the remainder split between Hot Water and Steam Boilers.

The base factor for measures associated with steam boilers (boiler blowdown heat exchanger, repair steam traps, insulate steam lines) is set equal to the steam boiler saturation. With regard to regenerative thermal oxidizers (RTO), it is assumed that 1/3 of industries where this technology is applicable could replace their standard thermal oxidizers with an RTO and 1/3 could replace their catalytic thermal oxidizers with an RTO. With regard to space heating, 50% of heating units are assumed to be furnaces, 40% gas unit heaters and 10% infrared heaters. Information from KEMA, Inc., California Industrial Existing Construction Energy Efficiency Potential Study, May 2006 (see Appendix F, pp. F-1 to F-6) was also used to develop the base factor estimates for specific industries.

Industrial Energy Efficiency Remaining Factor

The remaining factor is calculated based upon industrial end use efficiency estimates developed by the Energy Information Administration (EIA) and published in Model Documentation Report: Industrial Sector Demand Module of the National Energy Modeling System, DOE/EIA-M064(2008), June 2008; see especially pp. 86-88.

In the report, the EIA provides **relative energy intensities (REI)** for various industrial end uses and industrial sectors for both existing and new facilities in 2002. Relative energy intensity is defined as the ratio of energy use in a new or advanced process compared to 2002 average energy use. Future energy improvements were estimated for old (retrofit) and new processes and plants. The energy improvements for old plants as a group consist of gradual improvements due to housekeeping/energy conservation measures, retrofit of selected technologies and the closure of older facilities leaving the more efficient plants in operation. The energy savings for old processes/plants were estimated by the EIA using engineering judgment on how much energy savings were reasonably achievable in each industry. The estimated annual energy savings values for energy conservation are modest (up to 0.5% per annum).

Table C-2a. Summary of Industrial Natural Gas Energy Efficiency Factors, Massachusetts

			Remaining Factor					
ID	End Use	Base Factor	Paper	Food, Beverage, Petroleum, Chemicals, Nonmetalic Minerals	Trans. Equip.	Other Mfg.	Convertible Factor	Specific Savings Factor
	Conventional Boiler Use							
I-CBU-1	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE =85%-90%)	1%	50%	60%	70%	80%	100%	6%
I-CBU-2	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	1%	50%	60%	70%	80%	22%	16%
I-CBU-3	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	1%	50%	60%	70%	80%	100%	9%
I-CBU-4	High Efficiency Hot Water Boiler (>300,000 Btu/h) (EF>=85%-90%)	47%	50%	60%	70%	80%	100%	10%
I-CBU-5	Condensing Boiler (>300,000 Btu/h) (EF>90%)	4%	50%	60%	70%	80%	22%	13%
I-CBU-6	High Efficiency Steam Boiler (>300,000 Btu/h) (EF>=80%)	47%	50%	60%	70%	80%	100%	5%
I-CBU-7	Boiler Tune-Up	100%	50%	60%	70%	80%	85%	5%
I-CBU-8	Boiler Pipe Insulation	100%	50%	60%	70%	80%	100%	2%
I-CBU-9	Boiler Reset Controls	100%	50%	60%	70%	80%	100%	5%
I-CBU-10	Boiler O2 Trim Controls	100%	50%	60%	70%	80%	42%	2%
I-CBU-11	Electronic Parallel Positioning Controls	100%	50%	60%	70%	80%	42%	2%
I-CBU-12	Boiler Blowdown Heat Exchanger (Steam)	47%	50%	60%	70%	80%	100%	6%
I-CBU-13	Repair Malfunctioning Steam Traps	47%	50%	60%	70%	80%	80%	10%
I-CBU-14	Insulate Steam Lines / Condensate Tank	47%	50%	60%	70%	80%	80%	2%
I-CBU-15	Micro CHP	100%	50%	60%	70%	80%	100%	n/a
	Process Heating							
I-PH-1	High Efficiency Hot Water Boiler (>300,000 Btu/h) (EF>=85%-90%)	48%	50%	60%	70%	80%	100%	10%
I-PH-2	Condensing Boiler (>300,000 Btu/h) (EF>90%)	5%	50%	60%	70%	80%	22%	13%
I-PH-3	High Efficiency Steam Boiler (>300,000 Btu/h) (EF>=80%)	48%	50%	60%	70%	80%	100%	5%
I-PH-4	Direct Fired Make-up Air System	100% (a)	50%	60%	70%	80%	100%	16%
I-PH-5	Direct Contact Water Heater	100% (b)	50%	60%	70%	80%	15%	34%
I-PH-6	Boiler Tune-Up	100%	50%	60%	70%	80%	85%	5%
I-PH-7	Boiler Pipe Insulation	100%	50%	60%	70%	80%	100%	2%
I-PH-8	Boiler Reset Controls	100%	50%	60%	70%	80%	100%	5%
I-PH-9	Boiler O2 Trim Controls	100%	50%	60%	70%	80%	42%	2%
I-PH-10	Electronic Parallel Positioning Controls	100%	50%	60%	70%	80%	42%	2%
I-PH-11	Waste-Heat Recovery	100%	50%	60%	70%	80%	35%	6%
I-PH-12	Gas Drying & Heating Technologies	100%	50%	60%	70%	80%	35%	n/a
I-PH-13	Regenerative Thermal Oxidizer vs. STO	33% (c)	50%	60%	70%	80%	10%	95%
I-PH-14	Regenerative Thermal Oxidizer vs. CTO	33% (c)	50%	60%	70%	80%	10%	69%
I-PH-15	Infrared Oven	100% (a)	50%	60%	70%	80%	35%	23%
I-PH-16	Improved Sensors & Process Controls	100%	50%	60%	70%	80%	75%	5%
I-PH-17	Refrigeration Heat Recovery	100% (b)	50%	60%	70%	80%	35%	50%
	Facility HVAC							
I-HVAC-1	High Efficiency Furnace (<=300,000 Btu/h) (AFUE>=92%)	50%	50%	60%	70%	80%	100%	15%
I-HVAC-2	Gas Unit Heater - Condensing	40%	50%	60%	70%	80%	100%	14%
I-HVAC-3	Infrared Heater (low intensity)	10%	50%	60%	70%	80%	100%	26%
I-HVAC-4	Insulate and Seal Ducts	100%	50%	60%	70%	80%	85%	7%
I-HVAC-5	Stack Heat Exchanger (Standard Economizer)	100%	50%	60%	70%	80%	35%	5%
I-HVAC-6	Stack Heat Exchanger (Condensing Economizer)	100%	50%	60%	70%	80%	35%	10%
I-HVAC-7	Heat Recovery: Air to Air	100%	50%	60%	70%	80%	35%	13%
I-HVAC-8	Desiccant Dehumidification	100% (d)	50%	60%	70%	80%	35%	n/a
I-HVAC-9	Direct Fired Make-up Air System	100%	50%	60%	70%	80%	100%	16%
	Other Facility Support							
I-OM-1	Gas Fired Air Compression - Peak Shaving	100%	50%	60%	70%	80%	10%	n/a

