# Strategies to Increase Residential HVAC Efficiency in the Northeast

Final Report
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# 1. INTRODUCTION

In the Northeastern United States, residential heating, ventilation and air conditioning (HVAC) is an important component of the region's energy profile as

- Home heating accounts for roughly one-fourth of the region's oil and gas consumption annually, and
- Heating and cooling account for 60 percent of average annual household energy consumption in the region.[1]

Residential HVAC holds considerable promise for increased energy efficiency in the Northeast. The efficiency opportunities have the potential to displace electric and gas peak demand, as well as electric, gas and oil consumption. A variety of strategies are needed to achieve this potential due to the fact that the HVAC market is complex and includes multiple fuels, as well as the fact that many market barriers to energy efficiency are present. Moreover, there are some major gaps in coverage provided by current efficiency programs. However, with a comprehensive approach that takes advantage of technologies, organizations and programs currently available and that develops some of the emerging opportunities that have been identified, many obstacles can be tackled so that substantial long-lasting reductions in consumption can be accomplished. The NYSERDA Home Performance with ENERGY STAR® Program demonstrates the success of a comprehensive approach.

## 1. 1 Purpose and Context of Study

In 2004, the National Association of State Energy Offices (NASEO) awarded a State Technology Advancement Collaborative (STAC) grant to conduct research on strategies to increase residential HVAC energy efficiency in the Northeast. Under the provisions of the grant, matching funds were provided by the New York State Energy Research and Development Authority (NYSERDA) and the New Jersey Board of Public Utilities (NJBPU). The research examined various aspects of the opportunities and challenges associated with realizing the potential to reduce electricity, gas, and oil consumption available from existing and emerging efficiency technologies and practices. Its objective was to provide information useful in developing a strategic agenda for how to realize energy efficiency opportunities from residential HVAC in the Northeast. We believe that results of the research tasks reported here are useful to document key issues pertaining to delivery of HVAC efficiency in the Northeast and to inform decisions about future Northeast HVAC efficiency program directions. We hope this study serves as a starting point for expanded programs and continued regional dialogue on energy efficiency policy as well as development of future research.

[1] 2001 Energy Information Administration, Residential Energy Consumption Survey and 2005 Annual Energy Outlook.

## 1.2 Summary of Scope and Findings

The project scope called for a “comprehensive” assessment of residential HVAC efficiency opportunities and strategies. The analysis covers all major fuels, electricity, gas, oil and propane. For the purposes of this study, the sector and region are restricted to single-family homes in New York, New Jersey, and the New England states combined (Maine through Connecticut). The study assessed achievable energy efficiency potential over ten years from 2007 through 2016. It included most applicable HVAC efficiency measures, with the exception of fuel switching, building shell, and integrated heating and water heating.

The overarching objective of the study is to develop recommendations for energy efficiency strategies that address all the primary HVAC fuels in the region. The recommendations are informed by specific research tasks designed to characterize various market opportunities and challenges.

The study included the following research tasks:

- Characterize the regional HVAC market based on market research.
- Identify key emerging HVAC technologies and practices.
- Estimate the potential achievable cost-effective electric, natural gas, and oil savings in the Northeast region over a 10-year horizon from delivery of a portfolio of existing and emerging technologies and practices.
- Explore benefits of HVAC contractor training related to energy efficiency of central air conditioning installations based on field research.
- Explore the actual performance of high efficiency cooling and heating equipment based on field research.
- Develop a model duct sealing program scenario based on market research.

The study findings are summarized as follows:

**Economic Potential.** Our analysis finds that there is $3.02 billion (net present value) or 26,234.46 BBTU in achievable energy efficiency potential from residential HVAC measures and practices in the Northeast over the next ten years. This translates into 26,234.46 BBTU of cumulative electric, oil and gas savings - enough to reduce forecasted residential oil, gas and electricity consumption in the Northeast in 2016 by over 1 percent. The benefit:cost ratio to realize this potential is 3.34.

New England, New York and New Jersey account for 29 percent, 38 percent, and 33 percent of the value of the savings, respectively. Overall, most of the potential savings come from existing homes. Over half of the oil heat savings, however, are from new construction. In a breakout by end use, duct sealing, which has heating and cooling benefits, is the source of over half of the potential. Efficient heating equipment, practices associated with quality installation of central air conditioning, and cooling equipment (central air conditioners and ductless mini-split systems) contribute 21 percent, 19 percent, and 8 percent of the savings, respectively.

**Market Characterization.** An understanding of the structure of the HVAC market is necessary for identifying efficiency opportunities and understanding what strategies are needed to realize achievable potential. This includes industry trends, industry structure and culture, critical market barriers, and the role of national organizations, as well as current efficiency programs.

The Northeast is characterized by relatively old housing stock and heating systems, many of which are hydronic (steam or hot water) furnaces or boilers. The region is further characterized by increasing penetration of central air conditioning in existing homes, including installation of duct systems. The current market share for high efficiency central cooling and high efficiency oil heating equipment has been estimated at five percent or less, and it is not expected to increase significantly without efficiency program intervention. Current market shares for efficient gas heating equipment are somewhat higher, 40 – 65 percent for furnaces and 52 percent for boilers.

Critical market barriers to realizing increased energy savings associated with high efficiency HVAC measures include: limited consumer awareness of energy efficiency opportunities and benefits; inability to differentiate good contractors in the marketplace; inability to differentiate quality of installations; poor contractor sales skills; seasonality of sales; split incentives; and electric prices that do not reflect true societal costs of operating air conditioners at summer peak.

Recent legislation and activities by several HVAC trade organizations are helping to create opportunities for the Northeast market for efficient HVAC measures and practices. Chief among these are federal Energy Policy Act (EPACT) legislation, including tax incentives for efficient equipment, enactment of state efficiency standards, completion of quality installation specifications by the Air Conditioning Contractors of America (ACCA), preparation of a draft ENERGY STAR quality installation specification, as well as support for training and certification of HVAC contractors and technicians by the Building Performance Institute, North American Technician Excellence association (NATE), and others.

Most states have efficiency programs that address electric and gas heat and central air conditioning, but there is little or no consistency between the programs in the states in the Northeast. With the exception of NYSERDA's New York Home Performance with ENERGY STAR Program, duct sealing and quality installation of air conditioning are just beginning to become features of efficiency programs. With few exceptions, mostly related to Home Performance programs, oil heat is not addressed in efficiency programs.  Again, with the exception of NYSERDA's Home Performance Program, installation quality is not addressed by programs promoting efficient heating systems.  Overall, it is evident that a comprehensive, whole house approach to residential contracting and energy efficiency related work is most effective at delivering optimal savings and ensuring the home is left in a safe condition.

**Field investigation of benefits of contractor training.** Several field studies were conducted to improve our understanding of current conditions relating to contractor practices and equipment performance. In a field study to assess the benefits of contractor training, two groups of homes in New Jersey were examined, one with central air conditioning systems installed by NATE trained and certified contractors[2], and one with systems installed by contractors who were not NATE certified. This study found no statistically significant difference in installation quality, specifically: refrigerant charge, airflow, and equipment sizing, at the 90 percent confidence level. There was a significant difference in duct sealing quality (better quality with the certified group). Eighty-three percent of all homeowners across both groups were satisfied with their systems, and 76 percent were satisfied with their installers. Across the two groups, installation quality was found lacking: only thirty-six percent of the ducts were sealed and only twenty percent of the systems had the correct refrigerant charge. Forty-nine percent of the systems had insufficient airflow. These results suggest that contractor training and certification as a standalone requirement is important, but is not sufficient enough to ensure quality installation. Programs should seriously consider inclusion of a verification and quality assurance component. New York has found success in requiring 15% of all work done through the New York Home Performance with ENERGY STAR to be verified by field technicians to assure quality installations and identification of opportunities. Programs should also consider promoting equipment such as ductless mini-splits as alternatives to ducted central air conditioning, where appropriate. See Appendix B for further discussion of features of ductless mini- splits.

**Field performance of central air conditioning systems.** Five high SEER air conditioning systems (four two speed and one single speed) were monitored during the 2005 cooling season. While definitive conclusions are not possible from the small sample, results suggest that:

- Actual average seasonal efficiencies were significantly lower than rated efficiencies. (The average seasonal efficiency was 9.6 Btu/Wh or just 67 percent of the units' average SEER rating of 14.25).
- Actual steady-state operating efficiencies of variable speed units can differ from rated steady-state efficiencies. At low speed, they ranged from 79 to 95 percent of rated efficiency due to higher than rated watt draws, while variations from rated efficiencies at high speed were primarily a function of variances from rated capacities (some lower, some higher).

[2] In this study trained, certified contractors are defined as those working in a company in which over 75% of technicians employed have passed standardized tests on proper HVAC installation practices and as a result have received NATE certification.

- Manual J may significantly over-state actual total loads on the house. Average total loads were 56 percent of Manual J estimates. Oversizing contributed to an inability to control humidity levels in one home.
- Occupant behavior has a major impact on system efficiency and comfort. The two homes that ran their fans continuously saw significant deterioration of seasonal efficiency, and one of those homes also experienced a serious inability to control humidity levels.
- Over-sizing is not likely to significantly affect seasonal energy use of variable speed systems, since – for most units – the average duty cycle EER was very close to the end of cycle EER. However, proper sizing may still provide significant peak demand savings.

**Field performance of efficient gas furnaces.** Four high-efficiency condensing gas furnaces were monitored during the 2004/2005 heating season. While the sample is not statistically representative, the results revealed significant differences between rated and measured efficiency in these four cases. Measured efficiencies of all units ranged from 60 – 80 percent, compared with rated AFUEs over 90 percent. Because this monitoring task was an add-on to the original project scope, with limited funding, it was not possible to further study or identify the factors contributing to the discrepancy between actual and rated performance. The questions raised by these observations should be addressed in future research projects.

**Duct sealing research and program design.** Because duct sealing is an important source of efficiency potential, a case study on duct sealing program design was included as part of this research effort. Market research in support of program design included a focus group of HVAC contractors. Results of the focus group identified the following as important elements of a market-based duct sealing program:

- Verifiable program standards; different criteria for new and existing home applications;
- Customer education;
- Marketing support for contractors;
- Recognition of seasonality of sales – that duct sealing may compete with the equipment installation season; and
- Recognition that code change as a stand-alone strategy is insufficient, in that it reduces the ability to realize potential from the existing homes market.

A successful market-based duct sealing program must address the following barriers: customers' lack of information, lack of understanding that comfort humidity issues may be related to duct leakage, lack of a clearly defined product that customers can understand such as including measurable performance criteria, as well as customers' inability to identify contractors with the proper equipment and expertise. In addition, customer up-front investment is a barrier.

**Strategic agenda for realizing HVAC achievable energy efficiency potential.** Based on understanding of the achievable savings targets, the measures, market barriers and opportunities, the following regional strategic agenda consisting of four interrelated steps is proposed for achieving HVAC efficiency potential:

1. **Coordinate efficiency program efforts across fuels and sectors.** We recommend regional expansion and enhancement of the energy efficiency program that is most successful in the region, NYSERDA's Home performance with ENERGY STAR Program. New program standards should include: comprehensively addressing installation practices, training on the operation and maintenance of equipment, minimum efficiency equipment and thermal envelope upgrades. A regional goal should be to address all major fuels, oil, gas, and electricity, in all states, and in all sectors – new construction, remodel and retrofit. Furthermore, coordination of these efforts is needed to realize the full potential.

2. **Cultivate industry partnerships.** Many activities at the national level, such as ENERGY STAR, efficiency tiers defined by CEE, NATE and BPI certification procedures for HVAC contractors, and ACCA's recent development of specifications for heating and cooling equipment installation, should be enhanced and continue to be incorporated into efficiency programs.

3. **Upgrade state and federal building energy codes and equipment standards.** Upgrade codes and standards to raise the floor, or baseline energy efficiency. Codes and standards complement the market pull of efficiency programs and are thus an important aspect of market transformation. Energy efficiency standards for some HVAC equipment are under consideration in several Northeast states. Updated building energy codes would provide another opportunity outside of energy efficiency programs to encourage or enforce quality HVAC installation practices. For example, California's Title 24 building energy code on duct sealing sets measurable performance standards and has provisions for quality assurance verification. At the national level, the IECC updates building energy codes every three years.

4. **Support continued research and development of emerging and new technologies that reduce HVAC energy and peak demand.** Support new research to obtain a better understanding of in-field performance of some high efficiency equipment and to assure that the equipment delivers the savings that are expected. Continue research to move products under development into market. Market research is also needed to inform the development of program plans and customer education on new technologies as well as the benefits of quality installation.

## 1.3 Study Team

The project team consisted of many individuals and organizations, selected for their specialized expertise in HVAC technologies, efficiency program design, analysis and delivery, as well as market and field research. The multidisciplinary effort was managed by Northeast Energy Efficiency Partnerships, Inc. The contract was managed by NYSERDA. Table 1.1 lists the organizations and key contacts in the project team.

Table 1.1 STAC Project Team

| Organization | Key Contacts |
|---|---|
| Northeast Energy Efficiency Partnerships, Inc. (Lexington, MA) | Elizabeth Titus |
| New York State Energy and Research Development Authority (Albany, NY) | Brian Atchinson |
| New Jersey Board of Public Utilities (Trenton, NJ) | Cameron Johnson |
| Conservation Services Group ( Westborough, MA) | Mark Dyen |
| Proctor Engineering Group (San Rafael, CA) | John Proctor |
| Nexus Market Research (Cambridge, MA) | Lynn Hoefgen<br>Tim Pettit |
| Vermont Energy Investment Corporation (Burlington, VT) | Chris Neme |

The study team would also like to recognize the input provided by many staff members in these organizations and by Harvey Sachs of ACEEE.

## 1.4 Report Organization

This report is organized as follows:

- Section 2: Energy Efficiency Potential and Future Technological Opportunities
- Section 3: Northeast HVAC Market and Current Program Efforts
- Section 4: Current Conditions: Reports from the Field on Benefits of Contractor Training on Quality Installation and Equipment Performance in the Northeast
- Section 5: Case Study: Duct Sealing Market Research and Proposed Program Design
- Section 6: Conclusion and Recommendations: Strategic Agenda for Increasing Energy Efficiency in Northeast Regional HVAC

In addition, the following appendices are provided:

A. Regional HVAC Market Research Survey and Results
B. Review of Emerging HVAC Technologies and Practices
C. Benefits of HVAC Contractor Training: Field Research Results
D. Field Performance of High Efficiency Heating Equipment

E. Duct Sealing Market Research and Program Design Strategy
F. References

## 2. ENERGY EFFICIENCY POTENTIAL

### 2.1 Overview

One goal of this project was to estimate how much energy could be saved over the next ten years by implementing cost-effective residential HVAC energy efficiency measures and practices that are currently available or emerging. Emerging measures and practices are either commercially available but at low market share, or capable of reaching 5 percent market share or more over the next ten years. The study was further restricted to exclude the multifamily segment of the residential sector.

Achievable potential is defined as the savings potential based on market penetration of energy efficient measures that are cost-effective according to the Total Resource Cost (TRC)[3] test and would be adopted through a sustained campaign involving energy efficiency programs and market interventions over the ten-year time horizon. The work presented here is a strategic regional-level analysis. It provides an estimate of potential that could be captured through continuation and expansion of energy efficiency program activity in New England, New York and New Jersey. It includes the assumption that new campaigns at expenditure levels roughly similar to those of existing gas and electric programs can be introduced to obtain savings from oil heat measures, and that some new cost-effective measures and practices can be introduced to existing programs. The analysis is based on assumptions of ten-year projections of market penetration of a set of cost-effective DSM measures and practices.

We assume that the programs that deliver efficient products and services are designed to address market-driven, or lost opportunity investments. Pursuit of market-driven investments requires paying only the additional incremental cost of the efficient equipment as compared to purchasing standard efficiency equipment. Unlike retrofit investments that require paying the full cost of equipment and labor, a lost opportunity investment is typically a fraction of the total installation cost, often with no incremental labor cost. The goal of these Programs should be to make the incremental cost of the upgrades be less than the net energy cost savings. Programs are further broken down into new construction and existing households. For any given end-use, the size of the existing households market is typically determined as the fraction of households with equipment that is being retired.

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[3] The TRC test or modified version of it is used by most Northeast states. It measures net costs taking into perspective utility, participant, and non-participant costs. It can be applied at program and/or measure level. Costs accounted for in the test include: program costs paid by utility and participants; increase in supply costs during load increase periods; benefits are avoided supply costs; reduction in T&D, generation and capacity costs.

We note several caveats about this study:

- It does not estimate the overall technical potential (maximum achievable from cost-effective measures without consideration of market barriers). The technical potential for savings is significantly higher than the results of this study.
- The analysis also does not capture as fine a level of detail for each state or program as is commonly used in program design or cost-effectiveness screening. (In New England and New York in particular, there are many instances where information was blended to represent the various programs that are in existence).
- Thermal envelope improvements and space heating combined with water heating were not analyzed. Proper sizing and quality installation of heating equipment was also not considered.
- Peak day natural gas impacts were not estimated.
- The study inputs and assumptions are based on a combination of past analyses and expert judgment. Confidence levels were not developed for the results. The results are intended contribution to program planning and policy development, and a starting point for discussion, not as a final plan.

