You've Decided You Need A New Baseline Study—Now What? ENERGY STAR® Homes Baseline Studies: Challenges and Solutions

Dorothy Conant, Independent Consultant, Hudson, MA
William Blake, National Grid, Northborough, MA
Stephen Bonanno, NSTAR Electric and Gas, Westwood, MA
Bruce Harley, Conservation Services Group, Westborough, MA
Lynn Hoefgen, Nexus Market Research, Inc., Cambridge, MA
Joe Swift, Western Massachusetts Electric, Springfield, MA
Lisa Wilson-Wright, Nexus Market Research, Inc., Cambridge, MA

Abstract

Is a new residential construction baseline study needed? Where to start? How will the results be used? How much money to spend? What data do you want? What data do you need? How do you draw your sample? How large should your sample be? Should ENERGY STAR homes be excluded?

Sampling bias is a major issue for all baseline studies. It is impossible to account for all potentially confounding variables in a sample design, but it is important to learn from what others have done and exert your best effort to account for the most significant variables in order to minimize their destructive influence and maximize the validity of results. A well thought out sampling design will not ensure an unbiased sample and may, as was the case in the Massachusetts baseline study, uncover bias issues not considered or addressed in previous studies.

Without a census sample no baseline study can provide perfect results. The key to designing and conducting a good baseline study is taking proactive steps to avoid problems encountered in other studies; concentrating on collecting the information program planners, implementers and evaluators need; and addressing any known bias issues in applying the results. By taking these steps the Massachusetts study produced valuable information on how construction practices have changed over the past four years that could be used to update baseline home construction practice assumptions used in calculating program savings

Introduction

Periodically program baselines need to be updated to reflect changes in practices and equipment. This is especially true for new construction programs. The Sponsors of the Massachusetts ENERGY STAR Homes Program knew from previous program evaluation work that builders, both non-participating builders and builders who have only some of their homes ENERGY STAR certified, are constructing energy-efficient homes and installing high-efficiency HVAC equipment outside the program (NMR et al. 2004a, 2004b, 2005, 2007).[1] However, there was not enough information to estimate what percentage of the new homes being built in Massachusetts incorporated energy-efficient construction practices and/or high-efficiency HVAC and water heating equipment. The Sponsors wanted to know if average construction practices had changed since the last baseline study of Massachusetts home construction was conducted in 2001 (XENERGY 2001). In 2005, when the Sponsors of the Massachusetts ENERGY STAR Homes Program decided it was time to conduct a new baseline study, the input assumptions for the baseline home

[1] Interviews with ENERGY STAR and non-ENERGY STAR builders and HERS ratings performed on non-certified homes built by both ENERGY STAR and non-ENERGY STAR builders.

used in calculating program savings, also known as the User Defined Reference Home (UDRH), were based on a 2001 study of residential new construction practices conducted for the Massachusetts Board of Building Regulations and Standards (BBRS) (XENERGY 2001). The 2001 study inspected a random sample of 186 single- and two-family homes constructed in 1999 and 2000; homes were selected geographically in proportion to 1999 building permits issued and two to seven homes were inspected in each of 30 towns.

This paper describes how the Massachusetts ENERGY STAR Homes Program's 2005 Baseline Study (NMR & Conant 2006) addressed sampling, recruiting and data collection; how construction practices and mechanical system characteristics have changed since the previous baseline study; and how study findings were applied in updating the UDRH assumptions used to estimate program energy savings. In the 2005 study, 150 home inspections were conducted from mid June through mid September on homes that had been completed between May 2004 and September 2005. In addition to collecting information on construction practices, the study asked all participating homeowners to complete a short paper survey at the time of the home inspection. Combining information collected during the inspections with information provided by homeowners provided valuable insight on how aware homeowners are of the building materials and mechanical equipment in their homes.

Step One—Homework

Work on the 2005 Baseline Study began with a review of previous Massachusetts residential construction baseline studies and recent baseline studies conducted outside of Massachusetts, including interviews with the managers of these studies. In particular, this review assessed: budgets, sample sizes, sampling plans, recruiting protocols, data collected, and home inspection approaches. This review enabled the Sponsors to see what did and did not work well in previous studies and helped inform decisions on the 2005 Baseline Study design.