(a) Fabricated Metals, Machinery, and Transportation Equipment only.

(b) Food and Beverage only.

(c) Wood, Printing, Chemicals and Plastics & Rubber only.

(d) Food, Printing, Chemicals, and Plastics & Rubber only.

The EIA uses the rate at which energy efficiency improvements occur between 2002 and 2030 to define **technology possibility curves (TPC)**. (See Table B14 of the EIA Report for the coefficients of the technology possibility curves, or worksheet "EIA TPCurves" within the spreadsheet "mass_ind_gas_model.xls".) We use the TPC to estimate the relative energy intensity for end uses and industrial sectors in 2007, which is the starting point of the Massachusetts GasNetworks Analysis. That is,

REI(eu,existing,2007) = REI(eu,existing,2002) * ((1 – TPC(eu,existing))**5)

and,

REI(eu,new,2007) = REI(eu,new,2002) * ((1 – TPC(eu,new))**5).

For example, for Gas Process Heating (ph) in the Food Processing Industry,

*REI(ph,existing,2007) = 0.981 = 1.000 * ((1 – 0.0038)**5)*

and,

*REI(ph,new,2007) = 0.881 = 0.900 * ((1 - .0042)**5).*

New equipment, in this example, is approximately 10% more efficient than the stock average for existing facilities.

The **remaining factor** is calculated using the REI values and the relative relationship between new and old equipment. Assuming that the efficiency of new state-of-the-art (SOA) equipment is 85%, the average efficiency of the stock of existing equipment can be estimated as follows:

EF(eu,existing,2007) = REI(eu,new,2007)/ REI(eu,existing,2007) * 85%.

The average efficiency of equipment that is not SOA is assumed to be 90% of the average efficiency of the stock of existing equipment.

For example, the average stock efficiency for Gas Process Heating in the Food Processing Industry is estimated as

*EF(eu,existing,2007) = 76% = 0.881 / .981 * 85%, and*

the average efficiency of equipment that is not SOA is 90% of the average efficiency of the stock of existing equipment, i.e., 90% * 76% = 69%.

The portion of equipment that is not energy efficient (i.e., the remaining factor) is estimated based upon the relationship between the stock average efficiency, the

marginal efficiency and the efficiency of equipment that is not efficient. That is, for Gas Process Heating in the Food Processing Industry,

EF(eu,existing,2007) = (EF(eu,new,2007)*Pct. Efficient(eu,2007)) +

(EF(eu,not efficient,2007) *(1- Pct. Efficient(eu,2007))).

The portion of equipment that is energy efficient (Pct. Efficient) is estimated iteratively, starting with a 50% fraction. In the case for Gas Process Heating in the Food Processing Industry,

*EF(eu,existing,2007) = 76% ≈ (85% * 40%) + (69% * 60%).*

The same procedure is followed for each end use and industrial sector. (See the worksheet "EIA TPCurves" within the spreadsheet "mass_ind_gas_model.xls".)

The estimated values for the remaining fraction by end use and industrial segment can be found in the worksheet "Remaining Factor" within the spreadsheet "mass_ind_gas_model.xls" and summarized in Table C-2a.

Industrial Energy Efficiency Convertible Factor

The estimated values for the convertible fraction by measure can be found in Table C-2a. The convertibility factors are based on the applicability factors estimated for the NYSERDA gas potential study: Natural Gas Energy Efficiency Resource Development Potential in New York, October 31, 2006; see Table 4.5. In a number of cases, based upon analyses developed for GasNetworks commercial measures, we have adopted a 100% level of convertibility (e.g. for boilers, furnaces, and certain other measures) which is greater than assumed in the NYSERDA study. Where no information was available, 10% was used.

Industrial Energy Specific Savings Factor

Where appropriate, the industrial analysis used the same cost and savings relationships as utilized in preparing the energy efficiency potential estimates for the commercial sector. Otherwise, cost and savings estimates were adopted from available studies prepared for New York, California or New Hampshire. The estimated values for the specific savings factors by measure can be found in Table C-2a.

The following tables (C-2b, C-2c and C-2d) show the industrial sector energy efficiency measure savings data and sources for the data.