## 2.2 Economic Potential Analysis

*Savings Estimation Approach*

The conceptual framework for the analysis involved the following steps:

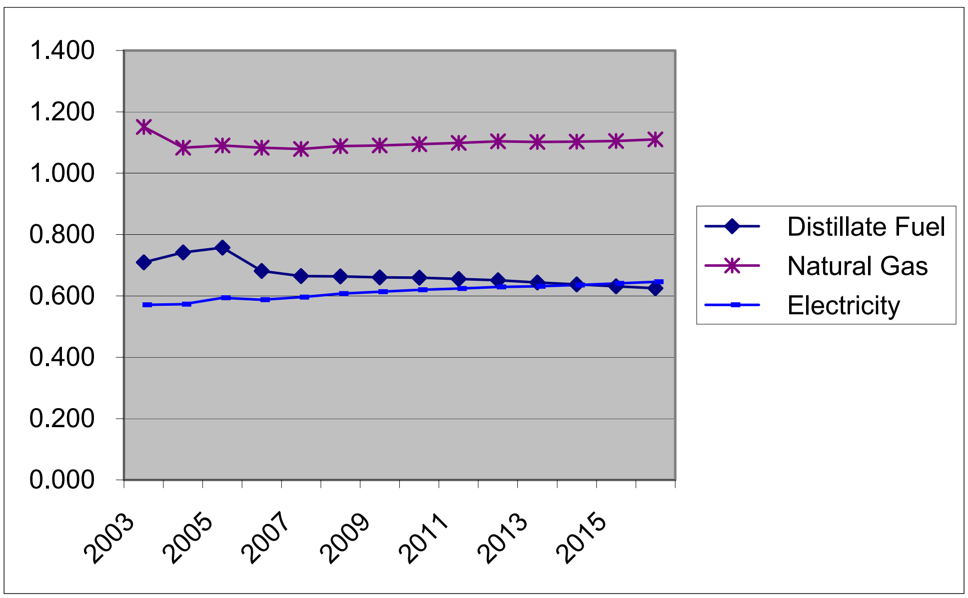
- Developing a comprehensive list of efficiency measures and practices; this was based in part on results of the review of emerging technologies conducted for the STAC study.
- Characterization of the measures and practices, including defining incremental costs and savings, and measure life.
- Characterizing the existing and forecasted markets for each measure and practice, quantifying housing units and equipment saturations, and forecasting new construction activity.
- Estimating baseline penetrations of measures and practices in the existing and forecasted markets.
- Developing regional weighted average avoided costs.
- Screening measures and practices for cost-effectiveness based on the avoided cost estimates.
- Estimating efficiency program costs and spillover rates.
- Applying the per-unit efficient technology and practice characterizations and baseline penetration projections to the relevant existing and forecasted markets to arrive at net achievable potential impacts and costs.

A large variety of data was used to support this process, including prior potential analyses; published research and baseline studies; and personal communication with industry experts; as well as research from other tasks in this STAC study.

*Savings Results*

The achievable potential for heating and cooling savings in the Northeast is large. We estimate achievable potential by 2016 of 647,000 MWh, 160,236 million cubic feet of gas, 53,780 million gallons of oil, and 892 MW demand savings. Combined, the cumulative savings translate to 26,234.46 BBTU. The present value of the net benefits is $3.02 billion. By 2016, residential HVAC efficiency strategies could reduce forecasted residential oil, gas and electricity consumption in 2016 in the Northeast[4] by over 1 percent. To help put these savings into perspective, the cumulative potential gas savings in New York represent 1.5 percent of forecast sales in 2016.[5] The potential HVAC savings in 2016, from New England, New York, and New Jersey for all fuels combined is roughly equivalent to 2 perecent of the HVAC-related energy consumption for the Northeast including Pennsylvania in 2001.[6]

Figure 2.1 Projected Residential Sector Fuel Consumption in the Northeast (Quadrillion BTUs)[7]




The benefit:cost ratio to realize this overall regional achievable potential is 3.34.

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[4] Note that the forecast includes Pennsylvania, although the energy efficiency measures are assumed to be applied to the Northeast excluding Pennsylvania.
[5] This is based on Optimal Energy Inc. forecast residential sales of 386 million dekatherms in New York in 2016.
[6]The Energy Information Administration's 2001 Residential Energy Consumption Survey reports 1.31 quadrillion BTUs consumed in the Northeast for space heating and electric AC.
[7] Energy Information Administration Forecasts for New England and Mid-Atlantic States Combined

Figures 2.2 through 2.4 illustrate how this potential is distributed. It is divided between New England, New York and New Jersey. By state, the largest share, 38 percent of the total potential, comes from New Jersey. By state and fuel type, the largest electric energy and demand savings come from New Jersey, and the largest oil savings come from New England. Gas savings are roughly evenly divided between New England, New York and New Jersey; however New York is the state with the largest potential for gas savings. Across all fuel types, over seventy percent of the savings can be achieved by programs for existing homes, while the remaining savings can be obtained from new construction.

Figure 2.2 2016 Savings in New England, New York and New Jersey (Million $) and as % of Total

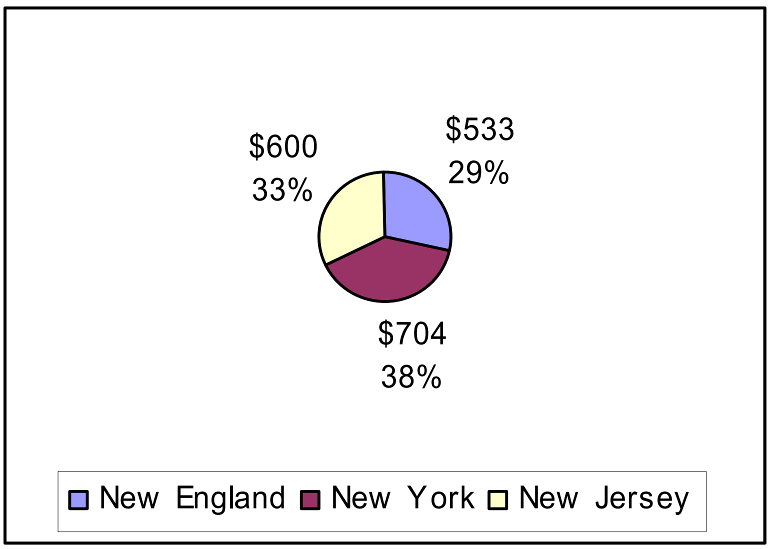



Figure 2.3 Distribution of Savings by Fuel Type and State

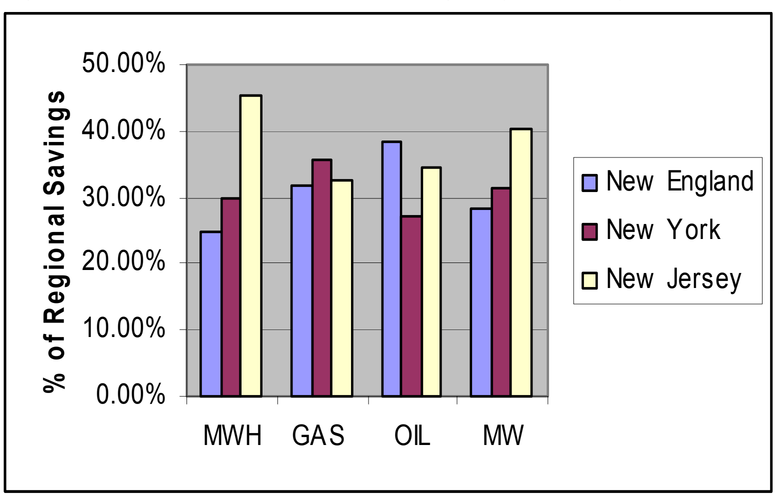


Figure 2.4 Savings by Program Type

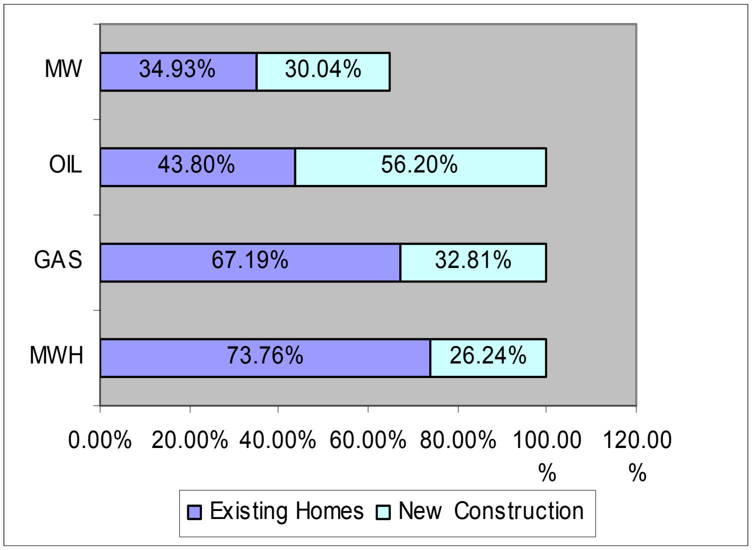



Figure 2.5 shows the forecast of cumulative net benefits over the ten year period. This forecast reflects assumptions of modest annual net increases in program-related penetration of efficient measures and practices. Table 2.1 summarizes first year and cumulative total energy, demand and environmental benefits in physical units.

Figure 2.5 Forecast of Cumulative Net Benefits Through 2016

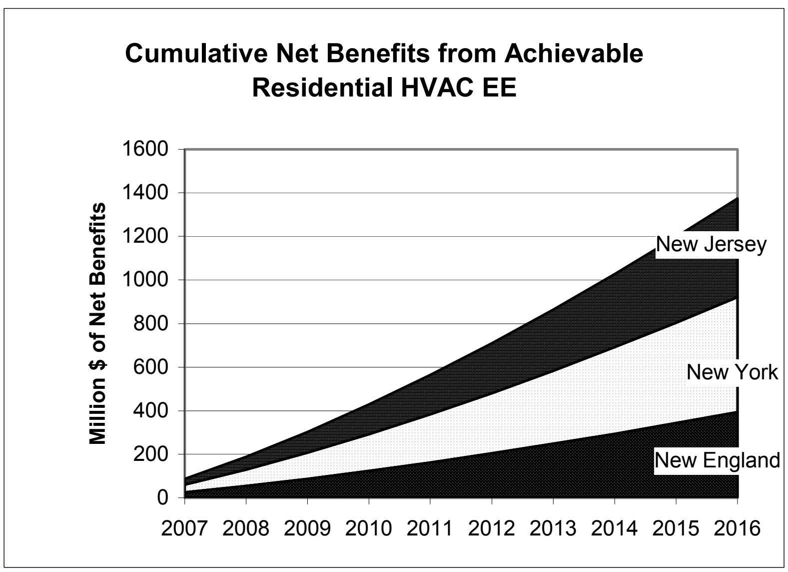


Table 2.1 Cumulative Annual Electricity, Natural Gas and Oil/Propane Energy Savings by Program, State, and Northeast Region

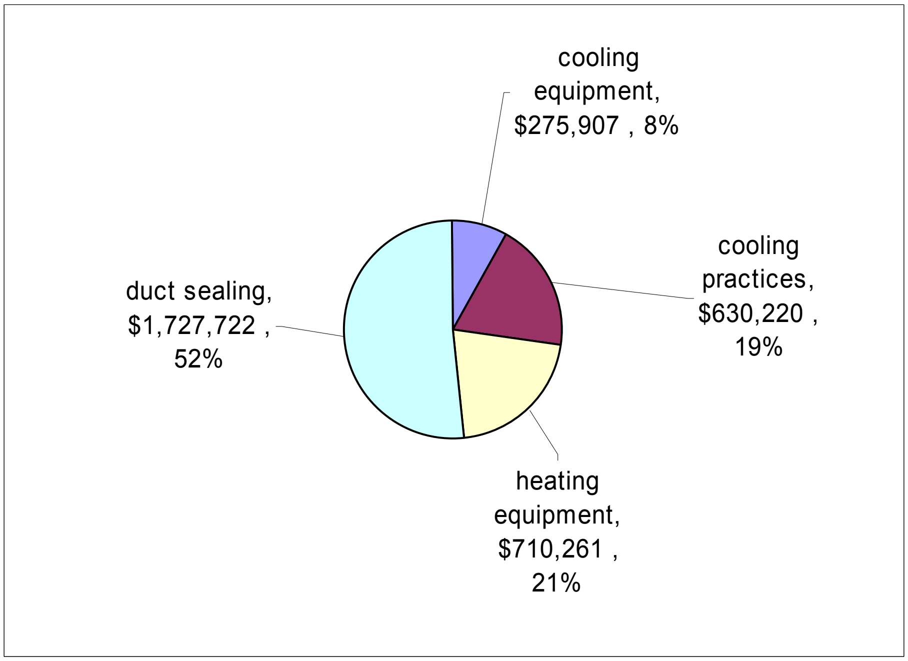
| State & Program | Electricity Savings MWh | | Natural Gas Savings $10^3$ccf $10^3$ccf | | Oil/Propane Savings $10^3$ gallons $10^3$ gallons | | Summer Capacity MW | | Cumulative Environmental Benefits Tons in 2016 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2016 | 2007 | 2016 | 2007 | 2016 | 2007 | 2016 | CO2 | NOX | SO2 |
| New England | | | | | | | | | | | |
| Existing Homesx | 6,695 | 114,559 | 1,574 | 31,344 | 503 | 11,095 | 10 | 163 | 87,065 | 120 | 355 |
| New Construction | 2,719 | 46,480 | 1,162 | 19,411 | 614 | 9,595 | 5 | 89 | 35,325 | 49 | 144 |
| Subtotal | 9,414 | 161,039 | 2,736 | 50,754 | 1,117 | 20,690 | 15 | 253 | 122,390 | 169 | 499 |
| NY | | | | | | | | | | | |
| Existing Homes | 8,703 | 144,445 | 2,371 | 47,218 | 390 | 8,095 | 12 | 203 | 109,778 | 152 | 448 |
| New Construction | 2,819 | 48,749 | 588 | 9,835 | 381 | 6,474 | 4 | 77 | 37,049 | 51 | 151 |
| Subtotal | 11,522 | 193,195 | 2,959 | 57,053 | 771 | 14,569 | 17 | 279 | 146,828 | 203 | 599 |
| NJ | | | | | | | | | | | |
| Existing Homes | 13,121 | 218,929 | 1,490 | 29,094 | 238 | 4,366 | 16 | 258 | 166,386 | 230 | 679 |
| New Construction | 4,562 | 74,756 | 1,474 | 23,334 | 927 | 14,156 | 6 | 102 | 56,815 | 78 | 232 |
| Subtotal | 17,683 | 293,685 | 2,964 | 52,429 | 1,164 | 18,521 | 22 | 360 | 223,201 | 308 | 910 |
| Northeast | | | | | | | | | | | |
| Existing Homes | 28,519 | 477,934 | 5,434 | 107,656 | 1,130 | 23,555 | 38 | 624 | 363,230 | 502 | 1,482 |
| New Construction | 10,101 | 169,985 | 3,224 | 52,580 | 1,922 | 30,225 | 16 | 268 | 129,189 | 178 | 527 |
| Total | 38,619 | 647,919 | 8,658 | 160,236 | 3,052 | 53,780 | 53 | 892 | 492,419 | 680 | 2,009 |

*End Use and Other Impacts*

As shown in Table 2.1, by 2016, the HVAC efficiency potential would reduce demand by 226 MW. Capture of the regional achievable potential would also result in emissions reductions; over the 10-year planning horizon these total 146,421, 202 and 597 tons of $CO_2$, $NO_X$ and $SO_X$ emissions, respectively. While not calculated, emissions reductions would continue beyond 2016, for the life of the measures installed.

Figure 2.6 shows how the potential savings are distributed over end use categories of heating and cooling measures and practices. Duct sealing is the single largest source of potential savings, followed by heating equipment. Cooling practices, which include proper sizing and installation of central air conditioners as well as AC tune-ups, are responsible for roughly one-fifth of the total potential.

Figure 2.6 Net Present Value of Cumulative End Use Savings (Thousands)




## 2.3 Efficiency Opportunities and Measure Characterization

*Cooling*

There are two key components to cooling savings potential: energy savings and peak demand savings. For the most part, residential customers in the Northeast see energy savings only. The impacts of efficiency on peak demands are important to the summer peaking grids in the Northeast.[8]

Two recent developments have advanced the market for efficient cooling: 1) the revision of the ENERGY STAR minimum standard on central air conditioners to SEER 14 (EER 11.5), and 2) the federal equipment efficiency standard of SEER 13, effective January 2006. Variable speed high efficiency air conditioners provide peak savings if operated properly, so that the high speed runs only during peak conditions. While there are products on the market with SEER ratings as high as 20, they are very rare and expensive. Although they may provide 40 percent energy savings relative to SEER 13s, they may not provide peak savings. Relative to the new federal efficiency standard, SEER 14 and 15 equipment provides up to seven percent and 13 percent energy savings, respectively.

[8] One study estimated that wholesale electricity costs in the top 1% of the 8760 hours in the year accounted for 16% of total annual costs (Cowart, Richard, Efficient Reliability, published by the Regulatory Assistance Project, 2001).

In contrast, savings potential associated with proper design and installation remains quite large. Numerous field studies, including the field research that is part of the STAC study, have demonstrated that equipment is usually over-sized, has inadequate airflow over the indoor coil, and has either too much or too little refrigerant in the system. Those same studies suggest that the efficiency penalty resulting from such problems is substantial. Proper sizing and installation can reduce electricity use by approximately 20 percent - the equivalent of upgrading from SEER 13 to SEER 16.[9] This further underscores the need for vigorous and ongoing Contractor training and in-field verification, as occurs in NYSERDA's Home Performance with ENERGY STAR Program.

Another strategy for improving efficiency is to install ductless mini-splits in lieu of conventional centrally ducted air conditioning. These systems have outdoor condensers connected by refrigerant lines to between one and four indoor units. These have several advantages of particular relevance in the Northeast. One advantage is that they avoid the need for ducts, and thus can be installed in existing homes with hydronic heating systems, at a lower overall cost than for installing ducts plus central air. Another is that the design and installation problems that reduce the energy efficiency of conventional air conditioning are avoided by this technology. Finally, they provide zoned cooling. With multiple units a homeowner can cool rooms as needed, rather than all or nothing. No field testing data are available to quantify all of the efficiency advantages. However, technical experts estimate savings of 50 percent or more are possible.[10] Although rarely found in homes in the U.S., ductless mini-splits are quite common in homes outside of the U.S. They are also commonly used in small commercial facilities.

