ENERGY STAR 3.0 ■ TOOL REVIEW—DIGITAL MANOMETERS ■ NREL'S BUILDING RESEARCH

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Home energy

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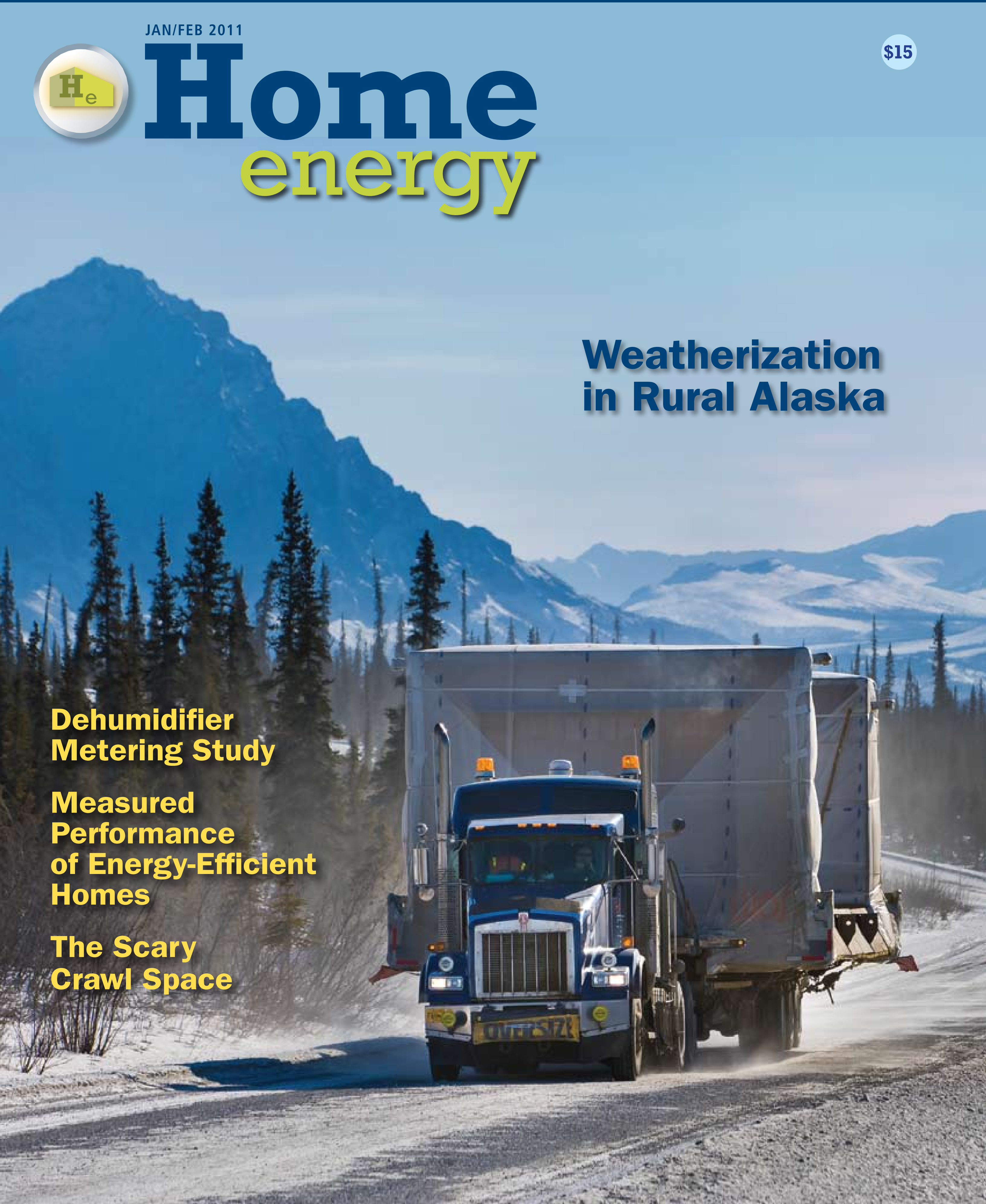


Weatherization in Rural Alaska

Dehumidifier Metering Study

Measured Performance of Energy-Efficient Homes

The Scary Crawl Space

ENERGY-EFFICIENT HOMES
Predictions, Performance, and Real-World Results

BY SHAUN HASSEL, BEN HANNAS, AND MICHAEL BLASNIK

Metropolitan Houston, Texas, has become one of the largest markets in the country for new-housing construction, with more than 350,000 new-home starts since 2000. Houston was an early adopter of the Energy Star label and currently has one of the highest market shares in the nation, with approximately 50% of new homes in 2008 certified as Energy Star. As the market share of Energy Star homes grew in Houston, some builders began to look for new ways of differentiating their homes. The guaranteed-performance labels from various organizations provided them with the opportunity to take a step beyond Energy Star in terms of energy performance, but without having to sacrifice many of the benefits they received from their participation in the Energy Star program.