The Sample

The 2005 Baseline Study inspected 150 attached and detached single-family homes, and the sampling plan ensured that the percentage of homes inspected in any area of the state mirrored the percentage of statewide 2004 single-family building permits issued in that area. U.S. Census Bureau data provided 2004 builder permit data by town. The state was divided into five regions, each containing approximately 20% of the single-family building permits issued in 2004. Each of the five regions was further divided into ten sub-regions, each containing approximately ten percent of the 2004 single-family building permits issued in the region, or two percent of statewide permits issued. By inspecting the same number of homes in each region and sub-region, this design ensured that the distribution of homes inspected reflected the percentage of 2004 single-family building permits issued in each region and sub-region. (See Figure 1.) A decision was made to exclude ENERGY STAR homes from the sample because the purpose of the study was to determine baseline construction practices of non-program participants.

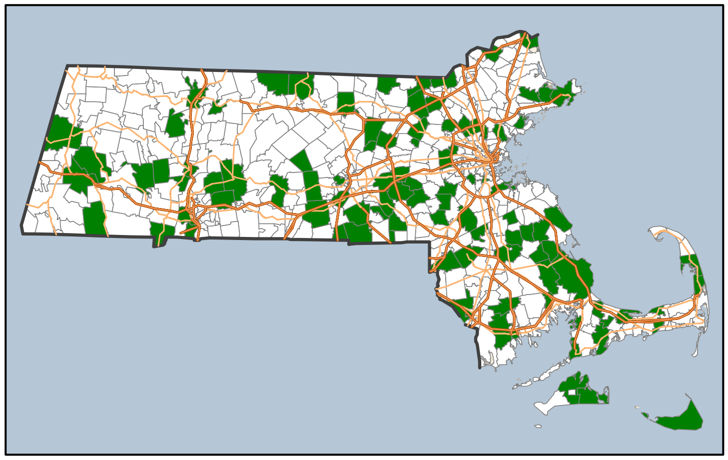

Figure 1. Towns Represented by Sample (NMR & Conant 2006, 15)

The Data

Sponsors decided to measure and record key data on materials and equipment used in each home, conduct blower door tests on all homes and conduct duct blaster tests on all homes with duct systems. Conducting a full HERS rating on each home was considered, but then rejected. The added cost of collecting all the measurements needed for a full HERS rating would be difficult to justify, when only the salient characteristics of a home (the specifications of its components, as well as its air and duct tightness).are necessary to describe a reference home. Sponsors also considered testing central air conditioning systems to identify their actual performance efficiency and capacity. Other studies have shown that many central air conditioning systems are not performing anywhere near their claimed SEER rating. One example is a Long Island, New York residential new construction baseline study conducted in 2003 that included performance testing. That study found a 23% reduction from labeled SEER when taking into account improper installation (i.e., improper charge and improper air flow), which increased to a 33% reduction when improper sizing impacts were included (VEIC et al. 2004, 28). For the 2005 study, after receiving bids from potential contractors for performing on-site inspections with and without testing air conditioning performance, the Sponsors concluded it would be more valuable to the Program to spend the available budget collecting basic information on a larger number of homes rather than include air conditioning performance testing on a reduced sample size.

Data Collection

Two companies were hired to conduct the inspections, one to conduct on-site inspections in three regions and the other in two regions. Maximizing the number of inspectors in the field increased the likelihood that all 150 home inspections could be completed and results available by the end of 2005. As inspections were completed, inspectors forwarded completed data forms electronically to a member of the evaluation team. A three-step verification and quality assurance process, under which all incoming data were reviewed by the evaluation consultant, a Program Sponsor, and the implementation contractor technical director, ensured the accuracy of the final data. All inspectors were very responsive to questions on the accuracy of reported data.

Recruiting Homes

Recruiting homes through homeowners rather than builders avoids the potential bias suggested in other studies that only builders who believe their homes are relatively energy-efficient will agree to participate. Study Sponsors provided lists of new residential permanent service requests from the beginning of March 2004 through the end of February 2005. These lists, which included customer name, address, phone number and date of the request or meter turn-on, were cleaned to eliminate records that were clearly units in multi-family buildings, records that contained builder or developer names rather than the homeowner's name and homes that could be identified as ENERGY STAR-certified. The remaining records were sorted by town and randomized lists of new homes in each of the sub-regions defined earlier were prepared.

One of the most important considerations in developing a recruiting protocol is to minimize bias in the sample. Letters introducing the 2005 Baseline study were sent to the first 20 names on the randomized list of new homeowners in each sub-region. The letter briefly described the study, informed homeowners they might be called by the contractor conducting the on-site inspections, described what the inspection involved, asked them to consider participating and told them that if they participated in the study and completed a short survey they would receive $150 on the day their home was inspected.