Table C-2b. Industrial Measure Data for Conventional Boiler Use

#	Industrial Measure	Equipment Replacement at End of Useful Life (ER) or Retrofit/New Construction	Equipment Useful Life (Years)	Useful Life Source	Baseline Efficiency Assumption	Baseline Efficiency Source	Savings Factor	Savings Factor Source	Cost per MMBtu Saved	Cost per MMBtu Saved Source
	Conventional Boiler Use (Boilers)									
I-CBU-1	High Efficiency Hot Water Boiler (<=300,000 Btu/h) (AFUE = 85%-90%)	ER	20	GDS Associates, GasNetworks Measure Assumptions Update, 2008	AFUE=80%	Energy Star Boiler Savings Calculator	6%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$38.34	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-2	Condensing Boiler (<=300,000 Btu/h) (AFUE>90%)	ER	18	GDS Associates, GasNetworks Measure Assumptions Update, 2008	AFUE=80%	Energy Star Boiler Savings Calculator	16%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$22.95	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-3	High Efficiency Steam Boiler (<=300,000 Btu/h) (AFUE >=82%)	ER	20	GDS Associates, GasNetworks Measure Assumptions Update, 2008	AFUE=75%	Energy Star Boiler Savings Calculator	9%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$44.98	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-4	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th. Eff. =85%-90%)	ER	25	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	10%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$30.54	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-5	Condensing Boiler (>300,000 Btu/h) (EF>90%) (Th. Eff. >=90%)	ER	18	GDS Associates, Measure Life Report, Residential and Commercial/Industrial, Lighting and HVAC Measures, Prepared for The New England State Program Working Group (SPWG) for use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), June 2007	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	13%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$28.67	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-6	High Efficiency Steam Boiler (>300,000 Btu/h) (Th. Eff. >=80%)	ER	25	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	5%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$38.95	Use Commercial Measure Data - See Appendix B, TABLE B-1
	Conventional Boiler Use (Other)									
I-CBU-7	Boiler Tune-Up	Retrofit	2	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito, KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Boiler that does not routinely receive a high efficiency boiler tune-up		5%	Use Commercial Measure Data - See Appendix B, TABLE B-1	$11.69	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-8	Boiler Pipe Insulation	Retrofit	15	NYSERDA Deemed Savings Database, Rev 09-08-2006	No boiler pipe insulation		2%	http://docs.cpuc.ca.gov/published/Report/30174.htm	$14.05	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-9	Boiler Reset Controls	Retrofit	20	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito, KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Boiler without reset controls		5%		$27.95	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-10	Boiler O2 Trim Controls	Retrofit	15	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	Boiler without O2 trim controls		2%	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp (Natural Gas Boiler/Burner Consortium, Oxygen Control)	$106.36	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-11	Electronic Parallel Positioning Controls (linkage less)	Retrofit	15	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	Mechanical linkage, jack shaft controls- Standard efficeincy		2%	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp (Natural Gas Boiler/Burner Consortium, Oxygen Control)	$154.22	Use Commercial Measure Data - See Appendix B, TABLE B-2
I-CBU-12	Boiler Blowdown Heat Exchanger (Steam)	Retrofit	20	NYSERDA Deemed Savings Database, Rev 09-08-2006	Boilers with no waste heat recovery		6%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	$42.51	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-13	Repair Malfunctioning Steam Traps	Retrofit	1	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix B p 36-37	Malfunctioning steam traps		10%	Found a wide range (4% - 16%) of savings estimates based on literature review Used a mid-range savings estimate factor of 10%	$5.42	Use Commercial Measure Data - See Appendix B, TABLE B-1

Table C-2b. Industrial Measure Data for Conventional Boiler Use

#	Industrial Measure	Equipment Replacement at End of Useful Life (ER) or Retrofit/New Construction	Equipment Useful Life (Years)	Useful Life Source	Baseline Efficiency Assumption	Baseline Efficiency Source	Savings Factor	Savings Factor Source	Cost per MMBtu Saved	Cost per MMBtu Saved Source
I-CBU-14	Insulate Steam Lines / Condensate Tank	Retrofit	15	NYSERDA Deemed Savings Database, Rev 09-08-2006	No steam line/condensate tank insulation		2%	5% - 10% improvement in energy associated with losses (Optimizing Steam Systems: Saving Energy and Money in Mexican Hotels, by David Jaber, Alliance to Save Energy) GDS estimates that poor insulation represents 15%- 20% of total gas input	$14.43	Use Commercial Measure Data - See Appendix B, TABLE B-1
I-CBU-15	Micro CHP	Retrofit	15	Emerging Energy-Saving Technologies and Practices for the Buildings Sector as of 2004, H.Sachs, S.Nadel, J.Amann, et al., Report No. A042, ACEEE, October 2004, p144.	No Micro CHP			Emerging Energy-Saving Technologies and Practices for the Buildings Sector as of 2004, H.Sachs, S.Nadel, J.Amann, et al., Report No. A042, ACEEE, October 2004 p 144		Use Commercial Measure Data - See Appendix B, TABLE B-1

