Measuring Efficiency Achievement in High Performance Homes

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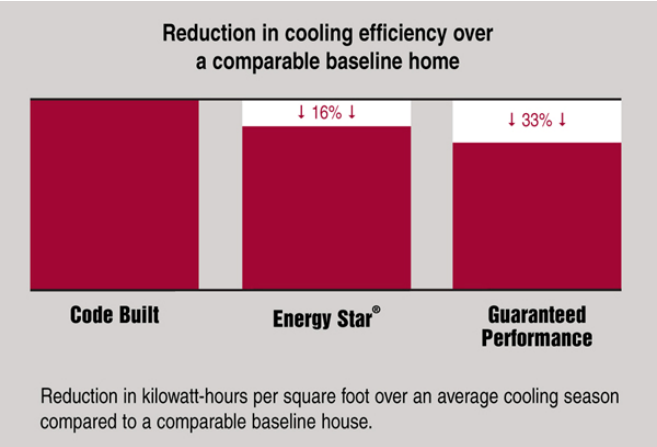
ABSTRACT

In 1995, the EPA launched its Energy Star New Homes program, which established guidelines for reducing home energy use and promoted partnerships with builders to construct energy efficient homes. It was reasoned that Energy Star labeled homes would offer consumers dependable savings on their monthly energy bills and reduce the overall consumption and impact of residential sector energy use. The Energy Star New Homes program has achieved significant success, with hundreds of thousands of labeled homes nationwide.



One of the first areas of the country to adopt Energy Star and High Performance homes programs was Phoenix, Arizona. Over the years, thousands of homes in the area have been certified with the Energy Star label, while thousands of others have taken the next step to include a guaranteed energy performance level. For the study described in this paper, more than 7,000 homes have been evaluated: 3,336 baseline homes, 2,979 Energy Star homes, and 826 guaranteed performance homes. Six years of energy data has been evaluated, along with building and occupant characteristics.

Results of the study show that Energy Star homes perform up to 16% better than standard construction homes. Guaranteed performance homes perform up to 33% better than standard construction homes. Further, the study found that because of the market's early adoption of Energy Star and Guaranteed Performance programs, even the standard construction homes perform better than those in other areas.

A follow-up study of 708 homes showed that customer satisfaction was positively correlated with program participation.

Introduction

Electric and gas utilities are more than ever looking for energy programs that have demonstrable and verifiable results, while also achieving improved customer satisfaction. The utility-driven model described in this paper has resulted in thousands of energy efficient and comfortable homes and the transformation of much of the new home marketplace in a major U.S. market. These results have come about because of multi-year support for high performance homes by the electric and gas utilities. These utilities provided building science training, marketing and incentives for the construction of energy efficient homes in their service territories. This paper provides a framework for how others can replicate the energy performance, customer satisfaction, and builder profitability. This is a model that can be replicated nationally.

Results

In 1997 Louisiana-Pacific began its Engineered for Life program which added a high performance guarantee (energy and comfort) to the Energy Star efficiency guidelines. Masco's Environments for Living followed in 2001. While the Louisiana-Pacific program has since been discontinued, Environments for Living has grown to well over 130,000 homes.

It is becoming clearer and clearer that focusing only on energy benefits of energy efficiency programs significantly limits the opportunities and markets for those programs. That being said, energy efficiency programs run by utilities must actually prove energy savings. With support from the U.S. Environmental Protection Agency and participation of Arizona Public Service and Southwest Gas, Advanced Energy conducted a study of more than 7,000 homes in Arizona. We determined benchmarks of three categories of new homes; standard construction, Energy Star, and guaranteed performance. Energy use profiles, square footage, number of stories, vintage, orientation, existence of pools and other general characteristics were collected. The size of the sample allowed for statistical sampling reducing the variables of individual energy habits.

Implementation of the Energy Star and Guaranteed Performance programs can yield improvements in the overall energy efficiency of new homes, as compared to homes built to standard practices. Our data analysis showed that standard construction homes use 4.16 kilowatt hours per square foot. Energy Star homes performed much better, using only 3.50 kWh per square foot. And guaranteed performance homes performed better still, using only 2.80 kWh per square foot.