*Heating*

An ENERGY STAR gas furnace provides savings of 11 to 17 percent relative to a standard model with an AFUE of 80 percent. As noted in the previous section, market shares of gas furnaces are relatively high. Additional savings can be achieved with efficient blower fans on gas, propane, and oil furnaces. An efficient fan can save up to 500 kWh per year in the Northeast.[11]

Oil boilers and furnaces have lower savings potential than gas equipment. For example, the difference in consumption between ENERGY STAR and standard oil equipment (AFUE 85 percent versus 80 percent) is only about six percent.

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[9] See Neme, Proctor and Nadel. National Energy Savings Potential from Addressing Residential HVAC Installation Problems, ACEEE, February 1999. Also see Proctor, Appendix B of this report.
[10] See Proctor, Appendix B of this report.
[11] Ibid. See also Pigg, Electricity Use by New Furnaces, A Wisconsin Field Study. Technical Report 230-1. Prepared for Focus on Energy. Madison, WI: Energy Center of Wisconsin. October 2003.

Condensing boilers and one condensing oil furnace are on the market, but very expensive.

Field research suggests that heating equipment is even more commonly oversized than cooling equipment. However, the energy penalty from this is relatively small. Little or no information about heating installation problems is currently available, and thus it was not addressed in the estimate of efficiency potential.

*Duct Systems*

Numerous studies have demonstrated that there are potentially very large efficiency benefits from improving duct systems – both through design and reducing overall leakage. The fact that many central air conditioner sales in the Northeast are first-time installations in existing homes with hydronic heat means that there may be greater potential to get efficient distribution systems, because it is easier to install new ducts correctly than it is to repair existing ducts that were not originally designed for central cooling.  Duct sealing is also extremely cost effective because it affects both heating and cooling energy use in many homes.

*Importance of Thermal Envelope*

Thermal envelope improvements were not analyzed for the assessment of achievable potential. And, although it was also not directly addressed in our overall assessment of HVAC efficiency opportunities, it is important to note that HVAC system efficiency is influenced by the thermal envelope and the efficiency of the home as a whole, further underscoring the need for comprehensive, whole house approach to residential contracting. In the STAC field research task that monitored five homes, the thermal envelopes in two of the homes were so leaky that the central air conditioners could not maintain relative humidity levels below 60 percent (one common indicator used to measure comfort). Such conditions can lead building occupants to increase the amount of heating and cooling energy they consume and/or to demand larger pieces of equipment at time of replacement.

*Measure Characterization for Achievable Potential Study*

The study of achievable potential analyzed 18 different efficiency measures and practices. After accounting for new construction and existing homes programs in New York, New Jersey, and New England, that number grew to over 100 permutations. Each measure was screened for cost-effectiveness. For illustrative purposes, Table 2.2 lists all measures and practices that were included in the analysis for the existing homes programs in New England, New York and New Jersey and the benefit:cost ratios resulting from the measure screening.[12]

Most measures have benefit:cost ratios within the range of 1 to 10. Note that 85 AFUE oil furnaces are at the lowest end of the benefit:cost ratio, with a value of 1.0. They were included in the analysis in recognition of the fact that efficient product options are very limited among oil furnaces. Two other noteworthy exceptions, duct sealing and ductless mini-splits, are highly cost-effective. Proper duct sealing is highly cost-effective because it requires relatively small incremental investment over conventional practices. In the Northeast, it can save up to 18 percent of cooling energy consumption and 13 percent of heating energy consumption, and it is applicable to many homes with forced air heat and/or central air conditioning. Ductless mini-splits, by contrast, are an emerging technology that is an alternative to conventional central air conditioning. In this analysis, the incremental costs were developed by comparing them to installing ducts and central air conditioning in an existing home. Cost savings resulting from not installing ducts are dramatic and more than offset the fact that the unit can cost 20-30 percent more per ton of cooling than conventional central air-conditioning. While this analysis assumes relatively small, gradual adoption of ductless mini-splits as an alternative to installing ducted central AC systems, further research is needed to understand the longer-term program effects of promoting this technology. It is possible that people with one or two room air conditioners might choose ductless mini-splits instead and end up increasing their cooling load.

Table 2.2 Residential HVAC Efficiency Measures and Practices Analyzed

| **Benefit: Cost Ratios for Existing Homes Measures by State** | | | | **Energy Savings per Measure** |
|---|---|---|---|---|
| | **New England** | **New York** | **New Jersey** | **All States** |
| **Existing Homes Cooling Measures** | | | | |
| CAC E-Star (14/11.5) | 1.71 | 1.82 | 1.89 | |
| CAC CEE Tier 1 (14/12.0) | 3.04 | 3.04 | 3.04 | |
| CAC CEE Tier 2 (15/12.5) | 1.57 | 1.67 | 1.74 | 13% |
| Ductless Mini-split - stnd w/3 units | 5525.15 | 5650.47 | 5734.02 | 50% |
| Ductless Mini-split - hi efficiency w/3 units | 1.46 | 1.49 | 1.51 | 50% |
| **Existing Homes Cooling Practices** | | | | |
| CAC proper sizing | 4.85 | 4.93 | na | 2 – 10% |
| CAC Proper Installation | 8.64 | 8.98 | 9.21 | 15% |
| CAC Tune-up | 1.04 | 1.09 | 1.13 | |
| Duct sealing (cooling) | na | 2.10 | 2.15 | 15% |
| **Existing Homes Gas Heating Measures** | | | | |
| Gas Furnace - Condensing (from 80% to 92%) | 3.00 | 3.00 | 3.00 | 11 – 17% |

[12] Similar measures were included in the new construction programs, and the values and ranges of benefit:cost ratios for new construction measures are roughly similar to those in the retrofit programs.

| | | | | |
|---|---|---|---|---|
| Gas Boiler - Energy Star (84%) | 7.93 | 7.93 | 7.93 | 6% |
| **Existing Homes Oil Heating Measures** | | | | |
| Oil furnace - 85 AFUE | 1.00 | 1.00 | 1.00 | 6% |
| Oil furnace – Condensing | 1.73 | 1.73 | 1.73 | |
| Oil boiler - 85 AFUE | 2.28 | 2.28 | 2.28 | 6% |
| **Existing Homes Heating Practices** | | | | |
| Duct sealing (heating) | 10.60 | 10.60 | 10.60 | 15% |
| **Combined Measures** | | | | |
| Gas Furnace - Condensing w/ECM (80% - 92%) | 9.67 | 9.67 | 9.67 | 50% of fan use |
| Oil furnace w/ECM | 6.38 | 6.38 | 6.38 | 50% of fan use |
| Duct sealing (cooling and heating) | 12.61 | 12.69 | 12.75 | 15% |

*Market Effects*

The estimate of achievable potential over a ten-year planning horizon is based on two components of a savings estimate: (1) program penetration rates – the number of efficiency measures that will be installed in each year, and (2) market effects often referred to as spillover – the fraction of program penetration that will be influenced by a program but not directly participate in it during the ten-year period that was analyzed.

The forecast of penetration rates relied heavily on an understanding of the market barriers informed by other tasks in the STAC project, as well as by other programs that have attempted to address similar barriers. In the case of oil measures, extrapolation from experiences with gas and electric programs was necessary. In the absence of documented current market shares, best estimates were used. Penetration rates take into account expectations about future codes and standards as well as expected program participation. Penetration rates were estimated for: 1) the base case - what is expected to occur in the absence of programs, 2) “with program” rates that include the effects of programs, freeridership and spillover combined, and 3) “in program” rates that reflect the portion that is expected to directly participate in programs, thus impacting program budgets.  Penetration rates are estimated separately for each measure.

As mentioned, spillover refers to program-influenced market actions that did not involve direct program participation. This occurs for a variety of different reasons - for example, trade allies not bothering with submitting rebate forms or builders or contractors acquiring skills that they incorporate into work that does not qualify for program participation. In this analysis a 10 percent spillover rate was assumed for all efficient equipment. Spillover for practices (duct sealing, quality installation for example) increases from 10 to 40 percent over a ten-year horizon[13].

[13] This assumption of a three-fold increase over ten years is based on the fact that relatively small incremental customer investment is required, and markets for these services can develop very quickly if efficiency programs are successful in removing the barriers.

*Post Program Effects*

A third component is the lingering market transformation effects that can be achieved following the end of the program. We note here that these have not been measured, but they can often be expected to persist more than five years after the end of a program. Thus, the effects of this savings potential would extend beyond 2016.

*Program Budgets*

The program budgets are partly a function of assumed in-program penetration rates because significant portions of most program budgets are variable and related to program participation levels. The estimated program budgets are based on experience with similar gas and electric efficiency programs in the Northeast. In the absence of other information, they assume that levels of administrative expenditures and equipment incentives required to realize oil heat energy efficiency potential are similar to expenditures in gas programs.

Figure 2.4a Projected Electric Program Budgets

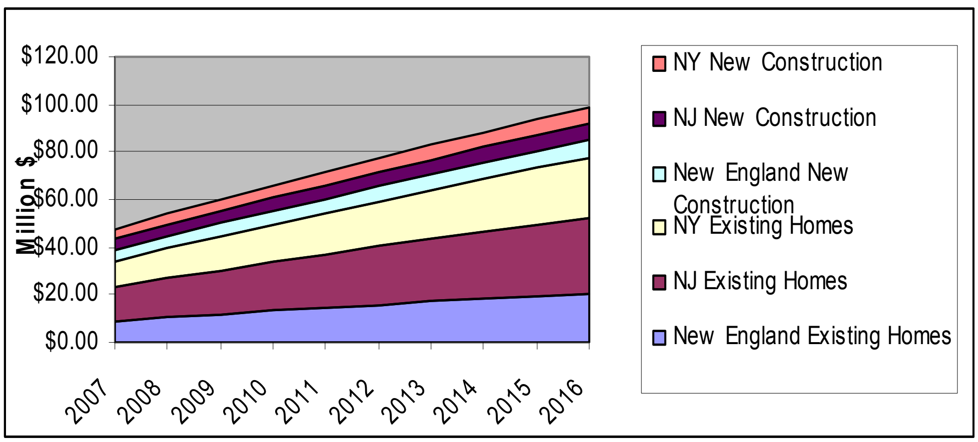
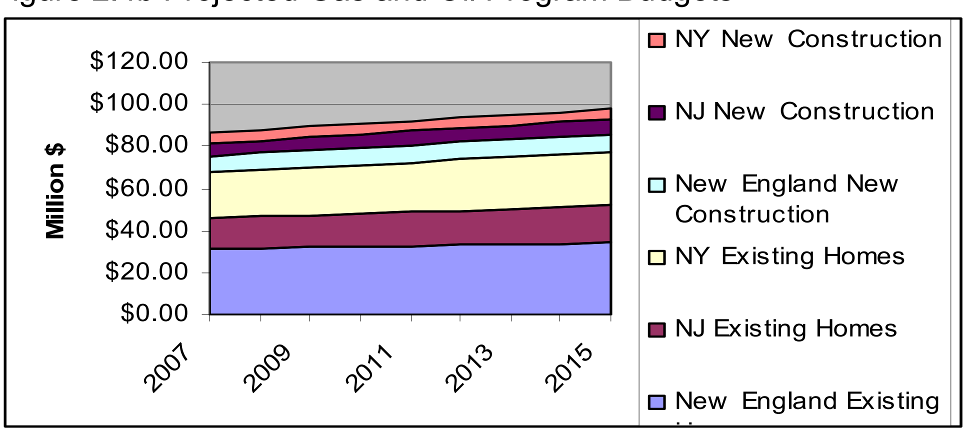



Figure 2.4b Projected Gas and Oil Program Budgets



## 2.4 Beyond 2016: Long Term Emerging Technologies

This STAC project included a review of emerging technologies and measures that have the potential to increase residential HVAC efficiency in the Northeast. Nine of the technologies are in a research and development stage and will not be ready for market within five to ten years, thus they were not included in the analysis of achievable potential. They are listed below because they may be of benefit in the longer run.[14] Table 2.5 ranks these technologies with respect to potential energy savings and readiness for market, where a rank of "1" indicates highest savings potential or most ready for market.

Evaporator Fan and Housing, which received the highest savings rank, is an improvement to the distribution system. It refers to a new design for fans and fan housing that can increase fan efficiency in an air conditioner or heat pump to 45 percent. Sizing and Matching, which could not be ranked, is a design strategy in which the various components of cooling systems would be selected based on consideration of capacity and energy efficiency, rather than current practice based on capacity alone.

Table 2.5 Efficient HVAC Technologies In Development[15]

| **Technology** | **Savings Rank** | **Readiness for Market Rank** |
|---|---|---|
| Evaporator Fan and Housing | 1 | 2 |
| Integrated Cooling, Dehumidification & Ventilation | 2 | 6 |
| Dedicated dehumidification system | 3 | 1 |
| Central AC for Cold Climate | 3 | 3 |
| Central AC and Dehumidification | 3 | 5 |
| Frostless Heat Pump | 4 | 4 |
| Cold Climate Heat Pump | 4 | 7 |
| Aerodynamic Outdoor AC/HP | 4 | 8 |
| Sizing and Matching Components | na | na |

*Need for Moisture Removal*

Many of these technologies integrate dehumidification with cooling and/or heating. These would be very applicable, particularly in New Jersey and New York, which are in "moist" climate zones, where outdoor air often contributes to the latent load on air conditioners. Moisture removal is becoming an increasing part of the cooling load throughout the Northeast, as improvements in building practices, such as increased insulation, low solar gain roofs, and high-efficiency window glass can block significant amounts of summer heat gain.

[14] Detailed discussion of these technologies is available in Appendix B.
[15] Rankings provided by John Proctor, personal communication, November 2005.

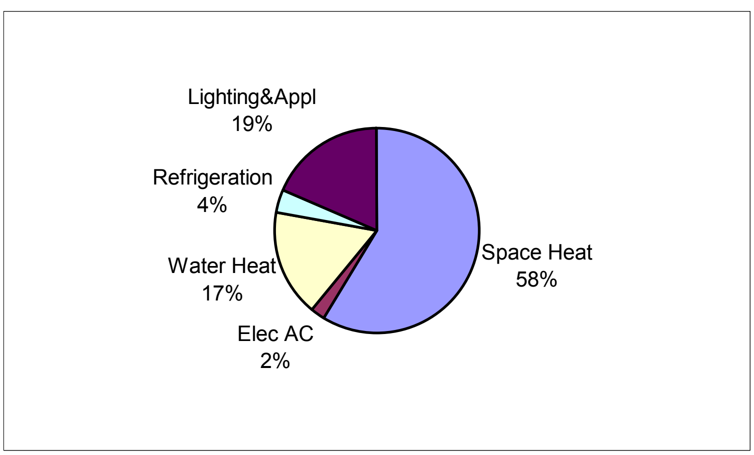
## 3. NORTHEAST HVAC MARKET AND CURRENT PROGRAM EFFORTS

As discussed, the Northeast has significant potential to reduce its residential HVAC energy consumption. Understanding the residential HVAC market conditions in the Northeast was necessary to estimate achievable potential. In addition, knowledge of market structure and trends, and key opportunities and barriers relating to energy efficiency improvements, is important to strategic planning and consideration of what changes are needed for the Northeast to realize its efficiency potential. Information on the HVAC market was obtained from industry experts and literature, supplemented by the market research task of the STAC project. The market research included telephone surveys of 50 HVAC and plumbing and heating contractors throughout the Northeast as well as structured interviews with eight distributors and wholesalers, five regional efficiency program administrators, and individuals from eight trade ally organizations. While results of these interviews are neither completely representative of the region nor statistically significant due to relatively small samples, they provide a helpful perspective on the industry in the region. Additional details about the market research, including tabulated responses to survey questions, are provided in Appendix A.

### 3.1 Household Characteristics

Compared to other parts of the U.S. and the nation as a whole, the Northeast has high heating loads. As shown in Figure 3.1, heating accounts for 58 percent of average household fuel consumption in the Northeast.

Figure 3.1 Energy Consumption by End Use as Percent of Total Residential Consumption in the Northeast[16]




[16] Energy Information Administration, 2001 Residential Consumption Survey, Northeast Region (Includes Pennsylvania)

There is a more diverse array of heating systems, a high penetration of fuel oil heating, and higher levels of hydronic heating than in the rest of the country.[17] This is partly due to the fact that housing stock and heating equipment are older, built before natural gas was available and before forced air heating became common. The Northeast has relatively modest seasonal cooling loads. Historically it had a low saturation of central air conditioning. However, the demand for central air conditioning has been growing rapidly in existing homes as well as in new construction, adding significant load to the summer peaking electricity grids.