Recruiting was done by the contractors hired to conduct the on-site inspections. Recruiters called the first three names on each sub-region list at least five times before moving on to the next name; at least three of these calls were to be made on weekday evenings (6 p.m. to 9 p.m.) or weekends. Recruiting began the first week of June, the first on-site inspection was conducted on June 13, and the final on-site inspection occurred on September 16. Recruiters made 1,378 calls to 624 homeowners. Most homeowners (68%) were recruited in one or two calls. Approximately one-third of the participating homeowners agreed to have their home inspected on the first call, another one-third agreed on the second call and an additional 15% on the third call. Only 17% of homeowners required more than three calls and in some of these cases the multiple calls involved finalizing or rescheduling the inspection date. The overall response rate was much higher than in other baseline studies reviewed; on-site inspections were completed at 24% of all the homes recruiters attempted to call and 40% of all the homes where recruiters were able to reach and talk with a homeowner.

Although homeowners were asked if their homes were ENERGY STAR certified during the recruiting calls, six inspected homes were later found to be ENERGY STAR homes; these six homes were excluded from the data used to update UDRH assumptions.

Overall Study Findings

Compared to the previous Massachusetts baseline study, homes in the 2005 study are slightly larger and more likely to have conditioned basement space, central air conditioning, and 2 x 6 framing. They also have higher R-value wall and ceiling insulation, better air sealing, and more efficient windows, heating systems, and water heating. Some things have not changed; fiberglass batts continue to be the insulation of choice, floor insulation R-values have not changed, and there is no evidence that duct leakage rates have improved.

A wide variety of homes participated in the study, ranging in size from 728 to 11,056 square feet of conditioned space. Nearly all of the homes (96%) are primary, year-round residences. In designing the sampling plan a decision was made to include secondary residences even though there was some concern that vacation homes might be built less efficiently than other homes. This concern turned out to be unfounded—the six vacation or weekend homes included in the study are slightly larger and, on average, have more wall insulation, more efficient water heaters and air conditioning, and lower air infiltration and duct leakage than primary residences.

Construction Practices and HVAC Systems

The data input form included space for inspectors to provide comments. Some inspectors commented more frequently than others, but all commented on at least some homes. Some of the more frequently mentioned specific poor construction practices inspectors noted are: 1) fiberglass batts poorly installed, 2) insulation missing in spots, 3) uneven cellulose insulation, 4) lack of air/moisture barriers, 5) no Thermodome or other insulation over pull-down attic stairs, 6) poor air sealing, and 7) poor duct work.

Wall Insulation. Fiberglass batts continue to be the insulation of choice by most builders, with 88% of homes using only fiberglass batts and another five percent using fiberglass batts in combination with fanfold, rigid or foam insulation. The highest R-values are in homes insulated with cellulose, Icynene, or a combination of fiberglass batts with other insulation. **Windows.** Inspectors recorded the type(s) of windows in each home, but found it difficult to identify the U-value and solar heat gain coefficient (SHGC) for most windows. A few homeowners left stickers on windows, while others retained paperwork, but most had removed and discarded the stickers and/or paperwork that identified the U-value and SHGC. In all, the inspectors gathered actual U-value and SHGC information on the primary windows in 43 of the 144 homes. In another seven homes they located actual U-value information but not SHGC information. Default values for both U-value and SHGC were assigned to all missing records. These default values are based on data provided by the program implementation contractor, Conservation Serviced Group (CSG), and a review of Andersen, Pella and Harvey window series that include both wood and vinyl framed clear, Low-e and Low-e with Argon double pane double hung windows. Inspectors did not collect data on window framing, but estimated that 60% had vinyl and 40% had wood frames; these estimates were factored into the development of default values.

Slab Insulation. Very little information on slab insulation was collected. Inspectors often were unable to determine whether slabs in conditioned basements were insulated; of the 30 homes with conditioned basements, inspectors were unable to determine if slab insulation was present in 17 homes (56%).

Heating Systems. Boiler-based heating systems are more likely to be hydro-air than in the previous baseline study and the market share of oil furnaces is much lower. Only 16% of the fossil fuel heating systems installed in the 2005 study homes are installed in conditioned space, but this is an improvement over the previous study when only five percent of heating systems were installed in conditioned space. Custom homes are more than twice as likely as spec homes to have boiler-based heating systems—78% of custom homes versus 36% of spec/development homes—and these systems are much more likely to be ENERGY STAR in custom homes. Also, custom homes are much more likely than spec/development homes to have hydro-air boiler systems—29% of custom homes versus only six percent of spec/development homes—and energy-efficient integrated water heating tanks are more common and tankless coil water heating systems less common in custom homes. Heating system sizing, measured in British Thermal Units per Hour (BTUH) per square foot of conditioned space ranged from 16 to 118, averaging 54; this wide range suggests many heating systems are oversized.