Advanced Energy also conducted a homeowner satisfaction survey of 708 homeowners in Phoenix. The survey results show that customers are more satisfied with their HVAC, energy costs, comfort, and perceived health of their families when they purchase a guaranteed performance home. Correctly sizing the HVAC, along with building science techniques, can reduce energy consumption at the same time as it improves customer satisfaction.

As a side note, the survey and study show that the trend toward increased home size has an impact on overall energy consumption. In the last 50 years, home size has more than doubled. During the 1980s and early 1990s, with expanded energy codes and efficiency efforts, residential energy consumption stayed relatively flat, even with increased home size. Our research demonstrates further that even though a home may use 30% less energy per square foot, that savings is negated if the home is 30% larger. It is not our position that we should control the size of homes. However, it is important that we continue to ramp up efficiency efforts with the expectation that the new house size growth trend will continue. Had efficiency not come into play in past decades, these larger homes would be consuming far larger amounts of energy today.

Energy Star and Guaranteed Performance Homes Programming

With one of the fastest growing and largest new housing markets in the country, utilities in Arizona realized that housing energy usage had a significant impact on their operations. Executives and program managers at the utilities began looking for programs that would help them deal with the rapid growth while also addressing utility profitability and customer satisfaction. The utilities decided to go with a builder education and incentive program to encourage high performance and guaranteed performance homes. Guaranteed performance means that heating and cooling bills are guaranteed not to exceed a certain amount on average per month. The energy performance of the home serves as a marketing hook for builders and realtors to solicit customers. The guarantee also includes the comfort of the home, assuring the buyer that each room of the house will be within three degrees of the thermostat set point.

Builders are able to achieve the energy and comfort guarantee by participating in the Environments for Living (EFL) program, operated by Masco. At the beginning of the study Louisiana-Pacific also had a similar program but it has since been discontinued. EFL follows many of the same steps as the Energy Star Homes program but the guarantee creates an important feedback loop to the builder. Both Energy Star and Guaranteed Performance require plan reviews and inspection of homes under construction. Builders pay a fee to participate in EFL.

The utilities participating in the program in Arizona provided incentives for builders to build homes to the higher standards. Training sessions, inspections and marketing support were used to encourage builders to join. Once they joined, many builders discovered an additional monetary value in that their callbacks had been significantly reduced. Other builders have found that the program results in higher customer satisfaction and referral purchases.

Achieving Guaranteed Performance

In theory, the science and process of building a high performance home are simple. All we need to do is to put in good windows, adequate insulation, create an air and moisture barrier between the outside and inside, and then install an efficient heating and/or cooling system to keep the building comfortable. Sounds simple. In reality though, it has proven much more difficult than it would seem. Each step of the construction process must be executed so that the next step of construction can be properly completed. For example, if the framers do not provide the proper spacing, it will be very difficult for the insulation installer to do a good job. If the spacing is too wide, insulation batts will not completely fill the space. If the spaces are too narrow, the insulation installer will need to spend time cutting the batts. More likely, he will just stuff the insulation inside, resulting in reduced R value in the cavity.

HVAC systems have long been identified as a major source of warranty costs and comfort complaints in new construction. Many state building codes require the completion of a Manual J or other type of scientific calculation of the conditioning needs of the home under construction. These important but fairly complex calculations are often not completed, or not completed well. Instead, contractors tend to rely on “rules of thumb” that are based on past experience. Their goal is to provide more heating or cooling than the home actually needs--in other words, the HVAC system is oversized. Over-sizing an HVAC system may keep the homeowner happy in the short term. But, an oversized system will cycle on and off more frequently, using more energy in the process and shortening the life span of the system. And it costs more up front. In humid climates, the consequences are even worse. An oversized air conditioner is unable to remove the moisture from the home as needed, resulting in high relative humidity and an increased likelihood of mold, dust mites, and other allergens.