Table 3.1 2006 Distribution of Predominant Heating and Cooling Equipment in the Northeast[18]

| | **Existing Construction** | | | **New Construction** | | |
|---|---|---|---|---|---|---|
| **Distribution of Equipment** | **New England** | **New York** | **New Jersey** | **New England** | **New York** | **New Jersey** |
| Gas Furnace | 15% | 33% | 39% | 19% | 19% | 45% |
| Gas Boiler | 21% | 28% | 24% | 26% | 26% | 28% |
| Oil Furnace | 17% | 6% | 8% | 20% | 20% | 7% |
| Oil Boiler | 34% | 22% | 17% | 30% | 30% | 15% |
| Central AC | 15% | 18% | 50% | 60% | 60% | 75% |

Table 3.2 2006 Mix of Residential Housing in the Northeast[19]

| | **New England** | **New York** | **New Jersey** | **Total** |
|---|---|---|---|---|
| **1-4 units** | 21.88% | 30.86% | 12.18% | 64.91% |
| **5+ units** | 3.71% | 21.05% | 9.82% | 34.58% |
| **New Construction** | 0.19% | 0.19% | 0.13% | 0.51% |
| **Total** | 25.78% | 52.09% | 22.13% | 100.00% |

### 3.2 Market Structure

*Market Channels*

The following groups play significant roles in the residential HVAC market:

**Manufacturers.** Manufacturers are at the beginning of the distribution chain. Typically, manufacturers sell to distributors who sell to contractors who sell to consumers.[20] Manufacturers play a key role in influencing HVAC contractor decisions, as contractors are often dedicated to one manufacturer. They are a source of training and technical assistance for HVAC contractors and plumbing

[17] The Northeast has among the lowest saturations of electric space heat in the country, and very few heat pumps are sold in the Northeast.
[18] Data provided by Vermont Energy Investment Corporation, based on extrapolations of U.S. Census data, EIA 2001 Residential Consumption Survey, and expert information.
[19] Data provided by Vermont Energy Investment Corporation, based on extrapolations of U.S. Census data.
[20] Lennox is an exception; they sell directly to contractors. Another exception is retail stores who sell directly to consumers.

and heating contractors. Seven major manufacturers are responsible for 98 percent of all U.S. sales of central air conditioners and furnaces.[21]

**Distributors.** Of the 500-700 HVAC wholesale distributors in the Northeast, 25 percent are in Massachusetts, 30 percent in New York, and 20 percent in New Jersey.[22] As the bridge between the dealer and the manufacturer, distributors frequently maintain inventory for dealers. They also serve as a conduit for promotional information and installation and sales training.

**Contractors.** This group is large and diverse. Nationally, 70 percent of HVAC firms are small, with fewer than five employees, and account for less than 10 percent of all HVAC sales. Medium firms up to 25 employees represent 25 percent of HVAC firms and account for 60 percent of all sales. The largest firms represent five percent of HVAC firms and account for 30 percent of sales.[23] Anecdotal information suggests that similar patterns hold in the Northeast. Estimates of the number of HVAC firms in the Northeast are difficult due to large turnover in firms each year (as much as one-third of the total). Dun & Bradstreet suggests that there are up to 25,000 HVAC contractors in the Northeast, with 35 percent in New York, 20 percent in New Jersey, and 35 percent in Massachusetts and Connecticut combined. HVAC installers and dealers play a key role in the industry, as they frequently drive equipment choices for customers as well as installing and servicing equipment. In most firms, contractors often work autonomously and have multiple responsibilities, such as sales, equipment installation, and management. The HVAC contractors surveyed for the STAC research reported that the cooling equipment and oil furnace replacement work they do is split evenly between breakdowns and planned replacements, while two-thirds of gas furnace installations are planned replacements. HVAC contractors are also often responsible for duct layout in residential new construction work. Like HVAC contractors, plumbing and heating contractors are mostly small companies with an average of nine employees. These firms typically install and service heating and cooling equipment. Many also sell the equipment.

**Retail Stores.** Big box retail stores such as Sears, Home Depot and Lowe's all sell HVAC equipment directly to consumers. In 2000, Sears was estimated to have a national market share of five percent for central air conditioners and furnaces. Although neither regional information nor updated market share information is available, anecdotal evidence suggests that this market channel is gaining in importance as a source of equipment. These stores buy equipment from distributors and sell to consumers. They typically use a local network of private HVAC contractors to then install the equipment.

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[21] Appliance Magazine, September 2005. The manufacturers, in declining order of market share are: UTC/Carrier, American Standard (Trane), Lennox, Rheem, York, Nordyne, Goodman (Amana)
[22] Personal communication with Bud Healy, HARDI Director of Education, November 11 2005.
[23] HVAC Market Characterization Study for New Jersey, Xenergy, 2001.

**Builders.** They are generally the buyers of equipment for new homes.

**Consumers.** Homeowners and landlords are responsible for purchasing equipment and services for existing homes.

*Market Trends and Market Share of Efficient Equipment*

Comprehensive industry data on regional sales and market shares are not available, and distributors and manufacturers interviewed as part of the STAC market research were unwilling to share proprietary information on market share, sales, and segmentation. HVAC contractors surveyed as part of the STAC research are not routinely installing the most efficient units on the market, and this practice has not changed much since 2003. The research also indicated that the proportion of high-efficiency central air conditioning units and high-efficiency gas furnaces being installed by HVAC contractors is higher in New England than in New York or New Jersey[24]. Table 3.3 presents baseline estimates of market shares of high efficiency equipment by state developed by Vermont Energy Investment Corporation for the economic potential analysis based on expert judgment.

Table 3.3 Estimated 2007 Market Share of High Efficiency HVAC Equipment by State

| | New England | New York | New Jersey |
|---|---|---|---|
| **CAC E-Star** | | | |
| Existing Homes | 3% | 3% | 3% |
| New Construction | 3% | 3% | 3% |
| **Ductless Mini-split** | | | |
| Existing Homes | 1% | 1% | 1% |
| New Construction | 1% | 1% | 1% |
| **Gas Furnace - Condensing** | | | |
| Existing Homes | 65% | 45% | 40% |
| New Construction | 52% | 52% | 52% |
| **Gas Boiler - Energy Star** | | | |
| Existing Homes | 20% | 20% | 20% |
| New Construction | 20% | 20% | 20% |
| **Oil furnace - 85 AFUE** | | | |
| Existing Homes | 5% | 5% | 5% |
| New Construction | 5% | 5% | 5% |
| **Oil boiler - 85 AFUE** | | | |
| Existing Homes | 25% | 25% | 25% |
| New Construction | 25% | 25% | 25% |

[24] This observation is consistent with 2004 information on high efficiency furnaces as a percent of total shipments – Massachusetts 70%, New Hampshire 64%, New York 43%. Information from GAMA as reported in "Market Transformation as a Tool to Meet Natural Gas Savings Targets", Bruce Johnson, Keyspan, March 21, 2006, MT Symposium, Washington, D.C.

Table 3.4 summarizes anecdotal information from contractors in the Northeast on their estimates of market shares of efficiency levels of equipment based on their recent sales.[25] For reference, current ENERGY STAR criteria are listed in Table 3.5. When examined in context with other information provided by contractors in the survey, the self-reported estimates of market shares for high efficiency equipment are unrealistically high. For example, most contractors said they were not likely to propose high efficiency air conditioners or furnaces to customers. Contractors are somewhat more likely to propose high-efficiency boilers to customers.

Table 3.4 Contractors' Estimates of Shares of Installation/Sales of HVAC Equipment by Efficiency Levels in the Northeast

| Shares, by Efficiency: | I | II | III |
|---|---|---|---|
| Central Air Conditioners | 74% (SEER <12.9) | 15% (SEER 13-14) | 11% (SEER 14+) |
| Gas Furnaces | 41% (AFUE <89.9) | 44% (AFUE 90-93.9) | na (AFUE 94+) |
| Gas Boilers | na | 50% (AFUE 85-89.9) | 18% (AFUE 90+) |
| Oil Furnaces | 100% (AFUE < 90) | | |
| Oil Boilers | na | 50% (AFUE 85-89.9) | 18% (AFUE 90+) |

Table 3.5 ENERGY STAR criteria for Residential HVAC Equipment[26]

| Equipment | Minimum ENERGY STAR Criteria |
|---|---|
| Central AC, Split Systems | EER 11.5/SEER 14 |
| Central AC, Package Systems | EER 11/SEER 14 |
| Gas, Oil, Propane Furnaces | AFUE 90 |
| Gas, Oil, Propane Boilers | AFUE 85 |

Anecdotally, the following trends over the next five to ten years were expected by some distributors and wholesalers who were interviewed:

- Barring any interventions, little change in market shares for high-efficiency equipment other than increasing efficiency levels of installed gas furnaces;
- 10-15 percent increase in forced air hydronic systems;
- 20-30 percent increase is expected in radiant heating systems;
- 10-25 percent increase in demand for variable speed technologies;
- 10-25 percent increase in demand for mini-split systems in the Northeast.

High efficiency equipment is typically priced higher than conventional HVAC equipment. Half of the distributors interviewed in the market research report that they do not further increase their markup rate for high efficiency equipment; half report that their markup rate increases from 2 to 15 percent, with the highest markup rates on boilers. As shown in Table 3.6 typical incremental prices

[25] Market shares are expected to change with the federal standard effective in 2006 that establishes SEER 13 as the minimum efficiency requirement for residential air conditioners.
[26] www.doe.energystar.gov

reported for most high efficiency equipment were $200, but they can be as much as 40 to 50 percent of the price of conventional equipment.

Table 3.6 Ranges of Incremental Price Differences for High Efficiency Heating and Cooling Equipment Reported by Distributors

| **Equipment Type** | **Efficiency Level** | **Number of Responses** | **Incremental Price Difference (either $ or %)** |
|---|---|---|---|
| Central AC | | | |
| | 10-13 SEER | 5 | $175 - $400 or 30-50% |
| | 13-14 SEER | 1 | 25% |
| Gas Furnaces | | | |
| | 85-90 AFUE | 5 | $200 or 15-40% |
| | 90-94+ AFUE | 1 | 20% |
| Oil Furnaces | | | |
| | 85-90 AFUE | 1 | $200 |
| Gas Boilers | | | |
| | 80-85 AFUE | 1 | 10% |
| | 85-90 AFUE | 3 | $500-$600 or 20-40% |

As part of the market research, HVAC contractors were asked to estimate the cost to upgrade customers to high efficiency equipment, and to rank customers' willingness to pay for high efficiency equipment. On a scale from 0 to 10, where 0 is unwilling and 10 is most willing to pay, contractors reported the following:

| **Equipment** | **Willingness to Pay Rank** | **Cost to Upgrade** |
|---|---|---|
| Central AC of SEER 14+ | 4 | $1388 |
| Gas Furnaces | 7 | $733-$800 |
| Oil Furnaces | 6 | $950-$2000 |
| Gas Boilers | 6.5 | $775 |
| Oil Boilers | 7.5 | $1,254 |

Contractors' definitions of high efficiency equipment were generally consistent with the ENERGY STAR criteria, with some differences. For example, contractors in New York considered lower SEER levels (below SEER 13) to be high efficiency units. Similarly, many of the contractors surveyed in New York said gas furnaces with AFUE ratings below 90 are efficient. As shown in Table 3.3, no contractors defined efficient oil furnaces as high as AFUE 90.

### 3.3 Industry Perspectives on Achieving HVAC Energy Efficiency

Distributors noted that contractors' reluctance to change hinders their ability to adapt to new products. As one commented, "Contractors are reluctant to try anything new. The higher efficiency equipment is more complex and the contractors don't want to be the guinea pigs trying out the newest stuff." Trade allies - national and regional trade associations, training and certification organizations that support the HVAC industry – are in general agreement with distributors on this point. Interviews with eight allies as part of the STAC study provided the following insights:

- A majority agreed that lack of consumer awareness about what to expect from a contractor is a major barrier to increasing energy efficiency.
- A majority agreed that lack of professional standards in the HVAC business is another major barrier.
- Most trade allies interviewed support contractor licensing.
- NATE certification is generally recognized as a valuable strategy to support training. Half of those interviewed believe licensing should be contingent on certification, including NATE certification. Most supported NATE certification when asked for their definition of a well-trained technician.
- Most respondents feel that technicians are not well-trained and that training is poorly accepted within the industry.
- Most of the respondents believe continuing education is central to having a well-trained base of technicians.
- Turnover is high in the industry; there are no barriers to entry for technicians to become HVAC contractors. Business owners do not offer amenities or services that they should for development, training, energy efficiency, or quality of service.

*Training and Marketing Energy Efficiency*

Manufacturers figure prominently in HVAC contractor training. Plumbing and heating contractors, by contrast, are more likely to have professional licensing and certification rather than manufacturer-provided training. In interviews, HVAC manufacturers and distributors were enthusiastic about NATE certification for HVAC contractors. NATE and BPI certifications now allow technicians to differentiate themselves. However, on BPI accreditation provides differentiation that applies to contracting firms. One benefit from their perspective is that the NATE certification will better equip contractors to sell the benefits of high efficiency equipment. Several distributors noted a concern that contractors do not dedicate sufficient amounts of time to following up on marketing and relationship building. “We need to get everyone in the marketing chain to partner with NATE, ACCA, and BPI to increase customer awareness; also data sharing from rebate processing up and down the market chain.” Program managers and trade allies further noted, “Contractors can’t handle selling up (promote the benefits of) the higher efficiency equipment.” And “we need to get into the field by educating installers…and get installers to educate consumers.”

There is consensus among program administrators that the average technician is inadequately trained. Training has importance as far more than a marketing strategy. As noted by one respondent, “new technologies and refrigerants will require additional training.” Currently, the business incentive is not to send NATE-certified technicians to installation jobs. They are sent for service or commissioning. However, as many studies have found, poor quality of installation can significantly reduce the energy savings potential of HVAC equipment.[27] In New York's Home Performance with ENERGY STAR Program, this problem is addressed by requiring BPI-certified technician to be on location HVAC work is being performed.

### 3.4 Market Barriers to Achieving Energy Efficiency

There are a number of important market barriers to achieving the savings associated with high efficiency HVAC measures. Some of the key barriers are summarized below:

**Limited consumer awareness of energy efficiency opportunities and benefits**. While some consumers have an understanding of efficiency differences and ratings of heating and cooling equipment, many do not. As suggested by the market research, contractors cannot be relied upon to educate or sell consumers on the benefits of efficient measures. Moreover, consumers have virtually no awareness of other aspects of efficiency or comfort associated with equipment installation.

**Inability to differentiate good contractors in the marketplace.** As the market research indicated, there are few barriers to entry into HVAC contracting and many contractors are inadequately skilled. There are limited opportunities for contractors to differentiate themselves. BPI is now accrediting contractors that meet its standards, and several Northeast states are promoting BPI standards through Home Performance with ENERGY STAR, but consumer education about the benefits of trained, certified professionals, accredited contractors and differences in the quality of equipment installation is slow to take hold.

**Inability to differentiate quality of installations.** Most consumers have no way to determine whether they have received a quality installation of their heating or air conditioning equipment. Although contractor training is necessary to ensure a quality installation, neither training nor certification can guarantee quality installations. This issue is discussed in more detail in Appendix C of this STAC study. Recently diagnostic tools have been developed that contractors can use to provide independent verification of quality installations, but this practice is neither widespread nor institutionalized.

**Poor HVAC contractor sales skills.** Most HVAC contractors lack sales skills, time, and motivation to educate consumers about product choices, particularly when they believe that they must compete almost exclusively on price to survive.

**Seasonality of sales**. Summer and winter are extremely busy seasons for central AC and heating equipment sales, respectively. They allow little or no extra time for special orders of efficient equipment, or proper sizing and

[27] For example see Neme, Proctor and Nadel, National Energy Savings Potential from Addressing Residential HVAC Installation Problems, ACEEE, February 1999).

installation. A large portion of contractors' business is replacement of failed equipment, when speedy service is essential.

**Split incentives.** As noted above, roughly 25% of all HVAC sales are for new homes. The builders making those purchasing decisions will not be paying the energy bills associated with their choices and, therefore, have little incentive to buy efficient equipment.

**Electric prices do not reflect true societal costs of operating air conditioners.** Electricity costs at peak times in the summer are often dramatically higher than during most of the rest of the year. However, residential consumers generally pay the same fixed price per kWh for their electric consumption throughout the summer, if not all year.

**Aesthetics.** Because there is no duct work behind the drywall, indoor units of the ductless mini-splits stick out from the wall or ceiling. This is seen by some as aesthetically unappealing.[28]

### 3.5 Regional and National HVAC Activity

Although many aspects of HVAC markets are local, national and regional activities also play an important role in shaping the Northeast market for efficient HVAC measures and practices. Chief among these are:

**ENERGY STAR Specifications**. The ENERGY STAR brand has been effectively leveraged by DSM programs and others promoting the sale of efficient equipment for years. In addition, ENERGY STAR has branded new construction, with ENERGY STAR Homes, as well as practices, such as ENERGY STAR duct sealing specification. Most recently, the U.S. Environmental Protection Agency has announced plans for an ENERGY STAR specification for quality central air conditioning installations beginning in 2007.

**Federal Energy Policy Act (EPACT) Legislation with Tax Incentives.** Tax credits are available for many types of home improvements related to building shell and HVAC from EPACT 2005. The credit applies to improvements made in 2006 and 2007, and the maximum amount a homeowner can claim is $500 during the 2 year period of the tax credit. They include the following[29]

[28] Ductless mini-splits are also generally quieter than room air-conditioners and may be quieter than some central air conditioners and fans, which is aesthetically appealing.
[29] Some windows, exterior and storm doors, metal roofs, and insulation qualify for tax credits. The complete list is available at www.energystar.gov/index.cfm?c=products.pr_tax_credits.

| Product Type | Tax Credit Specification | Tax Credit |
|---|---|---|
| Central AC | EER 12.5/SEER 15 split systems<br>EER 12/SEER 14 Package systems | $300 |
| Air Source Heat Pumps | HSPF 9 EER 13 SEER 15 | $300 |
| Geothermal Heat Pumps | EER 14.1 COP 3.3 Closed Loop<br>EER 16.2 COP 3.6 Open Loop<br>EER 15 COP 3.5 Direct Expansion | $300 |
| Furnace/Boiler | AFUE 95 | $150 |
| Circulating Fan | No more than 2% of furnace energy usage | $50 |

In addition, home builders are eligible for a $2,000 tax credit for each new qualifying energy efficient home. There is a $1,000 tax credit to the producer of a qualifying new manufactured home.