To qualify for Energy Star certification, construction plans and building components must meet specific criteria for energy performance and be certified by a qualified third-party home energy rater. Two methods can be used to assess predicted energy consumption: computer energy simulation modeling or prescriptive construction standards approved by EPA. In Houston, nearly 100% of the Energy Star homes built are modeled with software to demonstrate that they will meet the Energy Star guidelines. This computer modeling produces a HERS score that indicates the predicted energy performance of the home as compared to a reference home built to the appropriate version of the International Energy Conservation Code (IECC) or local energy code, whichever is more stringent.

Since the Energy Star New Homes program was launched in 1995, several organizations—Masco Corporation, with its Environments for Living program; General Electric, with its ecomagination Homebuilder Program; Tucson Electric Power, with its Guarantee Home program; and Advanced Energy, with its SystemVision program—have been promoting the construction of guaranteed-performance homes. These homes are designed to go a step beyond the Energy Star program, using advanced building science materials and techniques to lower home energy use even further. For guaranteed-performance homes, the standards and testing protocol is more stringent than Energy Star to ensure predictable energy performance.

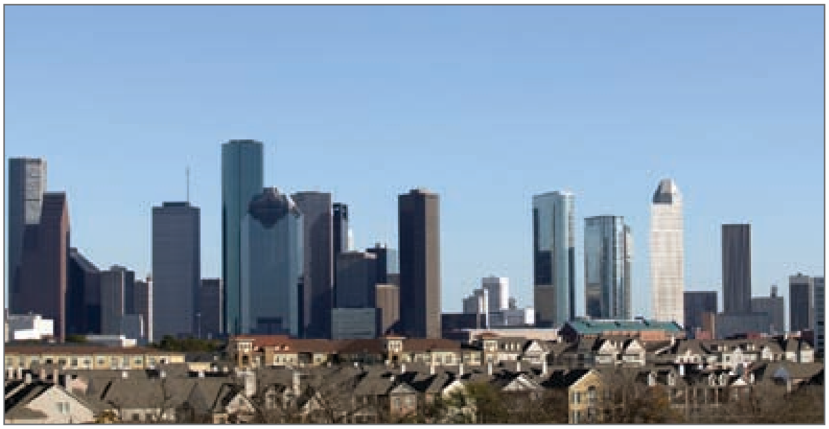
To offset the slightly higher cost of these guaranteed-performance homes and enhance their marketability, the builders or program administrators guarantee that annual energy usage for heating and cooling the home will not exceed a modeled annual amount. Any excess costs for heating-and-cooling energy use are reimbursed to the homeowners. The programs also include a comfort guarantee that complements the heating-and-cooling usage guarantee; it states that any room in the home will be within 3°F of the thermostat set point. To date, more than 130,000 houses nationwide have been built and certified to the guaranteed-performance standards of Masco, General Electric, Advanced Energy, and Tucson Electric Power.

The Study

Historically, billing data for Houston area baseline, Energy Star, and guaranteed-performance homes have not been collected and analyzed to determine how the homes have performed while occupied under real-world conditions. A handful of studies in Wisconsin, New York, and Arizona have analyzed actual energy bills in an effort to evaluate the performance of various new-home energy standards. The analysis of these studies showed an interesting trend: The Energy Star homes realized smaller savings than anticipated, compared with the baseline homes. The assumption that Energy Star homes would save more was driven primarily by inaccurate assumptions concerning the reference homes that Energy Star homes are compared with.

Table 1. Summary of Disposition of Homes In Final Database (Number of Homes)

	Baseline	Energy Star	Guaranteed Performance	Total
Overall analysis "good" homes	70,828	81,755	6,115	158,698
Electric usage analysis completed	40,981	42,154	2,795	85,930
Gas usage analysis completed	10,815	15,301	659	26,775



Houston, Texas, has become one of the largest markets in the country for new-housing construction.