With these and other issues in mind, we began working with utilities and builders to create a program that met everyone’s needs: energy efficiency for the utility, process improvement and cost reduction for the builder, and a more comfortable, durable, and energy efficient home for the occupants.

The result was the creation of the Guaranteed Performance program. The first national program was Louisiana-Pacific’s Engineered for Life, which began in 1997. The current program, Masco’s Environments for Living, followed in 2001 and the L-P program was eventually discontinued. Tucson Electric Power also developed a Guaranteed Performance program of their own, which was not part of this study.

The Guaranteed Performance programs essentially take the Energy Star efficiency standards and testing protocols and moves a step further, adding a feedback loop on every home in the form of the guarantee. The guarantee states that if energy use for heating and cooling exceeds a certain amount (based on the afore-mentioned calculation of the energy needed for space conditioning) the program sponsor will pay the difference. The guarantee also addresses comfort: if the temperature in the center of any room is not within three degrees of the thermostatic setting the program sponsor will take the necessary actions to

remedy the situation at no cost to the homeowner. The typical guarantee is for two years. And yes, there is fine print that protects the sponsor from issues such as unreasonable occupant behavior. But even with the fine print, the sponsor incurs a significant financial obligation to get the houses built right. Consequently, the sponsor has a considerable incentive to provide the training and technical assistance that is needed for the builder to build a better home.

Builders pay to participate in the Guaranteed Performance program. The cost per house is approximately $200, which includes plan reviews, testing, training and technical assistance and servicing the guarantee.

The Environments for Living Program is the only national program that offers an energy and comfort guarantee. To date, over 130,000 homes have been built under this program in more than a dozen states. Energy Guarantees for the program are calculated using REMRate, an energy-use estimation software commonly used in the home energy rating industry. The exact forumula used by EFL is proprietary but the guaranteed amounts closely match the energy savings goals of the Energy Star program (15-20% savings compared to IECC 2004). On average, this tends to run around 3-4 cents per square foot per month, obviously depending on the energy rate of the location. In essence, a typical 2000 square foot home would carry a guarantee of around $40 per month for heating and cooling.

Guarantees are paid annually based on the total amount that the actual usage exceeds the annual guarantee amount. Most homes have two-year guarantees. Builders that test 100% of their homes instead of using the usual sampling protocol receive a three year guarantee. While the guarantees are expressed in terms of dollars and cents as a marketing tool for customers, they are actually based on energy usage. If the price of energy changes, the guarantee also changes. The guarantee also specifies that the home's occupants must keep the home within a defined temperature range for the guarantee to be valid.

The comfort guarantee states that the center of each room will remain within three degrees Fahrenheit of the thermostat setting. If a home is not performing to this standard, EFL will investigate the cause(s) and have the appropriate trade fix the problem. Both the energy and the comfort components of the guarantee are triggered by the occupant.

In an area where the electric or gas utility has an incentive to create energy efficiency programs, some of these costs can be borne by that utility, as well as the accrued energy savings.

The Arizona Model: Builder Training

In Arizona, the utilities have substantially augmented the training provided by the Guaranteed Performance program, resulting in a utility/private partnership model that can be replicated in any other market. The first major point of the training program is to demonstrate to the builder exactly why each component of the efficiency process is important in the process of creating "whole house" improvements. Put another way, we demonstrate to the builder how one process or component impacts all the others. As mentioned above, it is important to properly frame the home so that the insulation installer can properly do his work. Failure at the framing stage can result in insulation that is very expensive to install or that is completely ineffective. This results in rooms that are uncomfortable, or the need for greater space conditioning or both. That one failure in execution has a whole raft of consequences for all later contractors, the builder, the home buyer and ultimately, the utility.

Once the builder recognizes the impact even small problems can have on the future performance of the home, he can take the next step toward improvement of process. Process improvement training focuses on those features that are critical to meeting the guarantee: air barriers, insulation, internal moisture management, pressure relief, and space conditioning.