**State Standards for heating equipment*.*** Several Northeast states have drafted legislation calling for appliance and efficiency standards, including standards for residential furnaces, boilers, and furnace fans. There has been slow but significant progress with this strategy of raising the bar on energy efficiency. For example, legislation in Maine failed in committee earlier in 2006. In Connecticut, a standards bill is pending, although it was modified so that the furnace and boiler provisions apply only to government procurements. Massachusetts has adopted standards. Its next step is to petition the U.S. Department of Energy for a waiver from federal preemption. Standards legislation is currently under consideration by the full legislature in Rhode Island and Vermont; in both states it was reported favorably in committees. In addition, New York has enacted minimum efficiency standards for government procurements. These include provisions for residential furnaces and boilers, which apply to some state facilities. Table 3.7 summarizes the furnace and boiler provisions of Northeast states' standards legislation.[30]

Table 3.7 State Efficiency Standards in Massachusetts and New York for Furnaces and Boilers

| | Minimum AFUE | Maximum Electricity Ratio |
|---|---|---|
| **MASSACHUSETTS** | | |
| Natural gas & propane furnaces | 90% | 2% |
| Oil furnaces: 94,000+ Btu/hour | 83% | 2% |
| Oil furnaces:<94,000 Btu/hour | 83% | 2.3% |
| Natural gas, oil, propane hot water boilers | 84% | na |
| Natural gas, oil, propane steam boilers | 82% | na |
| **NEW YORK** (21 NYCRR Section 506.4) | | |
| Natural gas furnaces: <225,000 Btu/hour | 90% | - |
| Natural gas, oil steam & hot water boilers: <300,000Btu/hour | 85% | - |

[30] Isaac Elnecave, personal communication, April 21, 2006.

**Trade Associations, including BPI, NATE, and ACCA.** Many relevant trade organizations are described in Table 3.8. The roles of several key trade associations that influence energy efficiency programs in the Northeast are summarized in the table below. One recent development is of note is that in 2006 an ACCA working group representing manufacturers, contractors, efficiency program administrators and advocates completed national specifications that are consensus definitions of a quality contractor and a quality installation. These specifications will inform the development of an ENERGY STAR installation specification.

Table 3.8 Overview of HVAC Program Allies

| **Program Ally** | **Description; Mission and Membership** | **Energy Efficiency Program Participation** | **Energy Efficiency Opinions**[31] |
|---|---|---|---|
| Air Conditioner Contractors' Association of America (ACCA) | Standards, Accreditation (National);ACCA accredits business practices to allow technicians to do job properly and is an information and networking resource for contractors. | ACCA is starting to become involved, particularly in Northeast and CA. | "We work with CEE on residential and commercial HVAC programs and support their efforts". |
| National Association of Technician Excellence (NATE)[32] | Certification (National); NATE is a non member organization since 2000 that provides a residential and light commercial test protocol for technician certification. NATE administered 22,000 exams in 2004 with a 68% passing rate on all exams. Nationally there are over 17,000 technicians with at least one NATE certification. | The extent of NATE's participation with utilities is with various organizations such as EPRI, CEE, and some larger utilities. Utilities are definitely a partner. Manufacturers support our testing protocol directly and indirectly through programs. | "Many efficiency programs take our certification as criteria for rebates." |
| Eastern Heating and Cooling Council (EHCC) | Training, Test Administration (NJ, Long Island, MA); EHCC provides contractor training mostly in NJ, but also for Long Island Power Authority, MA programs, Honeywell, and CT. EHCC has a test bank. It requires 75% of member company technicians to be NATE certified effective July 2004. Only 15% of budget is from membership. "We need to raise the bar of | EHCC implements for NJBPU and is expanding. It works in the residential sector only. Most courses are NATE credits. | "Training is and should be necessary for field staff to participate in rebate programs". |

[31] Quotes in this table were provided by individuals interviewed as part of the market research for this study.

[32]NATE is the leading certification program for HVAC technicians and is the only test supported by the entire industry. See www.natex.org for more information.

| | | | |
|---|---|---|---|
| | professionalism in industry. It's not just about training contractors." | | |
| Building Performance Institute (BPI)[33] | BPI is a non member organization. It has grown since 1996, expanding rapidly since receipt of a federal grant in 2004 to broaden its base. It promotes excellence in the contracting trades by establishing standards of performance for technicians and providing certifications for qualified contractors. | BPI contractors use a "whole house" approach to create energy efficient, durable buildings. | na |
| Refrigeration Service Engineers Society (RSES) | Training (National); RSES is a worldwide association, with 20,000 members in the U.S. and Canada. 75% of members are HVAC professionals. | RSES has recently been involved with installation and servicing heat pump programs in Indiana. Rebated systems were required to be installed and served by an RSES trained technician. | RSES and NATE are developing a federal program. RSES provides Board membership, develops training manuals, and trains for NATE certification; NATE bylaws prohibit NATE from training. |
| American Refrigeration Institute (ARI) | Trade Association, Standards, Education (National); ARI has 200 member companies, and sets standards industry-wide, provides training and education for curriculum and testing, and has an accreditation program. ARI's goals include upgrading the industry. One of ARI's concerns is that contractors often return good equipment at a high cost to manufacturers. ARI lobbies state governments to unify standards. | "We support Clean Air Act support for EPA testing to handle refrigerants." | Many members supported the move to a minimum standard of SEER 13. The EER might be a more effective measure for energy efficiency programs. |
| Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) | Trade Association, Standards, Training (National); Sheet Metal Workers International (SMWI) is the parent organization for SMACNA; the National Energy Management Institute handles most training for SMWI; it develops training curricula for technicians and dealers to do performance contracting, M&V standards, and IAQ. | SMWI is involved. For example, a local CA union gave money for installation training to its workers for the Title 24 California building energy code concerning duct sealing. | Supports NATE certification. |
| Plumbing, | Trade Association, Education | "None that I'm aware | "No opinion." |

[33] BPI, coupled with Home Performance with ENERGY STAR programs in the Northeast can bring added focus to quality HVAC work and a house as a system approach to energy efficiency.

| | | | |
|---|---|---|---|
| Heating, and Cooling Contractors' Association (PHCCA) | (New York representative); Regional membership differs between New England and NY/NJ, since oil and gas divide as primary fuel source. | of." | |
| Empire State Petroleum Association (ESPA) | Trade Association, Marketing (New York); The ESPA represents 300 companies delivering all kinds of petroleum products. ESPA is the statewide association of the Petroleum Marketers Association of America; it is one of 42 similar state organizations. | na | ESPA provides bill stuffers, etc. and serves as facilitator for NORA programs. |

### 3.6 Northeast Program History

Some states in the Northeast have promoted efficient HVAC equipment since the 1980s. By the late 1990's, programs started to become more complex, as they began to address a broader range of efficiency opportunities. Many are summarized in Table 3.8. Key program features are:

- **Promotion of proper sizing and installation in addition to SEER and EER equipment requirements.** New Jersey Clean Energy and the Long Island Power Authority (LIPA) required Manual J calculations and documentation of air flow measurements and refrigerant charge as a condition for receiving equipment rebates. New Jersey has also promoted NATE certification as part of its program. Rhode Island, Connecticut and Massachusetts program administrators have adopted central air conditioning (AC) programs with quality installation requirements. Connecticut provides incentives for contractors to use diagnostic software to improve system efficiency. Rhode Island requires Check-Me[34] verification of charge and airflow as a condition for an equipment rebate, and Massachusetts offers supplemental rebates for installations by NATE certified technicians. Massachusetts program administrators have introduced a quality installation verification (QIV) feature in efficiency programs as well.
- **Home Performance with ENERGY STAR.** NYSERDA launched and currently administers this program, which is a national model for efforts to transform the whole building retrofit services. Comprehensive treatment of HVAC system efficiency is an important part of the program. Vermont, New Jersey, Long Island, Massachusetts and Maine have also introduced

[34] Check-Me is one of the diagnostic software products currently available that assesses various aspects of central air conditioning installation and performance. It is used in air conditioning tune-ups and in verification of quality installations.

these programs. All include some aspects of BPI Certification and/or BPI Accreditation and BPI quality assurance.

- **Rebates for efficient furnace fans.** Massachusetts, Vermont, and New Jersey provide supplemental rebates for ENERGY STAR gas furnaces with efficient fans. Vermont offers rebates for high-efficiency fans on propane and oil furnaces as well.
- **Rebates for efficient gas furnaces and boilers.** In Massachusetts and Vermont, the programs have recently placed greater emphasis (higher rebates) on highest efficiency models.
- **Duct sealing programs.** In Connecticut in 2006, a duct sealing program was launched. It provides incentives for contractors to seal ducts in existing homes. The New York ENERGY STAR Labeled Homes Program requires a duct system tightness that allows leakage of no more than 10% of the rated cfm delivery. The ENERGY STAR Homes residential new construction program in Massachusetts now provides incentives to customers who meet duct sealing specifications even if their new home does not qualify for ENERGY STAR status based on its HERS rating.

Table 3.8 Overview of Selected Efficiency Programs in the Northeast

| Program | Sponsor(s) | Scope | Program Summary |
|---|---|---|---|
| Home Performance with Energy Star | NYSERDA | Cooling and Heating; Marketing incentives to contractors | A BPI-accredited contractor assesses the home, with recommendations for energy improvements and cost estimates. The program offers a 75% reimbursement on BPI certification and accreditation as well as low interest financing to home owners for energy improvements including heating and cooling systems and building shell improvements. |
| Cool Advantage | NJBPU | Cooling equipment incentives; training incentives | Equipment incentives are tiered. The program reimburses the cost of NATE certification for contractors that pass. NJ requires documentation of proper sizing and installation |
| Cool Homes | LIPA | Cooling; equipment incentives; installation requirements | This program has been in existence for over 5 years. Over time requirements have changed to include correct sizing, charge and airflow, and random inspection to ensure quality installation. Coordination with ENERGY STAR Homes and Home Performance with ENERGY STAR is seamless to the customer. “For heating there has never been any successful coordination between gas and electrical divisions of KeySpan, and regulation applies only to electric not gas service.” |

| | | | |
|---|---|---|---|
| Cool Smart | National Grid, NSTAR Electric | Cooling; equipment incentives; certification incentives; quality installation verification | This joint program has operated since 2000. It provides rebates for efficient central AC and ASHP (split systems with ECM motors). |
| Connecticut Residential HVAC Program | Connecticut Light & Power, United Illuminating | Cooling; equipment incentives | CT offers rebates on central air conditioning and heat pumps to consumers. |
| Warm Advantage | NJBPU | Heating; equipment incentives | Rebates are offered for qualifying high efficiency gas furnaces and boilers. |
| RI ENERGY STAR Heating System Program | RI State Energy Office, National Grid (RI) | Heating; equipment incentives | Program offers rebates for steam or forced heat oil boilers in RI. |
| Gas Networks | Consortium of MA, RI and NH gas utilities | Heating; equipment incentives; certification incentives | Incentives for high-efficiency furnaces and boilers with additional rebates for high-efficiency fans (i.e. ECM motors) split between MA electric utilities. Incentives for contractors to become NATE-certified and incentives per unit installed to NATE-certified contractor. |
| Whole House Efficiency Program | Efficiency Maine (Program developed by Governor's Office of Energy Independence and Security) | Heating Pilot Program; audits and equipment incentives | Program delivery will begin before fall 2006. The program will provide homeowners access to qualified contractors who can perform energy audits and undertake cost-effective energy improvements, as well as access to financing that ensures that monthly energy savings exceed monthly debt payments, and rebates on heating equipment as well as energy efficient lighting and appliances. Funding and services provided by Efficiency Maine, Maine State Housing Authority, Northern Utilities, the Maine Oil Dealers and oil overcharge funds. |
| Vermont HVAC Program | Efficiency Vermont, Vermont Gas | Heating and Cooling equipment incentives | Equipment incentives for central HVAC and efficient furnaces and boilers. Heating equipment through Vermont Gas. |

### 3.7 Summary

The energy efficiency programs in the Northeast go a long way toward overcoming some of the barriers to HVAC energy efficiency that are due to the business-as-usual conservative culture of HVAC contractors in the region. However, several gaps remain. These include:

- **Duct sealing.** With the exception of the Home Performance programs, the New York ENERGY STAR Labeled Homes Program, and fledgling efforts in Connecticut, there is no concerted effort to create a strong market for duct sealing.
- **Oil and propane heating systems.** Because these fuels are unregulated, they generally do not receive attention through efficiency programs.[35]
- **Alternatives to central air conditioning installations.** While there is some evidence of progress in quality installation, more remains to be done. Many energy efficiency programs and trade organizations have committed themselves to business models built on the premise that quality work is required. Training, use of diagnostic equipment, and requirement of field verification are growing in the region. However, as documented as part of this STAC project's field research, NATE certification does not produce noticeably different sizing practices or proper charge and airflow. One alternative that has not been explored by programs is promotion of ductless mini-split systems that avoid many of the installation problems of central air systems.

[35] New construction and Home Performance programs are exceptions, in that in most states they are designed to address all new buildings regardless of heating fuel.

## 4. CURRENT CONDITIONS: Reports from the Field on Benefits of Contractor Training for Quality Installation and Equipment Performance in the Northeast

The STAC project included two field research tasks: an assessment of the benefits of contractor training in quality installation of central air conditioning systems, and continuous monitoring of high efficiency heating and cooling equipment performance. Results of these tasks are described briefly below. Additional details are available in Appendices D and E.

### 4.1 Benefits of Contractor Training

The purpose of this research task was to investigate and measure the impacts of training and certification on recent HVAC installations, and to recommend possible modifications to current training approaches in order to increase customer benefits and cost-effectiveness. Specific research questions addressed included:

- Are there significant differences in system performance between new and existing homes?
- Are there differences in system performance between installations done by contractors with and without training and certification?
- What are the costs and benefits of installer training?
- How can the savings and cost effectiveness of current training activities be improved?

*Methodology*

The essence of the research plan was to collect quantitative information from on-site assessments of recent central air conditioning installations from two samples of homes—one with systems installed by trained/certified installers and one with systems installed by a not trained/not certified group—and to compare results obtained from the two groups. The onsite assessments were geographically clustered in New Jersey.

Customer recruitment had to meet several requirements. In particular, the installation had to be recent, within less than two years. The customer names had to be tied to researchable contractor contact information so that two distinct samples could be identified: trained/certified and not trained/not certified.[36] For those cases in which the HVAC contracting firms were identified, the firms were cross-checked against a membership database provided by the Eastern Heating

[36] Customer names were obtained by requesting and obtaining manufacturer warranty card information from sales of recent central air conditioning system installations to customers in New Jersey

and Cooling Council. This database identifies and classifies HVAC contractors according to participation in training and certification activities. We classified firms according to the level of training and certification in their staff, based on information provided in the database, and ranked them on a scale from 1 to 8, from most trained/certified to least. Firms in which over 75 percent of staff are NATE-certified were ranked as most trained/certified. Firms without NATE certification and that had participated in at most one seminar or course were ranked least trained/not certified. The two sample frames were constructed using this information: the trained/certified group included all rank 1 firms; the uncertified group included rank 7 and 8 firms.

The sampling plan called for a minimum of 68 completed onsite assessments of homes: 34 trained/certified, and 34 not trained/not certified. This size provides 13 percent precision at the 90 percent confidence level.

Onsite assessments were conducted during the cooling season, in outdoor temperatures over 65 degrees Fahrenheit, when air conditioning performance can be measured. A small technical team was responsible for the assessments, to ensure consistency in observations. To eliminate the introduction of bias into the onsite data collection process, the customer recruitment, scheduling and onsite assessments were blind. The Conservation Services Group (CSG) staff responsible for recruitment, scheduling and assessments did not know whether customers were in the trained/certified or not trained/not certified group.[37] Results of the site assessments were not shared with the customers. Participating customers received an incentive payment after completion of the onsite assessment.

**Final Sample.** Two teams of CSG field staff completed visits to 76 sites between June and August, 2005. Proctor Engineering Proctor Engineering Group (PEG) analyzed data on 76 air conditioner installations in New Jersey. Of these, 72 assessments passed the quality control review. As shown in Table 4.1, the distribution of the final sample included 37 and 35 certified and not certified sites, respectively.

Due to the challenges of recruiting, it was not possible to achieve balance in the sample with respect to new construction, rebated equipment, and efficiency levels of air conditioning systems installed, as shown in Tables 4.1 through 5.3. Roughly one-third of the homes in the total sample were new construction. The majority of the new construction sites were also in the certified group. Roughly one-fourth of the homes in the total sample had received a utility rebate for purchase of an energy efficient air conditioner, heat pump or furnace. The majority of the rebated equipment was installed in existing homes. The central air

[37] The CSG staff was provided the model numbers of the AC systems they were to assess, as some homes had multiple systems; in cases where there were multiple new installations from the same HVAC contractor, only one system from each home was assessed.

conditioners installed ranged from SEER 8 to SEER 15. The not certified group has a slightly larger proportion of higher efficiency equipment.

Table 4.1 Sample of On-Sites, by Certification and Construction Type

| | **Certified** | **Not Certified** | **Total** |
|---|---|---|---|
| Existing Construction | 14 | 32 | 46 |
| New Construction | 23 | 3 | 26 |
| n | 37 | 35 | 72 |

Table 4.2  Sample of On-Sites by SEER of Central AC System

| **SEER** | **Certified** | **Not Certified** |
|---|---|---|
| Min | 8 | 7.1 |
| Mean | 10.8 | 12 |
| Median | 10 | 12.4 |
| Mode | 10 | 13 |
| Max | 13.4 | 15.5 |

Table 4.3 Sample of On-Sites by HVAC Rebates Received

| | **Certified** | **Not Certified** | **Total** |
|---|---|---|---|
| Rebate Received (all existing construction)[38] | 3 | 14 | 17 |

*Results*

As shown in Table 4.4, the majority of customers were satisfied with their HVAC contractor and with their system installation. However, the majority of the homes in the sample failed to meet the criterion of "quality installation."  Only 20 percent of the systems (excluding those that had been serviced since installation) had the correct refrigerant charge and roughly one-third of all installations had duct sealing that was adequate.  Figure 1 illustrates that close to 50 percent of the systems in the certified and not-certified groups had lower than recommended airflow (under 400 cfm), while Table 10 shows that, overall, systems were oversized by 20 percent.