This article documents the methodology and findings of the Houston Home Energy Efficiency study, which examined the actual energy performance of a large number of baseline homes, Energy Star homes, and guaranteed-performance homes in the Houston area. The study was managed and conducted by Advanced Energy, with data analysis performed by Michael Blasnik and Associates. EPA and CenterPoint Energy sponsored the study.

More than 226,000 homes built from 2002 to 2007 by dozens of different production building companies were included in the study. They consisted of 114,000 baseline homes, 106,000 Energy Star homes, and 6,600 guaranteed-performance homes. Details on the physical design and construction of the various homes (such as HVAC ratings, window size and type, and volume of conditioned space) were obtained from homebuilders, utilities, contractors, and testing companies. CenterPoint Energy provided energy use histories for the homes from 2002 through 2008. Data collection included access to billing data for all new homes built in the local utility service territory from 2002 through 2007; general housing information from the county property assessor databases of four counties; and detailed building characteristics for thousands of the Energy Star homes derived from energy rater REM/Rate .blg files and field test results files.

This study was structured to compare the actual energy efficiency of baseline homes, Energy Star-qualified homes, and guaranteed-performance homes, while taking into consideration a large number of variables in home design. The study looks at real data and real energy performance of thousands of occupied houses, not computer models.

All of the guaranteed-performance homes analyzed in the Houston market were also Energy Star certified. The study team applied a set of criteria to define a "Good" home for the analysis, based on it having sufficient data to allow comparisons to other homes. Further criteria were used to define analysis groups. These groups consisted of homes for which there were sufficient electric and gas usage data for analysis. Extensive data matching and quality checks were performed on the data to exclude obvious errors. However, the following facts should be noted:

- Data provided by supporting organizations, raters, and county appraisal databases were not field verified by the study team.
- The energy consumption (lifestyle) habits of the occupants were not directly evaluated in this study.

Table 1 summarizes the disposition of homes in the final electric and gas usage data sets.

The large sample size made it impossible to examine many of the factors associated with an evaluation of actual home energy consumption—homeowner behavior, demographics, variability of building components and systems, among others. It was nevertheless important to develop a data set that included groups of similar homes. All three groups of homes in this study are of similar size and have about the same number of stories, although the baseline homes are about 4% smaller than the others and are slightly more likely to have two stories. There are also some differences in the age of the homes; the Energy Star and guaranteed performance homes tended to be newer, although all the homes in the study were built between 2002 and 2007.

Raw monthly energy usage data for each customer were first analyzed using weather-normalization procedures to adjust for variations in weather between the period covered by the meter readings and average weather patterns. Weather normalization is not perfect, but it provides a much better basis for comparing energy usage between homes and over time than simply summing or averaging the raw monthly energy bills.

The size of the data set, the scope of the data collected, and the quality control measures utilized allow for a more apples-to-apples comparison of homes built to different energy efficiency standards than would otherwise have been possible. It also allowed the study team to draw more accurate conclusions as

2008 Total and Baseload kWh Usage by Year of Construction

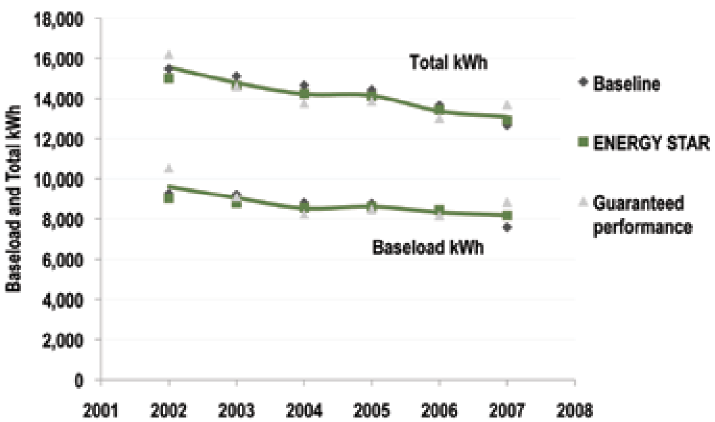


Figure 1. Total electricity consumption and base-load electricity consumption for homes built in different years.