Table C-2c. Industrial Measure Data for Process Heating

#	Industrial Measure	Equipment Replacement at End of Useful Life (ER) or Retrofit/New Construction	Equipment Useful Life (Years)	Useful Life Source	Baseline Efficiency Assumption	Baseline Efficiency Source	Savings Factor	Savings Factor Source	Cost per MMBtu Saved	Cost per MMBtu Saved Source
	Process Heating (Boilers)									
I-PH-1	High Efficiency Hot Water Boiler (>300,000 Btu/h) (Th. Eff. =85%-90%)	ER	25	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	10%	GDS Associates, Cost & Savings Estimates for Commercial Measures, GasNetworks Study, December 2008	$30.54	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-2	Condensing Boiler (>300,000 Btu/h) (EF>90%) (Th. Eff. >=90%)	ER	18	GDS Associates, Measure Life Report, Residential and Commercial/Industrial, Lighting and HVAC Measures, Prepared for The New England State Program Working Group (SPWG) for use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), June 2007	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	13%	GDS Associates, Cost & Savings Estimates for Commercial Measures, GasNetworks Study, December 2008	$28.67	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-3	High Efficiency Steam Boiler (>300,000 Btu/h) (Th. Eff. >=80%)	ER	25	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	Thermal Efficiency = 78%	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Commercial Gas Boilers	5%	GDS Associates, Cost & Savings Estimates for Commercial Measures, GasNetworks Study, December 2008	$38.95	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-4	Direct Fired Make-up Air System	Retrofit	20	GDS Associates, Measure Life Report, Residential and Commercial/Industrial, Lighting and HVAC Measures, Prepared for The New England State Program Working Group (SPWG) for use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), June 2007	Indirect fired make-up air system (78% Thermal Efficiency)	Direct Gas-Fired Air Handling Units: http://hpac.com/mag/direct_gasfired_airhandling/	16%	Natural Gas Energy Efficiency Resource Development Potential in New York, October 2006 Table 4.5, p. 4-32); CALIFORNIA INDUSTRIAL EXISTING CONSTRUCTION ENERGY EFFICIENCY POTENTIAL STUDY, CALMAC Study ID PGE0252.01 & PGE0252.02, May 2006 (Appendix F, p. F-8)	$53.69	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-5	Direct Contact Water Heater	Retrofit	20	GDS Associates, GasNetworks Measure Assumptions Update, 2008	Hot water system from steam/cold water manual mixing (65% Thermal Efficiency)	Energy Management Associates, Pearl Brand Meat: Calculations for Gas Savings, May 7, 2006	34%	Energy Management Associates, Pearl Brand Meat: Calculations for Gas Savings, May 7, 2006	$22.73	Bay State Gas, Commercial Kitchen Improve Process Efficiency Project, 2006
	Process Heating (Other)									
I-PH-6	Boiler Tune-Up	Retrofit	2	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito, KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Boiler that does not routinely receive a high efficiency boiler tune-up		5%	GDS Associates, Cost & Savings Estimates for Commercial Measures, GasNetworks Study, December 2008	$11.69	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-7	Boiler Pipe Insulation	Retrofit	15	NYSERDA Deemed Savings Database, Rev 09-08-2006	No boiler pipe insulation		2%	http://docs.cpuc.ca.gov/published/Report/30174.htm	$14.05	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-8	Boiler Reset Controls	Retrofit	20	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito, KEMA-XENERGY Inc., May 14, 2003 Appendix D.	Boiler without reset controls		5%	GDS Associates, Cost & Savings Estimates for Commercial Measures, GasNetworks Study, December 2008	$27.95	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-9	Boiler O2 Trim Controls	Retrofit	15	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	Boiler without O2 trim controls		2%	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp (Natural Gas Boiler/Burner Consortium, Oxygen Control)	$106.36	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-10	Electronic Parallel Positioning Controls (linkage less)	Retrofit	15	Tech Paper #924, Improving Boiler Room Efficiencies, Combustion Control Strategies For Single and Dual Element Power Burners, Federal Corporation, Rev. 07/01	Mechanical linkage, jack shaft controls- Standard efficeincy		2%	http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Efficiency/Oxygen_Control.asp (Natural Gas Boiler/Burner Consortium, Oxygen Control)	$154.22	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-PH-9	Waste-Heat Recovery	Retrofit	10	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (Table 4.5, p. 4-32)	Boilers with no waste heat recovery		6%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 Appendix B p 36-37.	$96.21	Use Commercial Measure Data - See Appendix B, TABLE B-2b; Cost for heat recovery, air-to-air, used.
I-PH-10	Gas Drying & Heating Technologies	Retrofit	10	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (Table 4.5, p. 4-32)	Electric drying and heating			Massachusetts Market Transformation Scoping Study, Stage II Final Report, September 30, 1997, pp. 2-129 to 2-138		Massachusetts Market Transformation Scoping Study, Stage II Final Report, September 30, 1997, pp. 2-129 to 2-138; Costs updated to 2009 dollars.

Table C-2c. Industrial Measure Data for Process Heating

#	Industrial Measure	Equipment Replacement at End of Useful Life (ER) or Retrofit/New Construction	Equipment Useful Life (Years)	Useful Life Source	Baseline Efficiency Assumption	Baseline Efficiency Source	Savings Factor	Savings Factor Source	Cost per MMBtu Saved	Cost per MMBtu Saved Source
I-PH-9	Regenerative Thermal Oxidizer vs. STO	Retrofit	10	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (Table 4.5, p. 4-32)	Non-regenerative VOC destruction systems	Brad Burns, B&B Engineered Systems, February 2009	95%	Brad Burns, B&B Engineered Systems, February 2009	$3.93	Brad Burns, B&B Engineered Systems, February 2009
I-PH-10	Regenerative Thermal Oxidizer vs. CTO	Retrofit	10	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (Table 4.5, p. 4-32)	Catalytic Oxidizer (60% Thermal Efficiency)	Brad Burns, B&B Engineered Systems, February 2009	69%	Brad Burns, B&B Engineered Systems, February 2009	$33.28	Brad Burns, B&B Engineered Systems, February 2009
I-PH-9	Infrared Oven	Retrofit	10	http://www.thermovation.com/pages/powdercoating1996.htm (Thermovation Equipment, Powder Coating 1996)	Non-gas process heating technologies		23%	Massachusetts Market Transformation Scoping Study, Stage II Final Report, September 30, 1997	$31.20	GDS Associates, NH Industrial Measure DB, Cost & Savings Estimates for Industrial Measures, $/MMBTU for HVAC & Other Facility Support, December 2008
I-PH-10	Improved Sensors & Process Controls	Retrofit	5	NYSERDA Deemed Savings Database, Rev 09-08-2006	Conventional Process Controls		5%	Natural Gas Energy Efficiency Resource Development Potential in New York, Final Report for NYSERDA, by Optimal Energy, ACEEE, VEIC, Resource Insight and Energy & Environmental Analysis, October 2006 (Table 4.5, p. 4-32)	$31.20	GDS Associates, NH Industrial Measure DB, Cost & Savings Estimates for Industrial Measures, $/MMBTU for HVAC & Other Facility Support, December 2008
I-PH-9	Refrigeration Heat Recovery	Retrofit	15	GDS Associates, GasNetworks Measure Assumptions Update, 2008	Storage tank water heater = 0.59 EF	US DOE- Federal Energy Management Program (FEMP): Energy Cost Calculator for Gas Water Heaters	50%	Therma-Stor Return on Investment calculation Form	$18.56	Use Commercial Measure Data - See Appendix B, TABLE B-2b