Cooling Systems. Almost 60% of the 90 homes cooled with central air conditioning have more than one unit. The 162 individual systems in inspected homes range in size from one and one-half tons to five tons and the efficiencies vary from 10 SEER to 17.25 SEER. The average home with central air conditioning has 5.2 tons of cooling with an average SEER of 10.6, but two-thirds of the homes have systems that average only 10.0 SEER. Fourteen (16%) of the homes with central air conditioning have hot water boiler heating systems, which require no duct work—a very inefficient combination.

However, combining central air conditioning with a boiler heating system is much less common now than in the previous baseline study when 50% of the homes with central air conditioning had this configuration. As with heating systems, cooling system sizing varies widely from home to home suggesting many systems are improperly sized. Square feet of conditioned space per ton of cooling for the 90 homes with central air conditioning ranged from 300 to 1,459, averaging 618. The average square footage of conditioned space per ton of cooling of 618 is higher than what was found in the previous baseline study (604 square feet per ton) but lower than the average 817 square feet per ton found in a 2004 HERS rating study of non-ENERGY STAR-certified homes built in 2003 (JMR et al. 2004b, 39).

Air Infiltration. Inspectors conducted blower door tests on all 144 non-ENERGY STAR homes. The average ACH50 for the 144 homes tested is 6.36. Results range from 2.23 on the low end (a very tight house) to 14.72 on the high end. Almost one-third of the homes (44 homes or 31% of all homes tested) meet the Massachusetts program's requirement of five air changes per hour at 50 pascals (ACH50) or less for ENERGY STAR certification under the Performance Path and the EPA requirement for homes following the Builder Option Package (BOP) path.

Ducts. Ninety-four of the 144 non-ENERGY STAR homes inspected have duct systems. In ten homes all duct work is in conditioned space. Eleven of the homes tested had multiple duct systems and inspectors were unable to test at least one system because it was inaccessible or too leaky to accurately measure. In these cases the leakage for the tested system(s) was divided by the square feet of conditioned space served by the tested system(s). Inspectors were unable to test ducts in five homes—two homes were too leaky to measure accurately, the duct system was inaccessible in one home, the testing equipment was not available for one inspection, and at one large home with several duct systems there was not time to perform the tests, but the inspector commented, "Overall the duct work in this home is very POORLY sealed." One inspector provided the following assessment of the quality of duct work in the homes he inspected; other inspectors agreed with his assessment (NMR & Conant 2006, Part I 47):

> "We saw some examples of decent duct work, but that was the exception. Preventable duct leaks, excessive flex runs, and building cavities used for return ducts are common. Ducts typically insulated to only R-4 are inevitably located above the R-30 attic insulation along with air handlers and furnaces located outside the conditioned space. In some cases catastrophic duct leakage, disjointed ducts and questionable workmanship resulted in duct leakages outside the range of the testing equipment. These issues become more relevant as ducted HVAC systems become the preferred choice in new construction."

Average total outside leakage measured in cubic feet per minute at 25 pascals pressure(CFM25) per 100 square feet of conditioned space for the 89 tested homes is 21.1; values range from zero (the tightest duct system) to 76 CFM25/100 ft^2. With three of the four untested homes being very leaky, the average of 21.1 is conservative—lower than it would be if information on the three additional homes with very leaky duct systems were included. Duct leakage in 16% of the 89 homes tested meets the new EPA requirement of six CFM25/100 ft^2 or less for homes following the Performance Path and ten percent of the homes meet the four CFM25/100 ft^2 requirement for homes following the BOP path.

Combined Air Infiltration and Duct Leakage. Many tight homes have leaky ducts and many leaky homes have tight ducts—builders who address air sealing may ignore duct sealing and vice versa. Figure 2 shows the air infiltration and duct leakage levels for the 89 homes where duct systems were tested. All of the homes with air infiltration less than four ACH50 have duct leakage less than 17 CFM25/100 ft^2, indicating very good air sealing and relatively good duct sealing practices. For most homes, however, there is no relationship between air infiltration and duct leakage levels. As shown, four of the homes with air infiltration at or below the requirement of five ACH50 for ENERGY STAR certification have duct leakage over 30 CFM25/100 ft^2. At the opposite end of the spectrum, several of the homes with high air infiltration levels have duct leakage rates below the new requirement of six or less CFM25/100 ft^2 for ENERGY STAR certification. Only four of the 89 homes tested meet the Massachusetts program's requirements for both air infiltration and duct leakage—ACH50 of five or less and duct leakage of six CFM25/100 ft^2 or less; 24 homes meet the air infiltration requirement but not the duct leakage requirement, ten homes meet the duct leakage requirement but not the air infiltration requirement and 51 homes meet neither requirement for ENERGY STAR certification. Of the 50 homes with no ductwork, 14 meet the requirement of 5 ACH50 or less for ENERGY STAR certification. In total, 22 (15%) of the homes inspected meet the 2006 Massachusetts program's air infiltration and duct leakage requirements for ENERGY STAR-certification.