Trends in 2008 Summer/Cooling Usage by Year of Construction

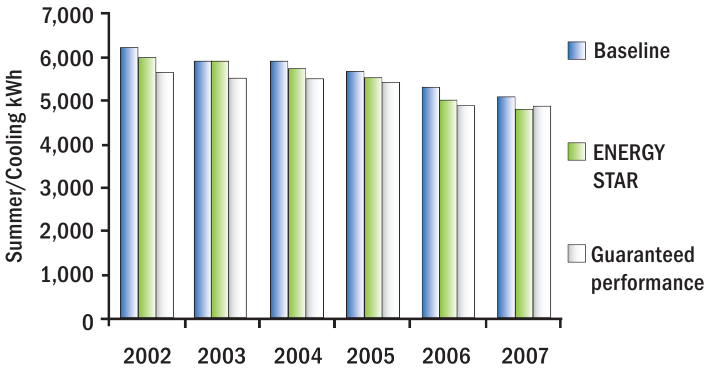


Figure 2. Over the same five-year period, Energy Star homes energy use dropped by 21% and guaranteed-performance homes energy use dropped by 14%.

to why certain groups of homes might perform better or worse than others.

Analysis and Results

Perhaps the most surprising outcome of the analysis is the fact that electricity consumption in new homes in Houston dropped dramatically for all three groups. Figure 1 shows 2008 total electricity consumption and base-load electricity consumption for homes built in different years. Both values trend down by the year of construction. Total electricity consumption decreases by 16% from homes built in 2002 to homes built in 2007.

Three factors may explain this 16% drop. First, Texas established a statewide residential energy code in 2001. Second, the federal standard for air conditioners was increased from 10 SEER to 13 SEER in 2006. And third, the high-performance home programs and initiatives adopted throughout the Houston market from 2002 to 2007 may have reduced energy consumption. These programs and initiatives included monetary incentives; training and technical support for builders; improvements in the home energy rater infrastructure; consumer marketing of energy efficient homes; and support from product manufacturers.

The entire residential new-construction marketplace cooperated to help reduce energy use across all homes. The change in federal SEER standards appears to have accounted for approximately half of the reduction in cooling usage. It is impossible to determine how much of an impact the other code changes had, or the spillover effects from the Energy Star program.

The data reveal that all homes in Houston experienced this drop in electricity consumption, and that differences in overall usage and cooling usage across different groups of homes were small. (Overall usage and cooling usage form the best basis for making comparisons in a cooling-dominated climate like that of Houston.) The cooling load of baseline homes declined by 18% over the period—from 6,194 kWh for homes built in 2002 to 5,068 kWh for homes built in 2007. Over the same period, Energy Star homes dropped by 21% and guaranteed-performance homes dropped by 14%. See Figure 2.

Consumption differences across the three groups of homes are smaller than that advertised for Energy Star and the guaranteed performance homes. However, Energy Star homes perform very close to the predictions of the models as a whole, while baseline homes perform better than the reference homes defined by the HERS standard.

The Energy Star program brought duct leakage testing and building envelope leakage testing into widespread use in the new-construction market in Houston. This testing probably encouraged contractors to improve their duct installation and building framing practices, so that their Energy Star homes would pass the tests. They then applied these same practices to all new homes. This phenomenon is known as market transformation, or spillover. The result is that baseline home performance improves, narrowing any observed difference in energy usage between the Energy Star homes and the baseline homes. Spillover, then, can make a program appear to have less impact than it is actually having.

Although we are unable to measure the impact of spillover on the findings, it is clear that, in Houston, typical construction practices are much better than practices for the reference homes as defined by the Energy Star standards. The reference home is defined as minimum local code specifications combined with the least efficient cooling, heating, and water heating equipment available; a leaky building envelope; and a poor duct system. Typical new construction clearly exceeded this level of performance even before the code change, and higher-SEER air conditioners were already common.

Table 2. Cooling Load Projections and Usage

Average load (kWh/yr)	
REM/Rate estimate	5,506
Billing Data	5,677
Difference	171 (3%)
Absolute error	
Mean	1,235 (21.8%)
Medium	992 (17.5%)
% Homes where REM/Rate was within:	
10% of billing data	28%
25%	64%
50%	91%
Correlations with billing data	
REM/Rate	0.62%

Accuracy of Modeling Predictions

The data collected in this project allowed the study team to examine the relationship between actual and projected energy usage. In this application, the primary quantity of interest is the projected cooling load, since base-load usage depends strongly on postoccupancy behaviors and purchase of new appliances; heating loads are small in this market and are also quite sensitive to behavioral preferences.