Table C-2d. Industrial Measure Data for HVAC & Other

#	Industrial Measure	Equipment Replacement at End of Useful Life (ER) or Retrofit/New Construction	Equipment Useful Life (Years)	Useful Life Source	Baseline Efficiency Assumption	Baseline Efficiency Source	Savings Factor	Savings Factor Source	Cost per MMBtu Saved	Cost per MMBtu Saved Source
	Facility HVAC									
I-HVAC-1	High Efficiency Furnace (<=300,000 Btu/h) (AFUE >=92%)	ER	18	GDS Associates, GasNetworks Measure Assumptions Update, 2008	AFUE = 78%	Energy Star Furnace Savings Calculator	15%	Use Commercial Measure Data - See Appendix B, TABLE B-2b	$17.20	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-2	Gas Unit Heater - Condensing	ER	19	Harvey M. Sachs, Unit Heaters Deserve Attention for Commercial Purposes, Report No. A031, ACEEE, April 2003 (http://www.aceee.org/pubs/a031full.pdf)	Gravity vented heater with seasonal efficeincy of 80%	Harvey M. Sachs, Unit Heaters Deserve Attention for Commercial Purposes, Report No. A031, ACEEE, April 2003 (http://www.aceee.org/pubs/a031full.pdf)	14%	Use Commercial Measure Data - See Appendix B, TABLE B-2b	$53.69	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-3	Infrared Heater (low intensity - two stage)	ER	17	GDS Associates, GasNetworks Measure Assumptions Update, 2008	Gravity vented heater with seasonal efficeincy of 63%	Harvey M. Sachs, Unit Heaters Deserve Attention for Commercial Purposes, Report No. A031, ACEEE, April 2003 (http://www.aceee.org/pubs/a031full.pdf)	26%	Use Commercial Measure Data - See Appendix B, TABLE B-2b	$15.49	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-4	Insulate and Seal Ducts (New Aerosl Duct Sealing)	Retrofit	20	NYSERDA Deemed Savings Database, Rev 09-08-2006	Leaky, unsealed and uninsulated ducts		7%	Inproved Duct Sealing, ASHRAE Journal, May 2003	$245.33	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-5	Stack Heat Exchanger (Standard Economizer)	Retrofit	20	NYSERDA Deemed Savings Database, Rev 09-08-2006	Boiler without economizer		5%	Use Commercial Measure Data - See Appendix B, TABLE B-2b	$14.29	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-6	Stack Heat Exchanger (Condensing Economizer)	Retrofit	20	NYSERDA Deemed Savings Database, Rev 09-08-2006	Boiler without economizer		10%	Use Commercial Measure Data - See Appendix B, TABLE B-2b	$10.10	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-7	Heat Recovery: Air to Air	Retrofit	20	CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito, KEMA-XENERGY Inc., May 14, 2003	No air-to-air heat exchanger		13%	GDS Associates, Energy-10 Simulation (PNM Study)	$96.21	Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-8	Desiccant Dehumidification	ER	20	User Guide for Desiccant User Guide for Desiccant Dehumidification Technology, Thomas E. Durbin and Michael A. Caponegro, U.S. Army Construction Engineering Research Laboratories, Champaign, IL	Conventional electric HVAC			Energy Consumption Characteristics of Commercial Building HVAC Systems, Volume III: Energy Savings Potential, TIAX LLC, July 2002		Use Commercial Measure Data - See Appendix B, TABLE B-2b
I-HVAC-9	Direct Fired Make-up Air System	Retrofit	20	GDS Associates, Measure Life Report, Residential and Commercial/Industrial, Lighting and HVAC Measures, Prepared for The New England State Program Working Group (SPWG) for use as an Energy Efficiency Measures/Programs Reference Document for the ISO Forward Capacity Market (FCM), June 2007	Indirect fired make-up air system (78% Thermal Efficiency)	Direct Gas-Fired Air Handling Units: http://hpac.com/mag/direct_gasfired_airhandling/	16%	Natural Gas Energy Efficiency Resource Development Potential in New York, October 2006 Table 4.5, p. 4-32); CALIFORNIA INDUSTRIAL EXISTING CONSTRUCTION ENERGY EFFICIENCY POTENTIAL STUDY, CALMAC Study ID PGE0252.01 & PGE0252.02, May 2006 (Appendix F, p. F-8)	$53.69	Use Commercial Measure Data - See Appendix B, TABLE B-2b; Cost for gas unit heater used.
	Other Measures									
I-OM-1	Gas Fired Air Compression - Peak Shaving	Retrofit	10	http://www.aircompressor.org/html/technology/nat_gas_engines.html	Electric air compression	http://www.aircompressor.org/html/technology/nat_gas_engines.html (Natural Gas Engines); http://www.energysolutionscenter.org/tech/tech_compressors.asp; http://www.aircompressor.org/pdf/cerl_demo.pdf				

APPENDIX D

Benefit-Cost Model Inputs and Assumptions

Tables D-1 and D-2 below show the GDS modeling assumptions used in this study for:

- Discount Rate
- Inflation rate
- Energy Loss Multipliers
- Demand Loss Multipliers
- Reserve margin Multiplier
- Avoided T&D Costs
- T&D Loss Multiplier

Table D-1 – Discount and Inflation rates	
Discount Rate	4.59%
Inflation Rate	2.50%
Real Discount Rate	2.04%

Table D-2 – Loss and Reserve Margin Multipliers and T&D Avoided Costs									
Electric Energy Loss Multipliers				**Electric Demand Loss Multipliers**		**Reserve Margin Multiplier**	**Avoided T&D Costs ($/kWYr)**		**T & D Loss Multiplier**
Winter		**Summer**		**Winter**	**Summer**		**Residential**	**C & I**	
On Peak	**Off Peak**	**On Peak**	**Off Peak**						
1.0389	1.0303	1.0389	1.0800	1.0553	1.0563	1.1430	$53.03	$80.00	1.00800

Avoided Costs and Non-Electric Retail Rates

Tables D-3, D-4 and D-5 show the electric and gas avoided costs and non-electric retail rates, respectively, that were used by GDS in this study. The source of this data is the following report:

Synapse Energy Economics, *Avoided Energy Supply Costs in New England*: Rick Hornby, Dr. Carl V. Swanson, Michael Drunsic, Dr. David E. White, Paul Chernick, Bruce Biewald, and Jennifer Kallay, Prepared for the Avoided-Energy-Supply-Component (AESC) Study Group, August 10, 2007.

The above report provided avoided cost values through 2040. After 2040 the avoided costs in year 2009 dollars are held constant at the 2040 values.