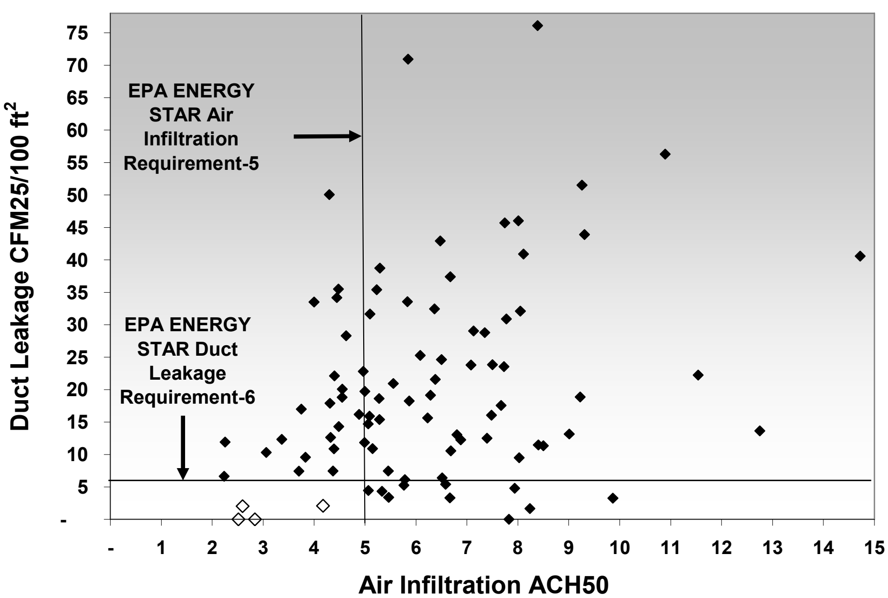

Figure 2: Air Infiltration and Duct Leakage (NMR & Conant 2006, 54)

Homeowner Survey

The homeowner survey was designed to obtain additional information from the owners of inspected homes. Homeowners were asked who made decisions about various components of their new homes and how efficient they think these components are. Combining information collected during the inspections with information from the homeowners provides insight on how aware homeowners are of the building materials and mechanical equipment in their homes, and whether or not homeowners who think they have energy-efficient homes really do. Results show homeowners are a highly unreliable source for estimating the penetration of ENERGY STAR products and equipment.

Virtually all homeowners say their homes are very comfortable (89%) or somewhat comfortable (10%). Only one homeowner says their home is somewhat uncomfortable, mentioning heat and air ducts. This is likely a reasonable complaint because this home has the highest duct leakage of all homes tested—76 CFM25/100 ft^2.

Homeowner Perceptions

Most homeowners (69%) think their home is about as energy efficient as or somewhat more energy efficient than most other new homes. When asked why, most homeowners mention specific materials, construction practices and/or high-efficiency mechanical equipment. Homeowners who have lived in their homes through an entire heating season are likely to mention their homes being warm and comfortable in the winter. In addition, owners of modular homes tend to say they think modular, pre-fabricated or factory-built homes are more efficient than traditionally built homes.

Not surprisingly, builders are most likely to make HVAC equipment, water heater, window, framing size and insulation decisions, and homeowners are most likely to choose kitchen appliances and lighting fixtures. Almost all homeowners who built or acted as the general contractor for their home said they made all the decisions. Excluding kitchen appliances and lighting fixtures, almost all of the non-builder homeowners saying they made decisions are owners of custom homes.[2]

Homeowner perceptions of the energy-efficiency of the windows and HVAC equipment installed in their homes are amazingly inaccurate. Homeowners described the energy efficiency of their windows and HVAC equipment using the following categories: "ENERGY STAR-labeled", "very energy efficient", "average," "not energy efficient" and "do not know." Combining information from the on-site inspections and the homeowner survey allows comparisons of what homeowners think about the energy efficiency of various components in their homes to what was observed during on-site inspections. Figure 3 shows the percentage of all homeowners who think components of their home are ENERGY STAR and the percentage of all homes where the component really is ENERGY STAR. As shown, the percentages of homeowners who think they have ENERGY STAR heating systems and windows are much lower than the percentages of homes where these components really are ENERGY STAR. The opposite is true of central air conditioning equipment.