Benefits

The Homeowner: homeowners who purchase a Guaranteed Performance home get a home that is healthier, safer, more comfortable, more durable, and more energy efficient than standard construction. There is some additional cost to them in the mortgage but the increase is usually more than offset by the energy savings. The reduced callbacks and claims also means these homeowners experience less "hassle" in living in these homes. Depending on the location, the increased cost may be anywhere from $200 to several thousand dollars. In several cases, the increased sales price was due to consumer demand for the homes, rather than the increased cost of the program.

The Builder: Probably the biggest benefit to builders that participate in the Guaranteed Performance program is that costs from callbacks and claims are reduced. The Guarantee also has a measurable marketing value: customers spend longer with the sales agents, homes sell faster and homes sell for higher prices than homes without the guarantee. Our surveys also show that customer satisfaction is significantly higher in Guaranteed Performance homes. This translates into customer loyalty and customer referrals. All these factors combined translate into increased profit for the builder.

The Utility: By creating and maintaining this program, the utilities in Arizona have taken a large step toward transforming the new construction market toward greater quality and energy efficiency. Both Energy Star and the Guaranteed Performance program have strong market shares in Phoenix, among the highest in the nation. In addition, our study showed that the knowledge of better building practices has filtered to most builders and improved the housing stock of even those homes not participating in either Energy Star or the Guaranteed Performance programs. Ultimately this means significant energy and consumption savings, prolonging the time when more generating capacity will be needed.

The Study

The study was structured to compare the actual energy efficiency of baseline homes, Energy Star, and Guaranteed Performance program homes, while taking into consideration a large number of variables in home design. The study looks at real data and energy performance of occupied houses, not computer models. The results of the study can be used to answer several fundamental questions about the effectiveness of these efficiency programs:

- How much energy did the Baseline, Energy Star, and Guaranteed Performance homes actually consume?
- How much energy savings are actually realized by Energy Star and Guaranteed Performance homes, compared to similar baseline homes?
- Has the implementation of energy efficiency programs in new home construction resulted in a reduction in of total energy consumption?

The study was not intended to determine the degree of success of the Energy Star and Guaranteed Performance programs. It does not make any interpretations as to why certain houses performed well or performed poorly, nor does it compare actual performance against computer modeling.

Survey Population – Energy Efficiency Study

More than 7,000 homes built from 1995-2004 by six different production building companies were included in this study: 3,336 baseline homes, 2,979 Energy Star homes, and 826 Guaranteed Performance homes. Details on the physical design and construction of the various homes (such as HVAC ratings, window size and types and volume) were obtained from the home builders, utilities, contractors and testing companies. Energy use histories for the homes were provided by Arizona Public Service and Southwest Gas Corporation, over the period of 1998-2004. County records were used to identify those homes with swimming pools and to collect additional information on floor area.

Data Sets

- **Baseline Homes** – these "code" built homes were not part of any energy efficiency program, but their building characteristics resemble those of the other homes in the study. Typical baseline homes built between 1998 and 2004 in the Phoenix area are anecdotally considered to be 20% more efficient than homes built to the 1993 Model Energy Code. The baseline homes provide a standard for energy use, allowing for comparison.
- **Energy Star Homes** – Energy Star homes meet or exceed the energy efficiency standards set by the EPA's Energy Star program. By definition, Energy Star qualified homes are independently verified to be at least 30% more energy efficient than the same home built to 1993 MEC or 15% more efficient than state energy code. Approximately 15% of the Energy Star homes in this study were field tested for duct and envelope leakage. A typical upgrade to qualify for Energy Star in Phoenix was either to install a SEER 12 air conditioner or low emissivity windows, or both.
- **Guaranteed Performance Homes** – Guaranteed Performance homes not only qualify for Energy Star but also generally include additional energy efficiency improvements. The energy performance of these homes is actually guaranteed by the builders or program managers not to exceed a certain level based on energy modeling. In order to successfully deliver on these guarantees, a minimum of 15% of these homes undergo a framing inspection, air barrier inspection, insulation inspection, duct leakage testing, envelope leakage testing and room pressure testing. Homes in this category are Energy Star qualified but for purposes of this study were not included in the data set of homes that exclusively participated in the Energy Star program.