Table D-3: Electric Avoided Costs

	Electric Energy - Region - Massachusetts				Electric Capacity - Region - Massachusetts	
	Seasonal Avoided Energy in Nominal $				Seasonal Avoided Capacity in	
	Winter Peak Energy	Winter Off-Peak Energy	Summer Peak Energy	Summer Off-Peak Energy	Summer Generation	Winter Generation
Years	(¢/kWh)	(¢/kWh)	(¢/kWh)	(¢/kWh)	($/kW)	($/kW)
2007	8.5389	6.2865	8.6774	6.5272	0.0000	0.0000
2008	9.8048	7.3134	9.0812	6.9261	0.0000	0.0000
2009	9.3662	7.195	9.309	6.708	0.0000	0.0000
2010	9.5251	7.010	9.592	6.581	57.2906	0.0000
2011	9.3367	6.870	9.685	6.568	105.9108	0.0000
2012	9.6413	7.211	10.115	7.039	121.4567	0.0000
2013	9.3421	6.838	9.931	6.790	132.2050	0.0000
2014	9.8577	7.030	10.194	7.058	135.5102	0.0000
2015	9.9281	7.246	10.900	7.161	138.8979	0.0000
2016	10.4419	7.544	11.245	7.695	142.3704	0.0000
2017	10.9573	7.949	11.844	7.841	145.9296	0.0000
2018	10.9781	8.060	11.959	8.116	149.5779	0.0000
2019	11.2040	8.098	12.503	8.136	153.3173	0.0000
2020	11.6412	8.523	12.918	8.397	157.1503	0.0000
2021	12.0856	8.793	13.849	8.706	161.0790	0.0000
2022	12.7739	9.156	14.394	9.109	165.1060	0.0000
2023	13.2831	9.521	14.968	9.472	169.2336	0.0000
2024	13.8126	9.900	15.565	9.850	173.4645	0.0000
2025	14.3632	10.295	16.185	10.242	177.8011	0.0000
2026	14.9358	10.705	16.830	10.651	182.2461	0.0000
2027	15.5312	11.132	17.501	11.075	186.8023	0.0000
2028	16.1503	11.576	18.199	11.517	191.4723	0.0000
2029	16.7941	12.037	18.924	11.976	196.2591	0.0000
2030	17.4635	12.517	19.679	12.453	201.1656	0.0000
2031	18.1597	13.016	20.463	12.949	206.1948	0.0000
2032	18.8836	13.535	21.279	13.466	211.3496	0.0000
2033	19.6363	14.074	22.127	14.002	216.6334	0.0000
2034	20.4190	14.635	23.009	14.561	222.0492	0.0000
2035	21.2330	15.219	23.926	15.141	227.6004	0.0000
2036	22.0794	15.825	24.880	15.745	233.2904	0.0000
2037	22.9595	16.456	25.872	16.372	239.1227	0.0000
2038	23.8748	17.112	26.903	17.025	245.1008	0.0000
2039	24.8265	17.794	27.975	17.703	251.2283	0.0000
2040	25.8161	18.504	29.091	18.409	257.5090	0.0000
2041	26.4615	18.966	29.818	18.869	263.9467	0.0000
2042	27.123	19.441	30.563	19.341	270.5454	0.0000
2043	27.801	19.927	31.327	19.825	277.3090	0.0000
2044	28.496	20.425	32.111	20.320	284.2418	0.0000
2045	29.209	20.935	32.913	20.828	291.3478	0.0000
2046	29.939	21.459	33.736	21.349	298.6315	0.0000
2047	30.687	21.995	34.579	21.883	306.0973	0.0000
2048	31.454	22.545	35.444	22.430	313.7497	0.0000
2049	32.241	23.109	36.330	22.990	321.5935	0.0000
2050	33.047	23.686	37.238	23.565	329.6333	0.0000
2051	33.873	24.279	38.169	24.154	337.8741	0.0000
2052	34.720	24.886	39.124	24.758	346.3210	0.0000
2053	35.588	25.508	40.102	25.377	354.9790	0.0000
2054	36.478	26.145	41.104	26.012	363.8535	0.0000
2055	37.389	26.799	42.132	26.662	372.9498	0.0000
2056	38.324	27.469	43.185	27.328	382.2736	0.0000
2057	39.282	28.156	44.265	28.012	391.8304	0.0000
2058	40.264	28.860	45.371	28.712	401.6262	0.0000
2059	41.271	29.581	46.506	29.430	411.6668	0.0000
2060	42.303	30.321	47.668	30.165	421.9585	0.0000
2061	43.360	31.079	48.860	30.920	432.5074	0.0000
2062	44.444	31.856	50.081	31.693	443.3201	0.0000
2063	45.555	32.652	51.333	32.485	454.4031	0.0000
2064	46.694	33.468	52.617	33.297	465.7632	0.0000
2065	47.862	34.305	53.932	34.129	477.4073	0.0000