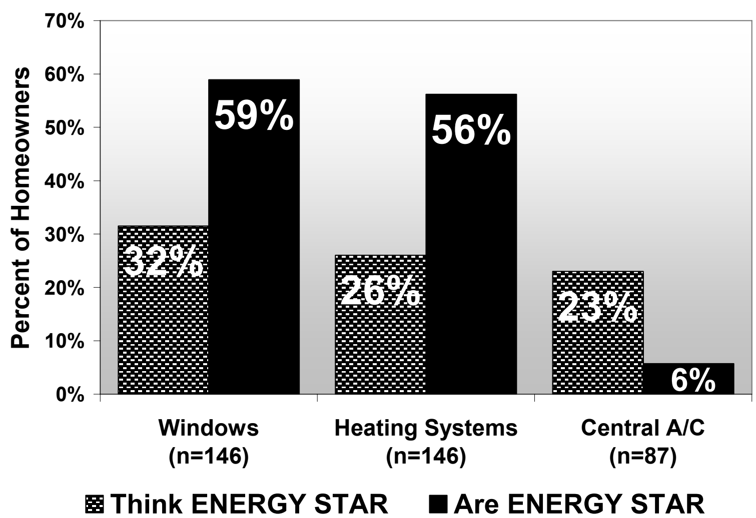

Figure 3: ENERGY STAR Building Components—Perceived versus Actual (NMR & Conant 2006, Part II 26)

The unreliability of homeowners' perceptions about the efficiency of their heating systems is somewhat surprising because ENERGY STAR heating systems are typically clearly labeled. Figure 4 shows that just over one-third (34%) of homeowners who think they have ENERGY STAR heating systems

[2] Percentages varied by building component from custom home owners being 89% of the homeowners saying they selected their air conditioning system to 96% of the those saying they selected their water heater.

do not. Furthermore, 62% of homeowners who say their heating systems are very energy efficient, but not ENERGY STAR, actually have ENERGY STAR heating systems, as do 42% of the homeowners who say the efficiency of their heating system is average and 48% of the homeowners who say they do not know how efficient their heating system is or did not answer the question. Finally, of two homeowners who say their heating systems are not energy efficient; one has an ENERGY STAR natural gas furnace (Annual Fuel Utilization Efficiency (AFUE) 92) and one has electric resistance heat.

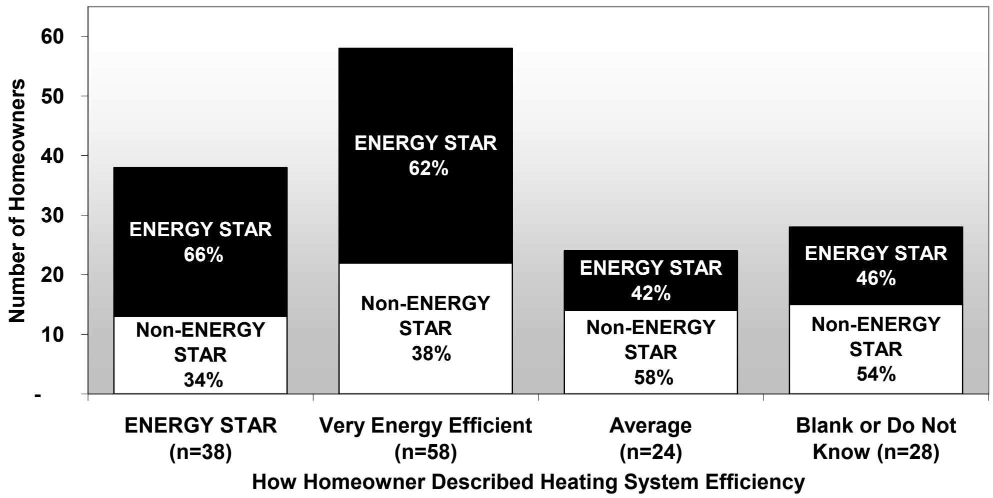

Figure 4: Heating System Efficiency—Perceived versus Actual (NMR & Conant 2006, Part II 28)

Potential Bias

A potential bias that was noticed in the 2005 Baseline Study is the very high percentage of custom homes in the sample. Custom homes accounted for 70% of all non-ENERGY STAR homes and 75% of non-ENERGY STAR detached homes. These percentages are likely higher than in the population of new homes in Massachusetts. US Census Bureau data reports show 32% of new single family homes completed in the Northeast in 2004 and 30% in 2005 are custom homes (US Census Bureau). A comparison of non-ENERGY STAR custom and spec/development homes in the 2005 study shows the average wall insulation R-Value is significantly different (higher) at the 90 percent confidence level in custom homes; differences in average heating system AFUE, water heating Energy Factor, air conditioning SEER and number of qualifying lighting fixtures between spec and custom homes are also statistically significant. There is no way to tell how this potential bias affects comparisons with the previous Massachusetts baseline study results because the potential "bias" variable—the percentage of spec and custom homes—was not recorded. However, the 2001 study also recruited homes through homeowners, which suggests it may have encountered the same bias toward custom homes as found in the 2005 Baseline Study.