[38] Rebates received in 2003 – 2004. Includes some rebates for heating systems.

Table 4.4a Comparison of Results of Assessments of Installation by Certified and Not Certified Installers

| | House Type | | Installer | | Sample |
|---|---|---|---|---|---|
| | New | Existing | Certified | Not Certified | |
| n | 26 | 46 | 35 | 37 | |
| Correct Charge[39] | 22% | 15% | 24% | 17% | 20% |
| Is Customer Satisfied with System Rating? | 81 % Satisfied | 82 % Satisfied | 78% Satisfied | 86% Satisfied | 83 %Satisfied |
| Is Customer Satisfied with Installer? | 61% Satisfied | 82% Satisfied | 67% Satisfied | 85% Satisfied | 76% Satisfied |
| Ducts Sealed | 42% | 33% | 56%* | 16%* | 36% |

* denotes significant differences at the 90% confidence level

Table 4.4b Comparison of Results of Assessments of Duct Sealing Quality by Certified and Not Certified Installers

| Duct Sealing Quality (Visual Assessment) | Certified | Not Certified |
|---|---|---|
| Not Sealed | 44%* | 84%* |
| Poor Quality | 27% | 13% |
| Fair Quality | 11%* | 0%* |
| Good Quality | 17%* | 2%* |
| * denotes significant differences at the 90% confidence level | | |

Furthermore, this study found that there is no statistically significant difference in installation quality, specifically charge and airflow, between the certified and not certified groups of installers at the 90 percent confidence level. Significant differences were found between certified and not certified groups with respect to duct sealing.

Many of the installation problems noted in this sample are common problems in air conditioner installations. For example, 49 percent of these air conditioners had insufficient airflow across the indoor coil, with little difference between those in the certified and not certified groups. Airflow in the AC systems installed by certified installers averaged 347 cubic feet per minute (cfm) per ton compared to a “standard” of 400 cfm per ton. Airflow in the systems in the not certified group averaged 368 cfm per ton. Similarly, there was little difference between groups with respect to refrigerant charge. Twenty-four percent of the units installed by certified installers had the correct amount of refrigerant charge, and 17% of the units installed by the not-certified installer group had the correct amount of refrigerant charge.

[39] Only Systems that have not been serviced since installation are included. Twenty-two percent of the units had been serviced since installation. When systems that have been serviced are included: New 16%; Existing 27% ; Certified 26%; Not Certified 18%

Oversizing was present in both the certified and not certified installer groups, and in both existing and new construction. The only measure with a statistically significant difference between certified and not certified installers was duct leakage. Based on a visual observation, it appears the certified installers do a better job of sealing the duct systems.

*Summary Findings and Recommendations*

With respect to charge and airflow, there were no statistically significant differences between installations in new and existing construction or by certified and uncertified contractors. Interestingly, in the case of duct sealing there were statistically significant differences; certified installers are more likely to seal ducts and their duct sealing is of higher quality than installers who are not certified. However, based on the visual assessments, even the certified installers did not consistently comply with building code (i.e. use mastic) for duct sealing. Findings of this study were consistent with recent baseline studies in that the quality of the majority of the central air conditioning system installations was inadequate. Results of this study imply that contractor training and certification alone will not produce the energy efficiency benefits that are technically achievable from proper installation.

Anecdotal evidence and market research findings indicate that many contractors receive some level of training on HVAC system installation. While many say they know what constitutes quality installation, various factors are barriers to quality installation. That said, even though systems are typically oversized, have insufficient airflow and leaky ducts, there is some anecdotal evidence that the degree of oversizing and leakage has decreased over time.

Recommendations related to the benefits of contractor training are that while training and certification are necessary, they are not sufficient to achieve energy efficiency benefits. Therefore, efficiency programs should continue to promote comprehensive training that includes field practice by approved organizations. Meanwhile, programs should also adopt inspection, testing and third party verification as part of energy efficiency program design, as is employed in NYSERDA's Home Performance with ENERGY STAR and New York ENERGY STAR Labeled Homes Programs. In addition, increased code official compliance and education and customer education are needed.

## 4.2 Equipment Performance in the Northeast

The purpose of this research task was to monitor the performance of high efficiency cooling and heating equipment in the field[40] and to assess the relationship between laboratory testing and real world performance.

[40] The original scope of the STAC project was amended to include monitoring of heating equipment.

## 4.3 Monitoring High Efficiency Central Air Conditioners

Proctor Engineering Group monitored five high SEER systems in New Jersey and New York during the 2005 cooling season with Campbell Scientific CR10X data loggers. The monitoring project included four air conditioners with recently installed high SEER two speed air conditioning systems and one high efficiency single speed AC system. Three of the systems were located in New Jersey and two of the systems were located in New York. The sample was a sample of convenience. The characteristics of the homes and air conditioners are listed in Table 4.5.

Data collected included heating and cooling capacity, power consumption, EER, indoor/outdoor temperature and relative humidity. The data were analyzed to assess the relationship between laboratory testing and real world performance.[41]

Table 4.5 Characteristics of Air Conditioners and Houses That Were Monitored

| House Characteristics | | | | | |
|---|---|---|---|---|---|
| | Site P[42] | Site S | Site T | Site N | Site W |
| House Size (square feet) | 1620 | 2375 | 1900 | 3500 | 2300 |
| Year Built | 2002 | 2000 | 1940s | 1960s | 1970s |
| Manual J7 Cooling Load (Btuh) at 90/75/63 | 22118 | 44683 | 24044 | 57380 | 25789 |
| Air Changes per Hour (ACH50) | 3.9 | 2.8 | 5.5 | 7.4 | 12.7 |
| Air to Air Heat Exchanger Flow (% of airflow) | 17% | 12% | none | none | none |
| % of Time Indoor RH >60% | 2% | 13% | 0% | 40% | 35% |
| **Air Conditioner Specifications** | | | | | |
| Rated SEER | 14.25 | 14 | 15 | 14 | 14 |
| High Speed Rated EER at 95/80/67 | 10.3 | 10.7 | 9.4 | 10.8 | 11.5 |
| Low Speed Rated EER at 95/80/67 | None | 12.2 | 11.7 | 12.4 | 12.6 |
| High Speed Rated Capacity at 95/80/67 (Btuh) | 34900 | 46080 | 34300 | 48230 | 48230 |
| Low Speed Rated Capacity at 95/80/67 (Btuh) | None | 25260 | 24700 | 27180 | 27180 |
| Number of Compressor Speeds | 1 | 2 | 2 | 2 | 2 |
| Metering Device | Fixed | TXV | TXV | TXV | TXV |

[41] These results were prepared by Proctor Engineering Group. Additional details are available in Cohn, Gabriel et al., 2006, "Two-Stage High Efficiency Air Conditioners: Laboratory Ratings vs. Residential Installation Performance" pending publication in ACEEE Summer Study Proceedings.

[42] ARI ratings are not available for the system combination (using a third party evaporator coil). The estimated rated SEER, EER, power, and capacities are for a manufacturer's combination with the same nominal capacity.

| | | | | | |
|---|---|---|---|---|---|
| Fan Motor Hp | 1/2 Hp | 1 Hp | 1 Hp | 1 Hp | 1 Hp |
| Fan Motor Type | ECM | ECM | ECM | ECM | ECM |
| Fan Mode (TD = Time Delay IO = Instant Off) | TD | Const. | TD | IO | Const. |

*House Characteristics*

All the sites were two-story homes with furnaces and ducts in the basement. Site P is a new modular home and Site S is a new ENERGY STAR home. The homes were tested for air leakage using a single point blower door test. There was a large variation in the measured air leakage (2.8 ACH50[43] to 12.7 ACH50). Sites N and W were the leakiest homes and the dual capacity/variable airflow air conditioners were unable to adequately control the inside relative humidity. The cooling loads were calculated using Manual J 7. Latent and sensible loads were calculated independently. Site N has a Manual J 7 estimated load that exceeds the nominal tonnage of the installed air conditioner – an unusual situation.

*Air Conditioner Specifications*

The air conditioners represented a narrow band of efficiencies from 14 to 15. The units were three-ton and four- ton units. There were three different types of furnace fan operation observed in these units: Constant on – this produces the minimum latent capacity since moisture on the coil at the end of the compressor cycle is evaporated back into the house air; Time delay – this is the most common fan control which is designed to maximize the SEER of the unit; and Instant off – the fan control which should produce the most latent cooling (moisture removal).

*Results*

<u>Low Speed Performance</u>

Sites P and T do not have low speed data because the former is a single speed machine and the latter dual speed machine that ran only on high speed. As noted in the table below, at low speed the other three units achieved 90+ percent of the rated capacity and their input power exceeded the rated values by 10 percent or more. The unit at Site N approached the rated capacity. The two speed high SEER air conditioning systems perform at 79 to 95 percent of their rated efficiency at low compressor speeds. This is due to a combination of lower than expected capacities and higher than expected compressor watt draws.

[43] ACH50 refers to air changes per hour at 50 pascals of pressure.

Table 4.6 Summary of Air Conditioner Performance at Low Speed

| Site | Site P | Site S | Site T | Site N | Site W |
|---|---|---|---|---|---|
| Average Outside Temperature (deg F) | NA | 82.3 | NA | 82.3 | 82.1 |
| Average Return Drybulb Temperature (deg F) | NA | 70.2 | NA | 71.1 | 73.7 |
| Average Return Wetbulb Temperature (deg F) | NA | 63.8 | NA | 61.9 | 64.9 |
| Average Cycle Length (min) | NA | 22.8 | NA | 62.1 | 64.7 |
| Number of Cycles | NA | 414 | NA | 26 | 184 |
| **Capacity** | | | | | |
| End of Cycle Net Capacity (Btuh) | NA | 21529 | NA | 29230 | 24972 |
| Mfr. Steady State (SS) Net Capacity (Btuh) | NA | 24333 | NA | 26855 | 26754 |
| % of Mfr. Steady State Net Capacity | NA | 88% | NA | 109% | 93% |
| End of Cycle Net Sensible Capacity (Btuh) | NA | 13483 | NA | 17225 | 17131 |
| Mfr. SS Net Sensible Capacity (Btuh) | NA | 15080 | NA | 18415 | 18837 |
| % of Mfr. SS Net Sensible Capacity (Btuh) | NA | 89% | NA | 94% | 91% |
| **Input Power** | | | | | |
| Total End of Cycle Input Power (W) | NA | 2011 | NA | 1943 | 2037 |
| Mfr. Steady State Input Power (W) | NA | 1792 | NA | 1692 | 1860 |
| % of Mfr. Steady State Input Power | NA | 112% | NA | 115% | 110% |
| **EER** | | | | | |
| End of Cycle EER | NA | 10.72 | NA | 15.09 | 12.27 |
| Mfr. Steady State EER | NA | 13.59 | NA | 15.88 | 14.39 |
| % of Mfr. Steady State EER | NA | 79% | NA | 95% | 85% |

High Speed Performance

The two speed high SEER air conditioners generally perform at or close to the manufacturers' ratings at high speed. Actual watt draws were close to manufacturer ratings. Thus, variations from rated efficiencies at high speed were primarily a function of variances from rated capacities (some lower and some slightly higher than rated).

Table 4.7 Summary of Air Conditioner Performance at High Speed

| Outside Temperature Bin | Site P | Site S | Site T | Site N | Site W |
|---|---|---|---|---|---|
| Average Outside Temperature (deg F) | 82.4 | 82.3 | 82.6 | 82.3 | 82.1 |
| Average Return Drybulb Temperature (deg F) | 72.5 | 70.2 | 71.9 | 71.1 | 73.7 |
| Average Return Wetbulb Temperature (deg F) | 64.7 | 63.8 | 63.7 | 61.9 | 64.9 |
| Average Cycle Length (min) | 14.5 | 9.2 | 128 | 10.3 | 29.6 |
| Number of Cycles | 366 | 186 | 9 | 9 | 52 |
| **Capacity** | | | | | |
| End of Cycle Net Capacity (Btuh) | 23560 | 32933 | 27445 | 46822 | 46161 |
| Mfr. Steady State (SS) Net Capacity (Btuh) | 33685 | 40964 | 32488 | 44382 | 42436 |

| | | | | | |
|---|---|---|---|---|---|
| % of Mfr. Steady State Net Capacity | 70% | 80% | 84% | 105% | 109% |
| End of Cycle Net Sensible Capacity (Btuh) | 17018 | 19560 | 22777 | 28005 | 30823 |
| Mfr. SS Net Sensible Capacity (Btuh) | 20964 | 23900 | 24954 | 27692 | 27471 |
| % of Mfr. SS Net Sensible Capacity (Btuh) | 81% | 82% | 91% | 101% | 112% |
| **Input Power** | | | | | |
| Total End of Cycle Input Power (W) | 2902 | 4375 | 2627 | 3909 | 4127 |
| Mfr. Steady State Input Power (W) | 2647 | 4423 | 2719 | 4164 | 3988 |
| % of Mfr. Steady State Input Power | 110% | 99% | 97% | 94% | 103% |
| **EER** | | | | | |
| End of Cycle EER | 8.13 | 7.54 | 10.45 | 12.05 | 11.19 |
| Mfr. Steady State EER | 12.74 | 9.27 | 11.95 | 10.66 | 10.64 |
| % of Mfr. Steady State EER | 64% | 81% | 87% | 113% | 105% |

Moisture Removal

The two homes (P and S) with the least air leakage had heat recovery ventilators that supplied ventilation to the home. The single speed air conditioner in one of the tight homes (P) was able to keep the indoor relative humidity to less than 60 percent for all but two percent of the time. The two speed air conditioner in the other tight home (S) succeeded in that task all but 13 percent of the time. Moisture removal in home S was seriously compromised by the use of a continuously running fan.

The two leakiest homes (W and N) exceeded 60 percent indoor relative humidity (Rh) 35 and 40 percent of the time respectively. It is likely that Site W had significant duct leakage which, when combined with constant fan, caused latent removal problems the air conditioner could not overcome. Site N with instant off fan and a nominally undersized air conditioner was still unable to adequately control the moisture in the home. One reason for this was that the actual load was only 30 percent of the Manual J estimate.

Sizing

In all cases the actual loads under design conditions were less than Manual J7 estimates. In four of the five cases the loads were less than 60 percent of the Manual J estimate, and actual loads at two of the five homes less than 40 percent of Manual J (i.e. Manual J estimates for those homes were two to three times the actuals). Manual J results for the sensible portion of total loads were even worse. Oversizing is not likely to significantly affect seasonal energy use of variable speed systems. For most of the units the average duty cycle EER was very close to the end of cycle EER.

Table 4.8 Comparison of Measured and Estimated Cooling Loads

| Site | Site P | Site S | Site T | Site N | Site W |
|---|---|---|---|---|---|
| **Design Cooling Loads** | | | | | |
| Manual J7 Estimated Total (btuh) | 22,118 | 44,683 | 27,513 | 57,384 | 25,789 |
| Measured Total (btuh) | 8381 | 15,702 | 15,026 | 34,565 | 23,660 |
| Actual/Total MJ7(%) | 38% | 35% | 55% | 60% | 92% |
| Manual J7 Estimated Sensible (btuh) | 19,298 | 37,841 | 24,044 | 52,682 | 23,226 |
| Measured Sensible (btuh) | 6687 | 10,648 | 12,395 | 15,767 | 16,244 |
| Actual/Sensible MJ7 (%) | 35% | 28% | 52% | 30% | 70% |

## Peak Energy Use

Proper sizing may provide significant peak demand savings. Based on analysis of the results, Proctor noted that for two machines with the same peak EER, there will be no difference in peak energy consumption if the two units are sized to run continuously on peak. Given two machines sized to a high speed duty cycle of 75 percent at peak, with the same peak EER, one single speed machine and one two speed machine: the two speed machine would save 12 percent on peak.

## Seasonal Energy Efficiency

Seasonal Energy Efficiency and consumption were calculated using TMY-2 temperature bins for locations selected for proximity, similar latitude, and similar distance inland. The capacities and input powers were averaged for all cycles in each temperature bin for Seasonal Efficiency calculations. Each site is compared to average central air conditioned homes in the Middle Atlantic region by AC Energy Intensity (kWh/sq.ft.) as reported by the Energy Information Administration Residential Energy Consumption Survey results from 2001.

In all cases the measured seasonal efficiency was less than the rated SEER. Sites S and W would both be substantially more efficient without the continuous fan. All homes except Site N had an AC Energy Intensity (seasonal air conditioning kWh per conditioned square foot that exceeded the average for the Mid Atlantic Region.

Table 4.9 Comparison of Measured and Rated Seasonal Energy Efficiency

| House ID | P[44] | S | T | N | W |
|---|---|---|---|---|---|
| Seasonal Performance | | | | | |
| Rated SEER | 14.25 | 14 | 15 | 14 | 14 |
| Measured Seasonal BTU/Wh | 7.92 | 8.6 | 11.5 | 11.7 | 8.25 |
| Seasonal BTU/Wh without constant fan | | 9.9 | | | 12.2 |
| Seasonal kWh | 1445 | 2351 | 2777 | 2168 | 1870 |
| Seasonal kWh without constant fan | | 1986 | | | 1299 |
| Average Seasonal kWh/sq.ft. in Region | 0.63 | 0.63 | 0.63 | 0.63 | 0.63 |
| Site Seasonal kWh/sq.ft. | 0.89 | 0.99 | 1.46 | 0.62 | 0.81 |

<u>Fan Operation</u>

The two sites (S and T) with constant fan display some of the problems with that type of fan control; the seasonal energy efficiencies of these two units were substantially degraded.