Table D-4: Gas Avoided Costs

Natural Gas in Nominal $ - Region - Northern and Central New England							
Commerical & Industrial			Residential				Retail
Non-Heating ($/MMBtu)	Heating ($/MMBtu)	All ($/MMBtu)	Heating Retrofit ($/MMBtu)	New Heating ($/MMBtu)	Hot Water $/MMBtu	All ($/MMBtu)	All ($/MMBtu)
10.5784	11.6316	11.3151	12.8848	12.7065	11.6533	12.3900	12.1217
11.8599	13.0093	12.6630	14.2993	14.1111	12.9617	13.7648	13.5117
11.6101	12.7507	12.4075	14.0700	13.8801	12.7395	13.5369	13.2657
11.3136	12.4424	12.1033	13.7916	13.6000	12.4712	13.2609	12.9703
11.0747	12.1959	11.8595	13.5760	13.3824	12.2612	13.0460	12.7369
10.9469	12.0684	11.7323	13.4809	13.2846	12.1631	12.9485	12.6229
10.4612	11.5586	11.2305	13.0024	12.8052	11.7079	12.4771	12.1270
10.7951	11.9249	11.5870	13.4051	13.2026	12.0729	12.8647	12.5075
11.0068	12.1608	11.8157	13.6777	13.4705	12.3165	13.1254	12.7580
11.4605	12.6556	12.2981	14.2114	13.9981	12.8030	13.6405	13.2678
12.0804	13.3283	12.9546	14.9247	14.7043	13.4564	14.3306	13.9557
12.2780	13.5499	13.1691	15.1857	14.9603	13.6884	14.5795	14.1930
12.5219	13.8213	13.4324	15.4977	15.2670	13.9676	14.8781	14.4805
13.0071	14.3507	13.9484	16.0700	15.8326	14.4889	15.4302	15.0264
13.4828	14.8703	14.4547	16.6334	16.3892	15.0016	15.9736	15.5629
14.2005	15.6489	15.2147	17.4581	17.2058	15.7574	16.7716	16.3589
14.7011	16.2006	15.7510	18.0735	17.8123	16.3128	17.3628	16.9355
15.2193	16.7716	16.3063	18.7105	18.4402	16.8878	17.9748	17.5325
15.7558	17.3628	16.8811	19.3701	19.0902	17.4831	18.6084	18.1505
16.3112	17.9749	17.4761	20.0529	19.7631	18.0994	19.2644	18.7903
16.8861	18.6085	18.0921	20.7598	20.4598	18.7374	19.9434	19.4527
17.4814	19.2644	18.7299	21.4915	21.1810	19.3979	20.6464	20.1384
18.0976	19.9435	19.3901	22.2491	21.9276	20.0817	21.3742	20.8483
18.7355	20.6465	20.0736	23.0334	22.7006	20.7896	22.1277	21.5832
19.3960	21.3743	20.7812	23.8453	23.5007	21.5224	22.9077	22.3440
20.0797	22.1278	21.5138	24.6859	24.3291	22.2811	23.7151	23.1316
20.7875	22.9078	22.2721	25.5560	25.1868	23.0665	24.5511	23.9470
21.5202	23.7153	23.0572	26.4569	26.0746	23.8796	25.4165	24.7911
22.2788	24.5512	23.8700	27.3895	26.9937	24.7213	26.3125	25.6650
23.0642	25.4167	24.7114	28.3550	27.9452	25.5927	27.2400	26.5697
23.8772	26.3126	25.5825	29.3545	28.9303	26.4949	28.2002	27.5063
24.7188	27.2401	26.4843	30.3892	29.9501	27.4288	29.1942	28.4759
25.5902	28.2003	27.4178	31.4605	31.0058	28.3957	30.2233	29.4796
26.4922	29.1944	28.3843	32.5694	32.0988	29.3967	31.2887	30.5188
27.1545	29.9243	29.0939	33.3837	32.9013	30.1316	32.0709	31.2818
27.8334	30.6724	29.8213	34.2183	33.7238	30.8849	32.8727	32.0638
28.5292	31.4392	30.5668	35.0737	34.5669	31.6570	33.6945	32.8654
29.2425	32.2251	31.3310	35.9506	35.4311	32.4484	34.5369	33.6870
29.9735	33.0308	32.1142	36.8493	36.3168	33.2596	35.4003	34.5292
30.7229	33.8565	32.9171	37.7706	37.2248	34.0911	36.2853	35.3924
31.4910	34.7030	33.7400	38.7148	38.1554	34.9434	37.1924	36.2772
32.2782	35.5705	34.5835	39.6827	39.1093	35.8170	38.1223	37.1842
33.0852	36.4598	35.4481	40.6748	40.0870	36.7124	39.0753	38.1138
33.9123	37.3713	36.3343	41.6916	41.0892	37.6302	40.0522	39.0666
34.7601	38.3056	37.2427	42.7339	42.1164	38.5710	41.0535	40.0433
35.6291	39.2632	38.1737	43.8023	43.1693	39.5352	42.0798	41.0444
36.5198	40.2448	39.1281	44.8973	44.2486	40.5236	43.1318	42.0705
37.4328	41.2509	40.1063	46.0198	45.3548	41.5367	44.2101	43.1222
38.3687	42.2822	41.1089	47.1703	46.4886	42.5751	45.3154	44.2003
39.3279	43.3392	42.1367	48.3495	47.6509	43.6395	46.4483	45.3053
40.3111	44.4227	43.1901	49.5583	48.8421	44.7305	47.6095	46.4379
41.3189	45.5333	44.2698	50.7972	50.0632	45.8487	48.7997	47.5989
42.3518	46.6716	45.3766	52.0671	51.3148	46.9950	50.0197	48.7889
43.4106	47.8384	46.5110	53.3688	52.5976	48.1698	51.2702	50.0086
44.4959	49.0344	47.6738	54.7030	53.9126	49.3741	52.5520	51.2588
45.6083	50.2602	48.8656	56.0706	55.2604	50.6084	53.8658	52.5403
46.7485	51.5167	50.0872	57.4724	56.6419	51.8736	55.2124	53.8538
47.9172	52.8047	51.3394	58.9092	58.0579	53.1705	56.5927	55.2001
49.1151	54.1248	52.6229	60.3819	59.5094	54.4997	58.0075	56.5801