Non-response bias may have contributed to the high percentage of custom homes in the 2005 study: Spec home buyers may have been less likely to agree to have their homes inspected than custom home buyers. In addition, it seems plausible that owners of custom homes, who are more involved than spec/development home buyers in design and construction decisions, are particularly likely to want to participate in a study that will provide them feedback on how well their home is built. Several homeowners who either built their own custom home or acted as the general contractor mentioned to inspectors that they were curious about how their home would perform; suggesting that participating in the study may have been particularly appealing to this group of new home owners.

Applying Results

The program Sponsors and members of the evaluation team met with the Technical Director of the program implementation contractor (CSG), to review study findings and discuss how to use those results in updating baseline home assumptions. The 2005 study provided greater detail on heating system efficiencies, insulation levels in different ceiling and foundation wall configurations, and duct insulation by location and duct type than the previous baseline study. The increased detail facilitated more accurate modeling of the individual baseline home, or UDRH, used in estimating the savings from a participating home. For example, the 2005 study provided individual AFUE assumptions for gas- and oil-fueled hydronic and air distribution heating systems; previously there was one average heating system AFUE input. Also, the previous baseline study provided only total CFM25 duct leakage; the 2005 study provided duct leakage in CFM25/100 ft^2 of conditioned space. Assumptions about the location of mechanical equipment were also incorporated because a home's overall energy efficiency is improved when mechanical equipment is installed in conditioned space. Finally, to ensure the UDRH assumptions reflect the type of single family homes targeted by the program, the new UDRH assumptions are based on spec home and custom home data weighted by the percentages of spec and custom homes signed in 2005 by the Massachusetts ENERGY STAR Homes Program: 97.6% spec homes and 2.4% custom homes.

Table 1 shows the old and the new UDRH input assumptions; shaded cells show where the greater detail from the 2005 study was incorporated, and values in **bold** text indicate increased energy efficiency.

Table 1. Old and New UDRH Assumptions (NMR & Conant 2006, Part I 7)

Input Category	Old UDRH	New UDRH
Wall U-Factor	0.094	**0.089**
Average Wall Cavity Insulation R-Value—Conditioned/Ambient Walls	14.1	**14.4**
Flat Ceiling U-Factor	0.056	0.058
Flat Ceiling Average Cavity Insulation R-Value Adjusted	31.5	31.0
Cathedral Ceiling U-Factor	n/a	0.057
Cathedral Ceiling Average R-Value	n/a	29.6
Slab Non-Radiant R-Value	4.9	0.1
Slab-Radiant R-Value	7.1	5.7
Window U-Value	0.41	**0.37**
Window SHGC Factor	0.47	**0.35**
Skylight U-Value	n/a	0.48
Skylight SHGC Factor	n/a	0.30
Gas Fuel Fired Air Distribution (Furnaces And Hydro-Air) AFUE	85.6	**89.2**
Gas Fuel Fired Hydronic Distribution (Hot Water Boilers) AFUE		81.7
Oil Fuel Fired Air Distribution (Furnaces And Hydro-Air) AFUE		83.9
Oil Fuel Fired Hydronic Distribution AFUE		84.4
Heating System Located In Unconditioned Space	n/a	Unconditioned
Gas Conventional Tank Water Heater Energy Factor	0.56	**0.58**
Gas Integrated Tank Water Heater Energy Factor	0.62	**0.75**
Oil Conventional Tank Water Heater Energy Factor	0.56	**0.61**
Oil Integrated Tank Water Heater Energy Factor	0.62	**0.69**
Electric Resistance Water Heater Energy Factor	0.86	0.86
Water Heater Located In Unconditioned Space	n/a	Unconditioned
Duct Leakage CFM25/100 ft^2	n/a	21.7