Actual Versus Predicted SEER Savings

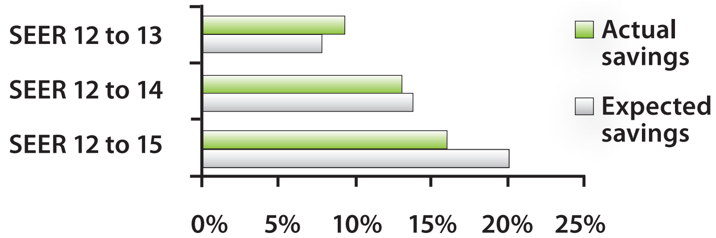


Figure 3. Savings from higher-SEER air conditioners are generally consistent with simple projections based on the SEER ratings.

Utilizing REM/Rate cooling-load projections from 10,258 homes with electric usage results, the study team found the REM/Rate projected average cooling load of 5,506 kWh per year was 3% higher than the billing analysis average cooling load of 5,677 kWh per year. See Table 2. REM/Rate also estimated the average heating usage of program homes fairly well—only 4% lower than the measured loads.

Although the analysis found no systematic bias in the REM/Rate cooling projections, there was considerable variability in the data. The correlation between house size and cooling load was higher than the correlation between REM/Rate projected cooling load and actual usage. However, the study team feels confident in stating that when current modeling software is used with energy-efficient new homes, there is a strong and fairly consistent relationship between actual and projected performance using REM/Rate for both heating and cooling.

Further Analysis—Regression Modeling

Simple comparisons of energy usage between groups of homes can be informative, but more sophisticated analyses are needed to disentangle the effects of many factors operating at once. Regression modeling is used to assess differences in energy usage over time and between groups. Regression modeling with REM/Rate file data is also used to explore some factors having to do with technical performance. Some of the results of regression modeling conducted on homes in the study could prove useful for those designing programs and determining priorities where the issue is one of technical standards:

- Savings from higher-SEER air conditioners are generally consistent with simple projections based on the SEER ratings, although they may decline a little for 15 SEER units. See Figure 3.
- About two-thirds of the reduction in cooling loads from 2005 to 2007 can be accounted for by changes in SEER ratings.
- Building shell leakage appears to increase cooling loads by about 0.4 kWh per CFM50 of leakage. Leakage accounts for about 14% of cooling loads in Energy Star homes.
- Base-load electric usage is strongly related to cooling loads. At 0.13 kWh cooling per annual kWh consumed, about 1,150 kWh (20% of cooling load) is removing base-load heat.

Discussion

The data from Houston indicate less energy savings than forecast between baseline and program homes. However, while consumption differences across groups of homes are smaller than advertised, Energy Star and guaranteed performance homes perform very close to the predictions of the models, while baseline homes perform better than the reference homes defined by the HERS standard. Similar conclusions have been found in other markets in which real-world data has been analyzed to determine savings from above-energy-code programs. The consistency of these findings suggests that the assumptions used to characterize and ultimately model reference homes may be inaccurate and may have led to smaller than expected savings in the programs evaluated.

While modeling and projected savings provide an excellent starting point, there is always a need for ongoing evaluation and feedback loops involving real-world data. Doing so will help clarify our models and develop more accurate assumptions. Billing analysis provides the most accurate measurement of program results and clarifies what specifications provide energy savings in new construction programs such as Energy Star. Likewise, there is a need for conducting studies such as this in less mature markets. Perhaps in a city or region with less market share for energy-efficient homes programs, differences between baseline homes and program homes would be larger. Spillover from programs may have less impact on standard practice in these markets. If so, the regression findings here, as well as some of the practices used to drive participation in Energy Star in Houston, could be adopted to help push forward such markets.

Shaun Hasell *works with multiple Energy Star new homes programs across the nation. He is a project manager with Advanced Energy based in Portland, Oregon.* **Ben Hannas** *is a freelance data analyst and programmer based in Raleigh, North Carolina.* **Michael Blasnik** *is one of the nation's leading experts on utility program evaluation and data analysis. He is principal at Blasnik and Associates, based in Boston, Massachusetts.*

>> For more information:

For the full report on the Houston study go to www.advancedenergy.org/buildings/knowledge_library/FINAL_Paper_Houston_Energy_Efficiency_Study.pdf.

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