<u>Single Speed System</u>

The one single speed machine was the worst performer of the units in this test; measured steady state efficiency was 64 percent of rated efficiency. This is inconsistent with the results of past field tests of other single speed air conditioners which suggested that properly installed units operated at efficiencies close to those suggested by manufacturer ratings.

*Summary of Air Conditioner Performance*

With a sample of four two-speed and one single-speed high efficiency systems definitive conclusions are not possible. However, results of the monitoring of these units suggest:

- **Actual average seasonal efficiencies were significantly lower than rated efficiencies**. The average seasonal efficiency was 9.6 Btu/Wh or just 67percent of the units' average SEER rating of 14.25. Part of this reason was that two units were operated with the fan running continuously. However, even adjusting for that effect the average seasonal efficency was just 10.6 Btu/Wh, or 74 percent of their average SEER rating.

- **Actual steady-state operating efficiencies of variable speed units can differ from rated steady-state efficiencies**. At low speed, they ranged

[44] ARI ratings are not available for the system combination (using a third party evaporator coil). The estimated rated SEER, EER, power, and capacities are for a manufacturer's combination with the same nominal capacity.

from 79 to 95 percent of rated efficiency. Higher than rated watt draws were the biggest contributor to lower efficiencies at low speed (although a couple of units also experienced slightly lower than rated capacities). Actual watt draws at high speed were very close to manufacturer ratings. Thus, variations from rated efficiencies at high speed were primarily a function of variances from rated capacities (some lower and some a little higher than rated).

- **The actual steady-state efficiency of the one single-speed AC was much lower than (i.e. 64 percent of) its rated efficiency;** this finding is inconsistent with the results of past field tests of other similar single-speed air conditioners[45].

- **Manual J may significantly over-state actual total loads on the house**. Actual average total loads were 56 percent of Manual J estimates (i.e. Manual J estimates were as much as 2 to 3 times the actual loads). Manual J results for the sensible portion of total loads were even worse.

- **Humidity control was a significant problem in two homes**. This appears to have been a function of significant over-sizing relative to actual loads (not relative to Manual J, which dramatically over-estimated the load) in one home, and continuous running of the fan in another.

- **Occupant behavior has important impacts on system efficiency and comfort**. The two homes that ran their fan continuously saw significant deterioration of seasonal efficiency as a result. One of those homes also experienced a serious inability to control humidity levels because continuous fan use negates the ability of a central air conditioner to remove moisture from the air (the moisture on the coils is re-evaporated when the compressor turns off).

- **Building envelope can impact system efficiency**. Significant air leakage in some of the homes was a factor contributing to the inability of some of the systems to control humidity.

- **Over-sizing is not likely to significantly affect seasonal energy use of variable speed systems**, since – for most units – the average duty cycle EER was very close to the end of cycle EER. However, proper sizing may still provide significant peak demand savings.

- **Variable speed ACs do not run continuously at full speed during the peak hour** if the thermostat is not manipulated to make them do so (this happened in one home).

[45] John Proctor, personal communication, January 2006.

- **The interaction of sizing, building tightness, and occupant behavior (thermostat settings and/or fan use) impacts system efficiency.** As noted in the discussion, all of these factors influence measured system efficiency.

### 4.4 Monitoring High Efficiency Gas Furnaces

Four of the five sites in the Central Air Conditioning Monitoring Study had high efficiency condensing gas furnaces that were monitored during the 2004/2005 heating season. Condensing gas furnaces are the most energy-efficient furnaces available, with seasonal efficiencies between 89 and 97 percent. Most have burners similar to conventional furnaces, with draft supplied by an induced draft fan. There are additional heat exchange surfaces made of corrosion-resistant materials (usually stainless steel) that extract most of the heat remaining in the combustion by-products before they are exhausted. In this condensing heat exchange section, the combustion gases are cooled to a point where the water vapor condenses, thus releasing additional heat into the home. The condensate is piped to a floor drain.

In this monitoring study, operating characteristics were measured and seasonal performance of the furnaces was calculated. Summary results are provided in the table below. Additional details, including charts of each furnace's cycle length and end of cycle and mean efficiencies throughout the range of temperature differentials, are provided in Appendix D.

Table 4.10 Summary of Furnace Specifications and Operating Characteristics

| House ID | W | T | P | S |
|---|---|---|---|---|
| House Size (square feet) | 2300 | 1900 | 1620 | 2375 |
| Year Built | 1970s | 1940s | 2002 | 2000 |
| Furnace/Air Handler Location | Basement | Basement | Basement | Basement |
| Manual J Heating Load | 49,709 | 30,594 | 20,701 | 58,680 |
| Air Leakage ACH50 | 12.7 | 5.5 | 3.9 | 2.8 |
| Air to Air Heat Exchanger Flow (% of total airflow) | None | None | 17% | 12% |
| **Furnace Specifications** | | | | |
| Rated AFUE | 0.941 | 0.943 | 0.91 | 0.941 |
| Low Fire Input (BTU/h) | 52,000 | 60,000 | 52,000 | 52,000 |
| High Fire Input (BTU/h) | 80,000 | 88,000 | 80,000 | 80,000 |
| Rated Temp Rise (deg F) | 50-80 | 35-65 | 50-80 | 50-80 |
| Rated High Fire Temp Rise (deg F) | 35-65 | 70-100 | 35-65 | 35-60 |
| Fan Motor Hp | 1 Hp | 1 Hp | ½ Hp | 1 Hp |
| Fan Motor Type | ECM | ECM | ECM | ECM |

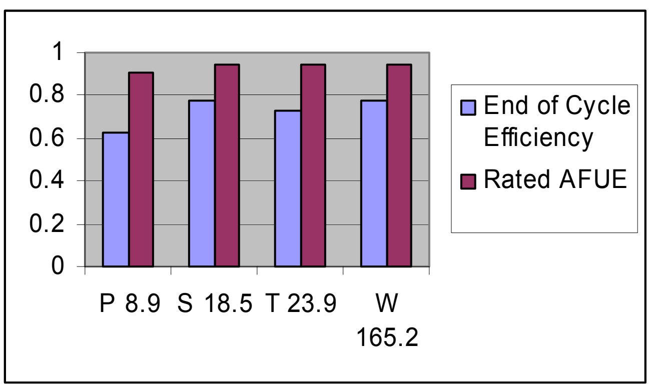
| Furnace Operating Characteristics | | | | |
|---|---|---|---|---|
| Mean Indoor Temperature (deg F) | 65.9 | 69.3 | 67.4 | 69.5 |
| Run Time at Bin of Highest Use | 48.5 | 16.5 | 6.2 | 13.0 |
| % of Time on High Fire | 16% | 8% | 0% | 5% |
| Seasonal Gas Energy Use (Therms) | 2006 | 937 | 724 | 465 |
| Seasonal Electrical Energy Use (kW) | 1023 | 313 | 302 | 158 |
| **Seasonal Performance** | | | | |
| Measured Heating Load BTU/h | 53,886 | 30,594 | 14,570 | na |
| Seasonal Efficiency | 0.67 | 0.68 | 0.59 | 0.79 |
| Measured Heating Load as % of Manual J7 | 108.4% | 71% | 70% | na |

*Summary of Furnace Performance*

The Annual Fuel Utilitization Efficiency (AFUE) is the most widely used measure of a furnace's heating efficiency. The U.S. Department of Energy defines AFUE as:

> "The measure of seasonal or annual efficiency of a furnace or boiler. It takes into account the cyclic on/off operation and associated energy losses of the heating unit as it responds to changes in the load, which in turn is affected by changes in weather and occupant controls[46]."

Figure 4.11 Comparison of End of Cycle Efficiency at Maximum Temperature Differential with Rated AFUE




Note: Both the site identifier and the cycle length (minutes) at maximum temperature differential are shown on the x axis.

In this sample of four condensing gas furnaces, all had AFUE Ratings over .9 (over 90 percent). The efficiencies measured based on monitoring results were in the 60-80 percent range. A sample of four condensing furnaces provides anecdotal information, and is not a representative sample. These results are

[46] http://www.furnacecompare.com/faq/definitions/afue.html

impossible to explain without additional information. For example, more information is needed to understand the degree to which building envelope factors and occupant behavior and sizing affect equipment performance. It would also be helpful to better understand assumptions and test conditions used in the establishment of manufacturer AFUE ratings.

Contrary to conventional and mid-efficiency furnaces, where efficiency decreases with furnace oversizing, some literature suggests that "condensing furnaces are actually more efficient when they are oversized and run for shorter periods."[47] To investigate these and other benefits of high-efficiency condensing gas furnaces in comparison to conventional furnaces, monitoring of the in-field performance of conventional equipment is also needed.

Note that measured heating loads of two furnaces, T and P, are 70 percent of Manual J7 loads. The furnace that is the closest to the actual heating load (W) has a measured efficiency similar to site T. Although W, and S have the same rated AFUE, they vary with respect to cycle length and measured efficiency. Cycle length is dictated by thermostat deadband and the volume of the house as well as furnace size. Based on cycle lengths, W at 48 minutes ought to be most efficient; however S with the second lowest cycle length, 13 minutes, is most efficient. P, which also has a smaller fan motor, has the shortest cycle length and also the lowest efficiency. The site with the longest cycle, W, has an intermediate efficiency.

Because this monitoring task was an add on to the original project scope, with limited funding, it was not possible to conduct a comparative study of conventional and condensing furnaces, or to identify the factors contributing to the differences between measured and rated performance of the four furnaces that were monitored. However, these monitoring results raise questions that may merit future research with larger sample sizes.

[47] This point is discussed in oee.nrcan.gc.ca. See this site also for further discussion of size ranges available in condensing furnaces.

## 5. CASE STUDY: Duct Sealing Market Research and Proposed Program Design

Duct sealing is an important but challenging component of a strategy to increase overall HVAC energy efficiency in residential buildings in the Northeast. One task in the STAC project was to propose a program design to deliver duct sealing, following review of current programs, literature and market research to test program design concepts. Key aspects of this task are summarized here, and additional details are available in Appendix E.

### 5.1 Barriers and Opportunities Related to Market-Based Duct Sealing Programs in the Northeast

While the potential market for duct sealing is large, current opportunities to deliver quality duct sealing are limited. A successful market-based duct sealing program must address the following barriers: customers' lack of information, their lack of understanding that comfort humidity issues may be related to duct leakage, lack of a clearly defined product that customers can understand such as the inclusion of measurable performance criteria, as well as customers' inability to identify contractors with the proper equipment and expertise. In addition, customer up-front investment is a barrier.

Lack of adequate training and certification of HVAC contractors is another barrier. Market research suggests that a majority of HVAC contractors are somewhat knowledgeable about duct sealing but not specifically trained and certified on duct sealing.[48] Moreover, those who are trained and certified do not necessarily apply their training in the field. Because the residential HVAC business is a low-bid business, HVAC contractors see little opportunity for profit from investing extra time, staff, paperwork or training on duct sealing. Furthermore, duct sealing is not typically a stand-alone activity. More commonly, when it is done, it is done in combination with other services.

Another barrier is that there is no quality assurance process in place to ensure that duct sealing is done properly. As indicated by various field studies, building codes have not proved sufficient to ensure proper duct sealing in these markets. Building code requirements in the Northeast address only the new construction and remodeling parts of the target market for duct sealing.

From a strategic perspective, the growing interest in duct sealing among efficiency program administrators in the Northeast, and the ENERGY STAR specification for duct sealing, are both opportunities and barriers. Utility

[48] Please see Appendix A for tabulations of HVAC contractor survey questions related to current duct sealing practices.

incentives and “branding” of duct sealing can assist contractors in delivering and marketing duct sealing, but the variety of programs and program requirements sends confusing signals and adds to the “cost and hassle” concerns of contractors. While performance requirements are common and often necessary for implementation of efficiency programs, flexibility is needed to capture a significant portion of the potential market. The Massachusetts residential new construction program for example, now offers tiers of duct sealing requirements, which enlarges its target market.

High fuel costs are an opportunity in the sense that they can help generate customer interest and awareness of energy savings; they also increase the value of the savings to utilities.

Finally, recent increases in the availability of training and certification of HVAC contractors on installation issues by utilities and trade organizations are an opportunity, as these can be leveraged by a market-based duct sealing program.

*Existing Duct Sealing Programs*

Experience with existing duct sealing programs is concentrated in the Southern and Northwestern states. A survey of current duct sealing programs is included in Appendix E. Some programs emerged in Florida in the early 1990’s. More recently Georgia, Texas, Arizona, Oregon, California, and New York introduced programs. Virtually all of the programs provide incentive payments to defray customer and/or contractor costs. Some (Connecticut for example) offer free duct sealing to customers or free contractor training (Texas, San Diego County). Many provide training for HVAC contractors. Two programs partner with the federal ENERGY STAR program (Texas, New York State Energy Development and Research Authority), and at least two have duct sealing performance requirements similar to the ENERGY STAR requirements (Sacramento California, Oregon). Most of the programs use conventional marketing including stuffers and mass media outlets, as well as relying on contractors for marketing. One unique community-oriented word-of-mouth-based marketing strategy used in a pilot program by Georgia Interfaith Power and Light and the Georgia Power Company is to recruit customers in church congregations.[49] Most programs specialize in serving either new construction or duct repair in existing homes, or in one case, the mobile home market. Given that contractors tend to specialize in one market and that the programs restrict participation to trained contractors, opportunities to increase the supply of trained HVAC contractors are somewhat limited.

[49] Katy Hinman, Executive Director, Georgia Interfaith Power and Light, personal communication, October 2005.

California provides examples of multiple duct sealing program strategies. Taken together, they combine the market pull of efficiency programs,[50] providing incentives to contractors to offer duct sealing as a remediation service, with the market push of a new building energy code that includes both measurable performance criteria and a quality assurance process for duct sealing in new construction and remodeling projects. Beginning October 1, 2005, under Title 24 of the California building energy code, a home's ducts must be tested for leaks when a central air conditioner or furnace is installed or replaced. Ducts that leak 15 percent or more (relative to total cfm distribution) must be repaired to reduce the leaks.[51] Under the Prescriptive Compliance Approach, every custom home and every seventh production home must be tested by a HERS rater. After the job is complete, the homeowner chooses whether to have an approved third-party field verifier check to make sure the ducts testing and sealing were done properly or to have the home included in a random sample where one in seven duct systems are checked. Under the Prescriptive Compliance Method ducts must be sealed in all climate zones. Under the Performance Compliance Method, the builder may make credit by "trading-off" between the building envelop, water heating and space conditioning, but will probably find that duct sealing is the most cost effective measure.[52]

### 5.2 Market Research on Duct Sealing Program Design

As part of the STAC project, three core program design scenarios for the delivery of market-based duct sealing programs were identified, and HVAC contractor reactions to these scenarios were tested in a focus group of ten contractors[53] in Clifton, New York in October 2005. Performance standards for the three scenarios were held constant. The scenarios included:

**Code Change**. Local building codes are changed so that all duct systems for newly constructed homes or major renovations must be sealed. For replacing equipment on existing duct work, systems leaking in excess of 20 percent must be sealed to less than 15 percent of total airflow. Before installing any new or existing system, a contractor must include plans for testing ductwork and measuring duct leakage. Code inspections may include testing and verification of adequate duct sealing, and failure to achieve an adequate level of duct sealing will result in failure to pass code inspection.

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[50] The Sacramento Municipal District 2006 Air Conditioner and Heat Pump Program, for example, offers incentives to contractors for duct sealing based on measurable criteria and includes a verification requirement.

[51] The mandatory requirements for duct systems include: UL 181 approved tapes and sealants; no duct tape without mastic and a draw band; building cavities cannot convey conditioned air; plenum insulation must have a R4.2 resistance factor; ducts must be supported every four inches to reduce sagging.

[52] See http: www.title24energy.com/title24_testing.php

[53] Five were recruited from the NYSERDA Home Performance with ENERGY STAR program list of participating contractors and five from the local yellow pages.

**Premium Service Program.** Financial incentives are offered for testing and sealing ductwork. This includes payment to the contractor upon testing duct leakage and providing test results to the customer; payment to the customer upon satisfactory completion of duct sealing; and payment to the contractor upon satisfactory completion of duct sealing. In addition, participating contractors will be required to attend a three-day training on duct sealing techniques. To ensure quality of service delivered, contractors will be required to call a dedicated call center and report on specific testing and performance measurements to verify that the duct system is adequately sealed. All jobs will be subject to independent testing and verification. Ten percent of all rebated systems will be independently tested and verified. Failed systems result in penalties to the contractor.

**Add-On to HVAC Installation Program.** Duct sealing services will be added on to existing energy efficiency programs, such as incentives to purchase high efficiency furnaces or central AC systems, or energy audits of existing homes, for example. Financial incentives are offered to the customer and contractor. Requirements for the contractor are similar to those in the premium service scenario – requirement of free training to participate. All jobs will be subject to similar independent testing and verification. The contractor receives an incentive to become NATE-certified that covers the training and exam costs. The customer receives an incentive payment for each high efficiency furnace, central AC or heat pump system that is installed by a NATE-certified contractor and sized by ACCA procedures. The customer receives an incentive for satisfactory completion of the duct sealing work as well.

Participants in the focus group scored each scenario based on their perceptions of the scenario's strengths and weaknesses, by rating a set of statements on a scale of 1 to 5, strongly agree to strongly disagree. Further details of the focus group research are included in Appendix E. The table below is based on a summary of the scores from the participants, based on aggregating evaluated statements into two groups, scenario benefits and scenario costs and ranking the respondent results from 1 to 3. A rank of 1 indicates the scenario is most preferred, based on strongest agreement with evaluated statements.