Input Category	Old UDRH	New UDRH
Duct Insulation R-Value—All In Unconditioned Space	4.37	n/a
Duct Insulation R-Value In Attic—Exposed	4.37	n/a
Duct Insulation R-Value—Supply Ducts in Unconditioned Basement	n/a	4.11
Duct Insulation R-Value—Supply Ducts in Attics	n/a	4.66
Duct Insulation R-Value—Return Ducts in Unconditioned Basement	n/a	2.43
Duct Insulation R-Value—Return Ducts in Attics	n/a	4.37
ACHnat	0.50	**0.46**
ACH50	n/a	6.72
Central Air Conditioning SEER—2006 Federal Efficiency Standard	10.2	**13.00**
Central Air Conditioner Located In Unconditioned Space (inc-attic)	n/a	Unconditioned
Floor Insulation U-Value—Unconditioned Basement	0.059	0.063
Floor Insulation R-Value—Unconditioned Basement	18.6	**19.4**
Foundation Wall Insulation R-Value—Conditioned Basement	4.9	**11.1**
Foundation Wall Insulation R-Value—Unconditioned Basement	n/a	3.1

Conclusions

- Custom homeowners, who tend to play a bigger role than spec homeowners in construction and equipment decisions, appear to be more likely to agree to having their homes inspected.
- The mix of spec and custom homes in a baseline study is a potential bias that has not been raised in previous studies, but merits consideration in the sampling plans of future studies.
- Recruiting through homeowners rather than builders eliminates the potential bias of having only builders who think they build quality homes agree to participate.
- Looking ahead, it may be theoretically problematic to exclude ENERGY STAR-certified homes from future studies if the penetration of ENERGY STAR homes increases and measures promoted in the program become standard practice for many builders outside the program. Focusing on homes built outside the program would not reflect how homes would be built if there was no program and would be conceptually incorrect if there was high free-ridership within the program and/or significant spillover from the program to non-certified homes.
- The high incidence of poor duct work and high duct leakage in the 2005 study suggests that many builders entering the Program will need duct sealing training to meet the new ENERGY STAR-certification requirements.

Recommendations

- Learn from others. A careful review of recent baseline new construction studies in other states can provide valuable information. Knowing the problems other studies have encountered allows study planners to consider and address these issues early in the study design process.
- Put some time into thinking about how results will be used before conducting a baseline study, and the appropriate level of data required to meet your needs; consider the cost trade-off between collecting less-critical data from every home versus collecting the most critical data from more homes.
- Recruit through homeowners, not builders; builders who are not building at least to code are not likely to agree to have their homes inspected.

- If homes in your program are predominantly spec/development homes, screen to identify custom homes when recruiting homeowners to ensure the homes inspected represent the market the program is targeting and to avoid bias in the final sample.
- Ask homeowners to complete a short questionnaire at the time of the inspection; this can provide valuable information for programs on the role homeowners play in construction decisions as well as their awareness of, interest in and understanding of energy-efficiency issues.

References

XENERGY Inc. 2001. *Impact Analysis of The Massachusetts 1998 Residential Energy Code Revisions.* The Massachusetts Board of Building Regulations and Standards (BBRS) Boston, Massachusetts.

Vermont Energy Investment Corporation (VEIC) and Optimal Energy, Inc. with field work and support from Conservation Services Group and Proctor Engineering Group. 2004. *Long Island Residential New Construction Technical Baseline Study Report.* Long Island Power Authority.

Nexus Market Research Inc. (NMR), Dorothy Conant, Shel Feldman Management Consulting, and GDS Associates Inc. 2004. *Evaluation of the Massachusetts ENERGY STAR® Homes Program—Appendix E: 2003 Massachusetts ENERGY STAR® Homes Builder Interview Report.* Joint Management Committee.

Nexus Market Research Inc. (NMR), Dorothy Conant, Shel Feldman Management Consulting, and GDS Associates Inc. 2004. *Evaluation of the Massachusetts ENERGY STAR® Homes Program—Appendix H: HERS Rating Analysis of Non-ENERGY STAR Homes in Massachusetts.* Joint Management Committee.

Nexus Market Research Inc. (NMR), Dorothy Conant, Shel Feldman Management Consulting, and GDS Associates Inc. 2005. *Evaluation of the Massachusetts ENERGY STAR® Homes Program—Appendix D: 2004 Massachusetts ENERGY STAR® Homes Builder Interview Report.* Joint Management Committee.

Nexus Market Research Inc. (NMR), and Dorothy Conant. 2006. *Massachusetts ENERGY STAR® Homes 2005 Baseline Study—Part I and Part II.* Joint Management Committee.

Nexus Market Research Inc. (NMR), and Dorothy Conant. 2007. *Evaluation of the Massachusetts ENERGY STAR® Homes Program—Appendix B: 2006 ENERGY STAR® Homes Builder Interview Report.* Joint Management Committee.

US Census Bureau website. 2007. http://www.census.gov/const/www/charindex.html#singlecomplete.