Survey Population – Homeowner Satisfaction Survey

There were 708 responses to the survey, as shown in Table 1. Respondents were categorized into one of three groups based on the actual energy designation of their home as reported to the appropriate local utility and verified by Masco Contractor Services, the sponsor of the Environments for Living program. Thirteen respondents could not be categorized because they did not provide their address and therefore the house in question could not be identified.

Table 1: Composition of Survey Respondents

Category	Code	Number of Surveys	Percent of Total
Baseline Homeowners	B	205	29%
Energy Star Homeowners	ES	255	36%
Guaranteed Performance	GP	235	33%

Homeowners			
Unknown		13	2%
Grand Total		**708**	**100%**

There are differences in demographics of the three groups of homeowners as illustrated in Table 2 and Table 3. For example, ES homeowners have the largest households with the most children. They are young and fairly affluent. GP homeowners are older, more affluent and live in smaller households. Their homes are large and presumably more expensive. Baseline homeowners are the least affluent and live in the smallest houses. Baseline homeowners are also between GP and ES homeowners in age and the presence of occupants under the age of 18.

Table 2: Survey Demographics

Demographic	Baseline Homes	ES Homes	GP Homes	Total Survey
Average Household size	2.7	2.9	2.5	2.7
Percent of household occupants under the age of 18	28%	32%	20%	27%
Percent of homes with household incomes over $50,000	60%	67%	77%	68%
Percent of respondents under the age of 45	47%	58%	33%	46%
Percent of homes over 1,600 square feet	53%	60%	86%	68%

Table 3: Characteristics of Homes that Responded to the Survey

Characteristic	Baseline	ES	GP
Average square feet	1,685 ft^2	1,877 ft^2	2,125 ft^2
Percent of homes with gas heat	26	47	73
Percent of homes with 2 or more floors	20	23	15
Percent of homes with a swimming pool	19	20	18
Average SEER rating	11.6	11.9	11.7
Average square feet per ton of cooling	423 ft^2/ton	416 ft^2/ton	474 ft^2/ton

Data Sets

The data sets for the customer satisfaction survey are the same as for the energy efficiency study.

Conclusion – Energy Efficiency Programs Appear to be Working

Statistically valid energy savings were found for both the Energy Star and Guaranteed Performance homes, when compared to baseline homes. One surprise was how well the baseline houses performed, but it is our belief that this is partly due to the impact made on the marketplace by the Energy Star and Guaranteed Performance programs. Obviously, savings are directly related to how far a builder/contractor pushes specification and improves installation. A major catalyst for this push is programs such as Energy Star and Guaranteed Performance and all the activities that go into supporting them.

Beyond building efficiency improvements, the study also shows that base loads are large, growing, and need to be addressed. Continued efforts to reduce the overall energy usage in residential buildings should not be focused solely on space cooling/heating and water heating. While the savings are positive, the larger context of these savings is not as impressive. Space cooling/heating and water heating are the largest individual energy users in a home, although they represent roughly 40% of the home's overall energy usage. This means that even a 10% reduction in cooling/heating and water heating costs – a significant reduction – only equates to a 4% savings on the home's total energy bill. Obviously, all areas of energy use within residential buildings must be investigated to discover the maximum energy savings potential.

In addition to energy savings, efficiency advocates must be more aggressive in promotion of non-energy benefits. A builder is not very much concerned with the energy consumption of the home. However, many of the features that lead to energy efficiency also lead to improved profitability for the builder. Further, where appropriate, energy efficiency can translate to benefits for the local electric utility. It can also be promoted and supported by local air quality initiatives. In summary, basing energy efficiency decisions only on modeling characteristics that meet various cost tests can miss major energy savings opportunities. Sharing the benefits helps bring in participants which also shares the costs.