Table 5.1 Set of Program Attributes Evaluated by Focus Group

| **Benefits** |
|---|
| This program offers clear verifiable standards so that my work will be held to the same standard as my competition |
| This program will give me added business during slow seasons. |
| This program gives me a good way to differentiate myself from the competition. |
| I think my customers would take advantage of this program. |
| **Costs** |
| Paperwork and inspection process sound reasonable to me. |
| My training needs will be adequately addressed. |
| This program would be a tough sell to customers. |
| This program will cost me more in equipment than I can recover. |
| **Applications** |
| This program will be effective in new construction and first-time installations. |
| This program will work well for retrofits. |

Table 5.2 Focus Group Results: Rank of Scores by Scenario

| Attributes | Code | Premium | Add-On |
|---|---|---|---|
| Maximum Contractor Benefits | 3 | 2 | 1 |
| Minimum Contractor Costs | 3 | 2 | 1 |
| Effective for: | | | |
| New Construction | 3 | 2 | 1 |
| Retrofit | 3 | 1 | 2 |
| Overall Grade | 3 | 2 | 1 |

Note: Rank where 1 is scenario most-preferred by respondents and 3 is least- preferred, based on their scores on evaluated statements

In summary, the results of the focus group indicate that the participants preferred incentive programs to code change as a program approach. Discussion revealed that a major concern was inconsistency of code enforcement by code officials. Also, the incentive programs are more likely to serve a larger variety of customers (new construction and retrofit). These results imply that elements of a program design that will be successful from contractors' perspective should include:

- Clear verifiable performance standards;
- Different criteria for new and retrofit applications;
- Customer education;
- Marketing support for contractors;
- Recognition that in current practice duct sealing competes with the installation season, most training is on-the-job, and that code change as a stand-alone strategy restricts the target market and energy savings potential from duct sealing unnecessarily.

### 5.3 Plan for Duct Sealing Program

*Strategies and Goals*

The fundamental goal of this program will be to create a residential duct sealing market in the Northeast to one in which quality installations or repairs are standard practice. Making properly sealed ducts the norm in the residential housing sector will be expected to generate substantial energy and peak demand savings.

*Program Features*

The program combines lessons learned from the analysis of existing programs. Key features of the recommended market-based program strategy include:

- Verifiable and enforced performance criteria;
- A comprehensive incentive structure that allows contractors to address nearly every system that has potential in both new construction and existing homes;

- Hands-on in-field training for contractors;
- Leveraging other national efforts, including quality installation specifications developed by ACCA and the national ENERGY STAR Homes program criteria and ENERGY STAR duct sealing specifications;
- Building energy code requirements that define measurable standardized minimum acceptable performance criteria for duct sealing in new HVAC installations.

To be successful in transforming the market, the program will need to address all the market barriers to duct sealing. Given the diverse nature of the barriers and the large potential target audience, the program will have several components that are described below.

**Verifiable Performance Criteria and Comprehensive Incentive Structure.** Table 5.3 identifies the performance criteria and incentive structures developed for three categories of potential duct sealing customers: ENERGY STAR Homes program participants, customers with new duct installations, and customers with existing ductwork in need of repair and sealing. These requirements are intended to reinforce customer education and provide incentives for contractors. Additional incentives to raise the skill level of HVAC contractors and to assist with marketing and customer education are also provided.

Table 5.3 Summary of Proposed Performance Criteria and Incentives

| **Target** | **ENERGY STAR Homes** | **New Ductwork** | | | **Duct Repair** | | |
|---|---|---|---|---|---|---|---|
| | | Performance Criteria | Customer Incentive | Contractor Incentive | Performance Criteria | Customer Incentive | Contractor Incentive |
| Base | | | | | | $50 towards audit measuring of pre-treatment CFM | $.50/CFM<br>Reduction for documente d treatment |
| Tier 1 | ≤6 CFM to outdoors per 100 sq ft of conditioned space[54] | ≤6 CFM to outdoors per 100 sq ft of conditioned space | $100 per qualifying job | $150 per qualifying job | Reduce leakage by 50% or achieve <20% of system air flow | $100 per qualifying job | $50 per qualifying job |

[54] The EPA duct leakage requirement reported in the ENERGY STAR Qualified Homes National Performance Path is: "Ducts must be sealed and tested to be ≤ 6 cfm to outdoors/100 sq. ft. of conditioned floor area, as determined and documented by a RESNET-certified rater using a

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Tier 2 | <4 CFM to outdoors per 100 sq ft of conditioned space[55] | <4 CFM to outdoors per 100 sq ft of conditioned space | $200 per qualifying job | $225 per qualifying job | Reduce leakage by 67% or achieve ENERGY STAR duct sealing criteria of 10% of total system leakage.[56] | $200 per qualifying job | $100 per qualifying job |

**Contractor Incentives to Support Training and Marketing.**

- Any participating contractor who successfully completes the training and certification qualifies for a partial rebate on the purchase of duct measurement equipment (e.g. a Duct Blaster).
- Participating HVAC Contractors who successfully complete a minimum threshold number of jobs in a year will be entered into a drawing for a prize.
- Contractors who measure whole house leakage and submit documentation of the test results to the customer and program administrator will receive an incentive to help defray the cost of the test.

This is a first step in educating customers about the possible interactions of duct leakage and house leakage and the impact of house leakage on the performance of HVAC equipment. It will provide customers and program administrators with information that can assist in identifying and prioritizing additional energy efficiency opportunities.

**Contractor Training and Certification.** Participating contractors are required to successfully complete an approved training program that includes infield practice. If contractors have previous training that covers the training program content, they must demonstrate completion of that training (e.g. certification) and be observed in the field prior to participation.

**Referral/Marketing.** Program administrators will market the duct sealing services, and post lists of certified participating contractors on a web site.

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RESNET-approved testing protocol or through an equivalent ASTM-approved testing protocol. Duct leakage testing can be waived if all ducts and air handling equipment are located in conditioned space (i.e., within the home's air and thermal barriers) AND the envelope leakage has been tested to be ≤ 3 ACH50 OR ≤ 0.25 cfm50 per sq. ft. of the building envelope." (www.energystar.gov/partners)

55 This condition meets ENERGY STAR criteria under the Building Option Package (BOPS) in which HERS ratings are not used (Richard Faesy, personal communication, May 25, 2006).

56 Supply and return leakage divided by fan flow should be no more than 10% or 40 cfm/ton per ENERGY STAR DUCT SPECIFICATIONS (www.energystar.gov/ia/products).

**Quality Assurance.** Contractors must submit documentation of pre- (retrofit) and post-duct sealing tests prior to receiving rebates. Independent testing and random verification of some sample of all jobs will take place. For example, the NYSERDA Home Performance program requires independent quality assurance technicians check the first three jobs of every participating contractor. After that, they inspect 15 percent of all the jobs completed. Customers can also request inspections.The test results are included in quarterly reports[57]. Failure in the testing and verification will result in penalties to the contractor.

**Delivery.** These duct sealing provisions may be offered as one or more stand-alone programs or as components of a building performance program and/or an efficient equipment program, depending on the portfolio and needs of individual program administrators. Economies of scale are available by providing training to contractors and independent verification and testing as services to all possible target audiences.

**Building Energy Code Upgrade.** The incentive and performance criteria recommended to increase duct sealing is a strategy to build a market. Adopting a longer term perspective, program administrators have the opportunity to help increase opportunities for duct sealing through building code upgrades. The combination of California Title 24 building energy code experience combined with evaluation results from current and future Northeast duct sealing efforts could serve as inputs to recommendations for building code change at the national level. Program administrators can identify and begin to work with an appropriate organization, such as the Alliance to Save Energy Building Code Assistance Project, on this issue. The next opportunities for updates of the International Construction Code are three and six years in the future, March 2009 and 2012, respectively. Recommending code changes typically requires enlisting interest and support from around the country, including documentation of impacts including expected costs and energy and other benefits. While state-level building energy code upgrades can also be made, change at the national level would have a larger market-based impact.

*Impacts on Market Barriers*

The table below summarizes how the market barriers will be addressed by various duct sealing program features.

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[52] Mark Dyen, personal communication, February 2006.

Table 5.4 Market Barriers Addressed by Intervention Strategies

| **Market Barriers** | **Program Feature/ Intervention Strategy** |
|---|---|
| Customers | |
| Lack of Information | Marketing and outreach |
| Lack of Understanding | Use ENERGY STAR Brand where applicable and incentives to send message, piggy back on other efficiency programs |
| Inability to Differentiate Contractors | Establish Preferred contractor program with requirements for participation in incentive programs |
| Up -front Investment Required | Incentives |
| Contractors | |
| Lack of Training and Certification | Work with trade allies to design and offer training on techniques; |
| Installation Skills not applied | Provide in the field training; quality assurance component; building code change; measurable criteria |
| Quality not Assured | Require third party inspection, verification; impose performance requirements that are measurable standards |
| Lack of Profit Motive | Tiered incentives; penalties for failed performance; provide for training; change building code to level playing field |
| Lack of Utility Program Consistency | Encourage consistency in approaches with neighboring utilities.<br>Evaluate pilot efforts early to refine incentives, messaging, savings estimates.<br>Leveraging national efforts including the ACCA quality installation specifications and Energy Star Homes Programs. |

*Evaluation and Tracking: Indicators, Outcomes*

Measurable progress in the following areas can be tracked. In the first two to three years, the program will attempt to:

- Increase the number of HVAC contractors with good skills by promoting in-depth training on equipment, sealing products, and key issues related to design and repair;
- Increase the quality of duct installations and repairs by including measurable performance standards and third party verification of workmanship into the practice of duct sealing.
- Raise the market penetration of duct sealing services in conjunction with other efficiency services available to single family residential homes, including new construction, remodeling/replacement, and existing homes.
- Increase customer awareness by providing customer incentives for proper

duct sealing practices in conjunction with other energy efficiency services.
- Increase customer and contractor perception of value.
- Prepare for future building energy code update by documenting regional baselines and duct sealing program results, as the next opportunity to update ICC code will be in 2009.

The program should be judged according to its ability to meet these objectives over the next three years. Longer-term objectives of the program are to

- Identify and make use of appropriate mechanisms for permanently institutionalizing demand for and supply of duct sealing practices in the residential HVAC market.
- Reduce the costs of duct sealing practices.
- Establish consistent duct sealing requirements in the region.
- Update national building energy code concerning duct sealing.
- Facilitate or support efforts of regional and national stakeholders to modify ICC Building Code to establish performance standards and a third party inspection process for duct sealing for consideration in the 2009 or 2012 update.
- Increase the regional baseline energy efficiency of new HVAC installations by changes to building energy codes related to duct sealing in some Northeast states.

*Program Integration*

Many of the program features can be added on to existing programs that promote high efficiency heating and cooling equipment and to programs that offer home audits and weatherization services.

To maximize participation, gas and electric efficiency programs should share in benefits and costs of the program features, as well as providing coordinated training, marketing, and outreach to appropriate customers.[58]

Program administrators should leverage other opportunities to communicate the duct sealing message to homeowners and contractors, such as outreach about equipment operation and maintenance or health benefits related to indoor air quality.

[58] If/when oil energy efficiency programs are developed, these should also share in benefits and costs of developing a market for duct sealing.

# 6. CONCLUSIONS AND RECOMMENDATIONS: Agenda for Increasing Energy Efficiency in Northeast Regional HVAC

## 6.1 Conclusions

As shown in previous sections of this study, it is possible to achieve enough energy and demand savings from improved efficiency of residential HVAC systems over the next ten years to reduce consumption by over one percent of forecasted residential oil, gas and electricity demand in 2016. This can only be accomplished by significant improvements in HVAC systems throughout the region and across all fuels. These improvements will require changes in HVAC installation practices as well as in the distribution chain of HVAC equipment in the region including:

- Proper sizing and quality installation of residential HVAC equipment
- Equipment efficiency
- Distribution systems, duct sealing and thermal envelope
- Market mechanisms that lead to maintenance and optimal operating efficiency of HVAC systems.

## 6.2 Strategy

The first step in realizing the savings potential is to identify strategies that are needed to overcome barriers present in the Northeast HVAC market. In recognition of the complex nature of the market, the agenda for change needs to engage many, and varied, stakeholders in the market. We recommend four interrelated strategies to achieve the desired changes in the Northeast region, specifically:

1. **Coordinate efficiency program efforts across fuels and sectors.** Energy efficiency programs that are active in the region already play a key role in overcoming customer and HVAC contractor-related barriers to improved energy efficiency. We recommend that these programs continue with some enhancements and that new programs are launched, with the end result that installation practices, operation and maintenance, HVAC equipment for all fuels, and thermal envelope improvements are program elements in all states, across all fuels – oil, gas, and electricity, and for all sectors – new construction, remodel and retrofit. Coordination is needed so that customers and HVAC contractors receive consistent messages about HVAC energy efficiency opportunities. Coordination across programs, sectors and fuels could also leverage opportunities to affect the costs of providing HVAC contractor training and installation inspections, and sharing of information.

2. **Cultivate industry partnerships.** Many activities that break down barriers

to increased HVAC energy efficiency take place among industry stakeholders, often at the national level. Examples are ENERGY STAR branding of efficient equipment, efficiency tiers defined by CEE, NATE and BPI certification procedures for HVAC contractors, and ACCA's recent development of specifications for heating and cooling equipment installation. We recommend that program administrators and other stakeholders from the Northeast continue to take an active role in these and other industry partnerships. In this way, the needs and interests of the Northeast are represented to industry, and the products of the industry partnerships can be incorporated into efficiency programs.

3. **Upgrade and enforce state and federal building energy codes and equipment standards.** Codes and standards complement the market pull of efficiency programs. Upgrading codes and standards raises the baseline energy efficiency and is thus an important aspect of market transformation. Energy efficiency standards for some HVAC equipment are under consideration in several Northeast states. Updated building energy codes would provide another opportunity outside of energy efficiency programs to encourage or enforce quality HVAC installation practices. For example, California's Title 24 building energy code on duct sealing sets measurable performance standards and has provisions for quality assurance verification. At the national level, the IECC updates building energy codes every three years. Once these codes are established, it is necessary that they are actively enforced by code inspectors. The incorporation of code and standards enforcement is crucial to the success of any strategy involving increasing residential HVAC efficiency.

4. **Support continued research and development of emerging and new technologies that reduce HVAC energy and peak demand.** New and improved HVAC technology is one of several ways to increase HVAC efficiency. New research that is needed includes better understanding of in-field performance of some high efficiency equipment to assure that it delivers the savings that are expected; continued research to move products under development into market; and market research to inform the development of program plans that incorporate new technologies.

### 6.3 Recommended Tactics

For convenience, recommendations on how to carry out strategies have been grouped in to three categories below.

1. Enhance and increase regional coordination of current program efforts emphasizing comprehensive (whole house) approaches to residential contracting, contractor training, certification and accreditation, as well as quality control in program delivery.

- Expand Home Performance with ENERGY STAR and the "house as a system" approach to residential contracting.
- Coordinate Program efforts to achieve consistency across state lines.
- Continue market transformation based gas furnace/boiler incentives with quality installation verification (QIV).
- Continue central A/C incentives but in conjunction with a QIV requirement.
- Continue and expand HVAC contractor sales training.
- Enhance and expand consumer education (social marketing) about the importance of quality installation and the value of trained HVAC contractors.

2. Launch new efforts.

- Promote cross-program integration across fuels, sectors, and states.
- Develop or expand HVAC service and repair programs.
- Launch duct sealing initiative as a new program or an element in existing programs targeting new construction, retrofit, and remodeling customers.
- Create an oil/propane heating program funding mechanism.
- Develop a ductless minisplit initiative.

3. Support national efforts, industry collaboration, and research and development.

- Update equipment standards and building energy codes.
- Support ACCA, BPI, ENERGY STAR, CEE and other national efforts.
- Support industry efforts to establish QIV specification.
- Conduct additional market, field research and product development.

### 6.4 Measures of Success

By implementing the comprehensive set of recommendations we should expect to see many changes in the HVAC market. Listed below are some quantifiable measures that can be used to track progress over time.

*Short Term Measures*

The list below identifies measurable changes that are expected over the next three to five years, as a result of increasing institutionalization of recommended strategies to increase HVAC efficiency.

- Increasing number of HVAC technicians receiving training and certification;
- Increasing number of HVAC firms being accredited;
- Growing use of third-party field verification tools;
- Increasing market shares for efficient HVAC equipment;

- Increasing consumer awareness of importance and benefits of efficient equipment and – at least as importantly – quality installations;
- Increased marketing of efficiency – particularly quality installation and servicing – by HVAC manufacturers, distributors and contractors.

*Long Term Measures*

The list below identifies measurable changes that are expected over the next five to ten years, as a result of increasing institutionalization of recommended strategies to increase HVAC efficiency.

- A small, but significant percentage (e.g. 3 to 5 percent) of HVAC contractors see duct sealing as a profitable business opportunity and aggressively sell such services.
- The majority of new furnaces sold have efficient fans.
- New gas furnaces sales are typically condensing (i.e. over 80 percent market share).
- New oil furnace sales typically have AFUEs of at least 85 percent, with condensing units (90 pecrent AFUE) having a significant market presence (i.e. five to 10 percent market share).
- Sales of boilers – gas and oil – with AFUEs of 85 percent or higher are standard (i.e. over 80 percent market share).
- Sales of condensing boilers – gas and oil – have a significant market presence (i.e. five to 10 percent).
- Among new installations, average heating and cooling system over-sizing is half of current national averages (i.e. reduce to average over-sizing of 50 percent or less for heating systems and 30 percent or less in cooling systems).
- Fewer than 25 percent of all new central air conditioners are charged incorrectly.
- Fewer than 25 percent of all new central air conditioners have inadequate airflow (i.e. have less than 350 cfm/ton).