Table D-5 Non-Electric Retail Rates

	New England Average Price Forecast of Other Fuel Prices by Sector									
	Fuel Oil in Nominal $					Propane in Nominal $			Wood in Nominal $	
	Res. Distillate	Com. #2 Oil	Com. #4 Oil	Ind. #6 Oil	Kerosene	Residential	Commercial	Industrial	Greenwood	Seasoned
Years	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBtu)	($/MMBTU)	($/MMBTU)
2007	15.8379	13.9659	11.7147	9.4634	16.4738	26.8095	26.8095	26.8095	5.67	7.43
2008	16.8422	14.8515	12.4575	10.0635	17.5184	29.4739	29.4739	29.4739	6.03	7.90
2009	16.8603	14.8675	12.4709	10.0743	17.5372	30.4341	30.4341	30.4341	6.04	7.91
2010	16.7738	14.7912	12.4069	10.0227	17.4473	31.6923	31.6923	31.6923	6.01	7.87
2011	16.6731	14.7024	12.3324	9.9625	17.3425	32.7904	32.7904	32.7904	5.97	7.82
2012	16.6012	14.6391	12.2793	9.9196	17.2678	34.0298	34.0298	34.0298	5.95	7.79
2013	16.4941	14.5445	12.2000	9.8555	17.1563	34.3335	34.3335	34.3335	5.91	7.74
2014	16.6799	14.7084	12.3375	9.9665	17.3496	35.2196	35.2196	35.2196	5.97	7.83
2015	17.1742	15.1443	12.7031	10.2619	17.8638	35.9983	35.9983	35.9983	6.15	8.06
2016	17.6834	15.5933	13.0797	10.5662	18.3934	36.9710	36.9710	36.9710	6.33	8.30
2017	18.2905	16.1286	13.5287	10.9289	19.0248	38.2139	38.2139	38.2139	6.55	8.58
2018	18.9221	16.6856	13.9959	11.3063	19.6818	39.0520	39.0520	39.0520	6.78	8.88
2019	19.5685	17.2556	14.4740	11.6925	20.3541	39.9311	39.9311	39.9311	7.01	9.18
2020	20.2409	17.8485	14.9714	12.0943	21.0535	41.0785	41.0785	41.0785	7.25	9.50
2021	21.0200	18.5356	15.5477	12.5599	21.8640	41.9294	41.9294	41.9294	7.53	9.86
2022	21.8313	19.2510	16.1478	13.0446	22.7079	43.1877	43.1877	43.1877	7.82	10.24
2023	22.6700	19.9905	16.7682	13.5458	23.5803	44.4844	44.4844	44.4844	8.12	10.64
2024	23.5309	20.7497	17.4049	14.0602	24.4757	45.6600	45.6600	45.6600	8.43	11.04
2025	24.4270	21.5398	18.0677	14.5956	25.4077	46.8136	46.8136	46.8136	8.75	11.46
2026	25.2437	22.2600	18.6718	15.0836	26.2572	48.0369	48.0369	48.0369	9.04	11.84
2027	26.0925	23.0085	19.2996	15.5908	27.1402	49.4094	49.4094	49.4094	9.35	12.24
2028	26.9613	23.7746	19.9422	16.1099	28.0438	50.9086	50.9086	50.9086	9.66	12.65
2029	27.8572	24.5646	20.6049	16.6452	28.9757	52.3454	52.3454	52.3454	9.98	13.07
2030	28.7881	25.3855	21.2935	17.2014	29.9440	53.7240	53.7240	53.7240	10.31	13.51
2031	29.8029	26.2803	22.0441	17.8078	30.9995	55.6178	55.6178	55.6178	10.67	13.98
2032	30.8535	27.2067	22.8211	18.4355	32.0922	57.5783	57.5783	57.5783	11.05	14.48
2033	31.9410	28.1658	23.6256	19.0854	33.2235	59.6080	59.6080	59.6080	11.44	14.99
2034	33.0670	29.1586	24.4584	19.7581	34.3946	61.7091	61.7091	61.7091	11.84	15.51
2035	34.2326	30.1864	25.3205	20.4546	35.6070	63.8844	63.8844	63.8844	12.26	16.06
2036	35.4393	31.2505	26.2131	21.1756	36.8622	66.1363	66.1363	66.1363	12.69	16.63
2037	36.6885	32.3521	27.1371	21.9221	38.1616	68.4676	68.4676	68.4676	13.14	17.21
2038	37.9818	33.4925	28.0937	22.6948	39.5068	70.8811	70.8811	70.8811	13.60	17.82
2039	39.3206	34.6731	29.0840	23.4948	40.8994	73.3797	73.3797	73.3797	14.08	18.45
2040	40.7067	35.8953	30.1092	24.3230	42.3411	75.9663	75.9663	75.9663	14.58	19.10
2041	41.7243	36.7927	30.8619	24.9311	43.3996	77.8655	77.8655	77.8655	14.94	19.58
2042	42.7675	37.7125	31.6334	25.5544	44.4846	79.8121	79.8121	79.8121	15.32	20.07
2043	43.8366	38.6554	32.4243	26.1932	45.5967	81.8074	81.8074	81.8074	15.70	20.57
2044	44.9326	39.6217	33.2349	26.8480	46.7366	83.8526	83.8526	83.8526	16.09	21.08
2045	46.0559	40.6123	34.0658	27.5192	47.9050	85.9489	85.9489	85.9489	16.50	21.61
2046	47.2073	41.6276	34.9174	28.2072	49.1027	88.0976	88.0976	88.0976	16.91	22.15
2047	48.3875	42.6683	35.7903	28.9124	50.3302	90.3001	90.3001	90.3001	17.33	22.70
2048	49.5971	43.7350	36.6851	29.6352	51.5885	92.5576	92.5576	92.5576	17.76	23.27
2049	50.8371	44.8284	37.6022	30.3761	52.8782	94.8715	94.8715	94.8715	18.21	23.85
2050	52.1080	45.9491	38.5423	31.1355	54.2002	97.2433	97.2433	97.2433	18.66	24.45
2051	53.4107	47.0978	39.5058	31.9139	55.5552	99.6744	99.6744	99.6744	19.13	25.06
2052	54.7460	48.2752	40.4935	32.7117	56.9440	102.1662	102.1662	102.1662	19.61	25.69
2053	56.1146	49.4821	41.5058	33.5295	58.3676	104.7204	104.7204	104.7204	20.10	26.33
2054	57.5175	50.7192	42.5435	34.3678	59.8268	107.3384	107.3384	107.3384	20.60	26.99
2055	58.9554	51.9872	43.6071	35.2270	61.3225	110.0219	110.0219	110.0219	21.12	27.66
2056	60.4293	53.2868	44.6972	36.1076	62.8556	112.7724	112.7724	112.7724	21.64	28.35
2057	61.9400	54.6190	45.8147	37.0103	64.4270	115.5917	115.5917	115.5917	22.18	29.06
2058	63.4885	55.9845	46.9600	37.9356	66.0376	118.4815	118.4815	118.4815	22.74	29.79
2059	65.0757	57.3841	48.1340	38.8840	67.6886	121.4435	121.4435	121.4435	23.31	30.53
2060	66.7026	58.8187	49.3374	39.8561	69.3808	124.4796	124.4796	124.4796	23.89	31.30
2061	68.3702	60.2892	50.5708	40.8525	71.1153	127.5916	127.5916	127.5916	24.49	32.08
2062	70.0795	61.7964	51.8351	41.8738	72.8932	130.7814	130.7814	130.7814	25.10	32.88
2063	71.8314	63.3413	53.1310	42.9206	74.7155	134.0509	134.0509	134.0509	25.73	33.70
2064	73.6272	64.9248	54.4592	43.9936	76.5834	137.4022	137.4022	137.4022	26.37	34.54
2065	75.4679	66.5480	55.8207	45.0935	78.4980	140.8373	140.8373	140.8373	27.03	35.41