HERS Estimates Vs. Energy Consumption

Introduction

The California Residential Building Energy Efficiency Standards are widely respected as the best in the United States, but they apply primarily to new construction, which is a tiny number compared to the existing stock of homes. The vast majority of California homes were built under earlier, less stringent versions of the Residential Standards or predates the Standards entirely. Most of these existing homes offer cost-effective opportunities for significant efficiency upgrades. Also, because of their large number, the total opportunity for savings is many times greater than can be expected from improvements in new construction.

Current energy calculation tools have an abysmal record at estimating the energy use and energy efficiency of poorly insulated existing homes. In an earlier study for the California Energy Commission and Pacific Gas & Electric Company, Wilcox compared Home Energy Rating System (HERS) I ratings with utility bills. He found that HERS calculations overestimated heating energy consumption by up to a factor of four (Figure 1) and that higher rated homes actually used more cooling energy than low rated homes (Figure 2).

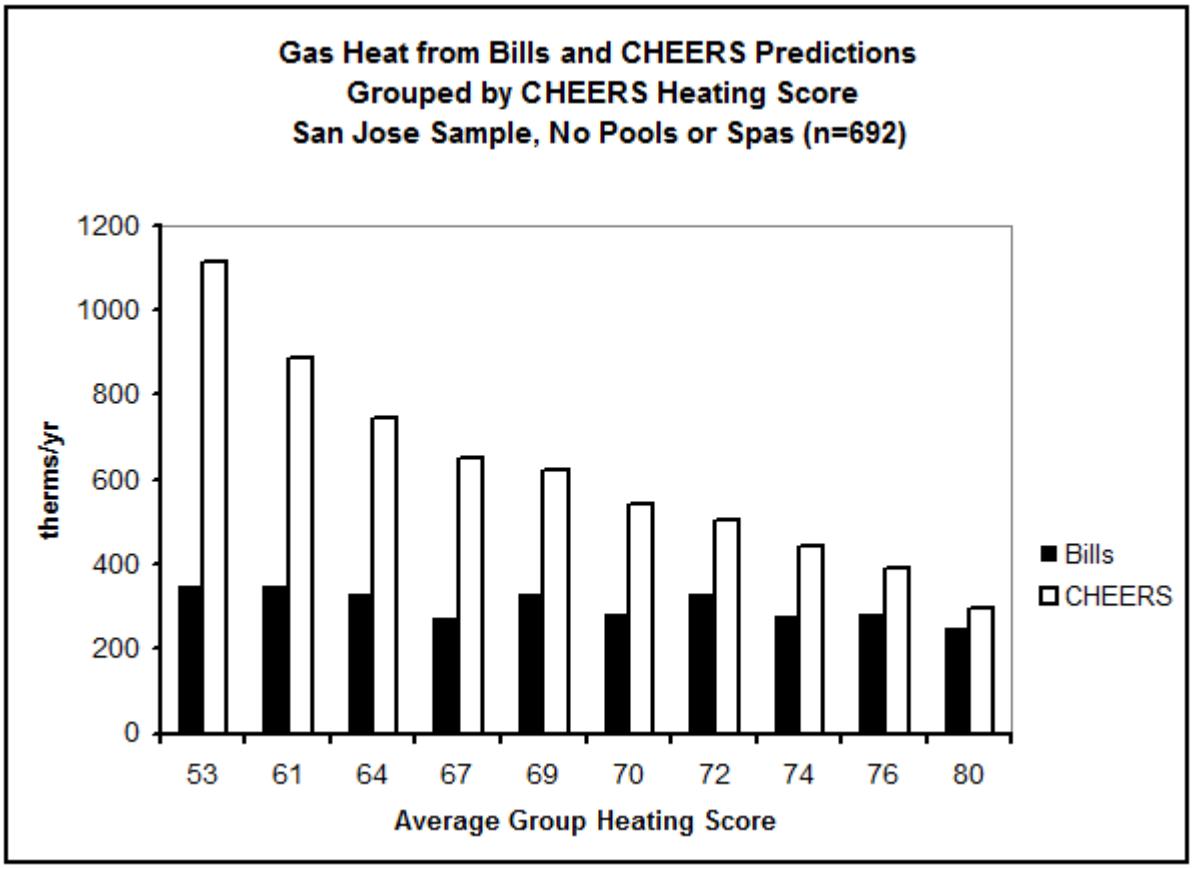


Figure1 . Gas Heating Bills vs. CHEERS Heating Score

(Source: Wilcox)

Wilcox, Bruce A. and Hunt, Marshall B., "Comparison of CHEERS Energy Use Predictions with Actual Utility Bills," Proceedings of the ACEEE 1998 Summer Study, American Council for an Energy Efficient Economy, Washington, DC, 1998.

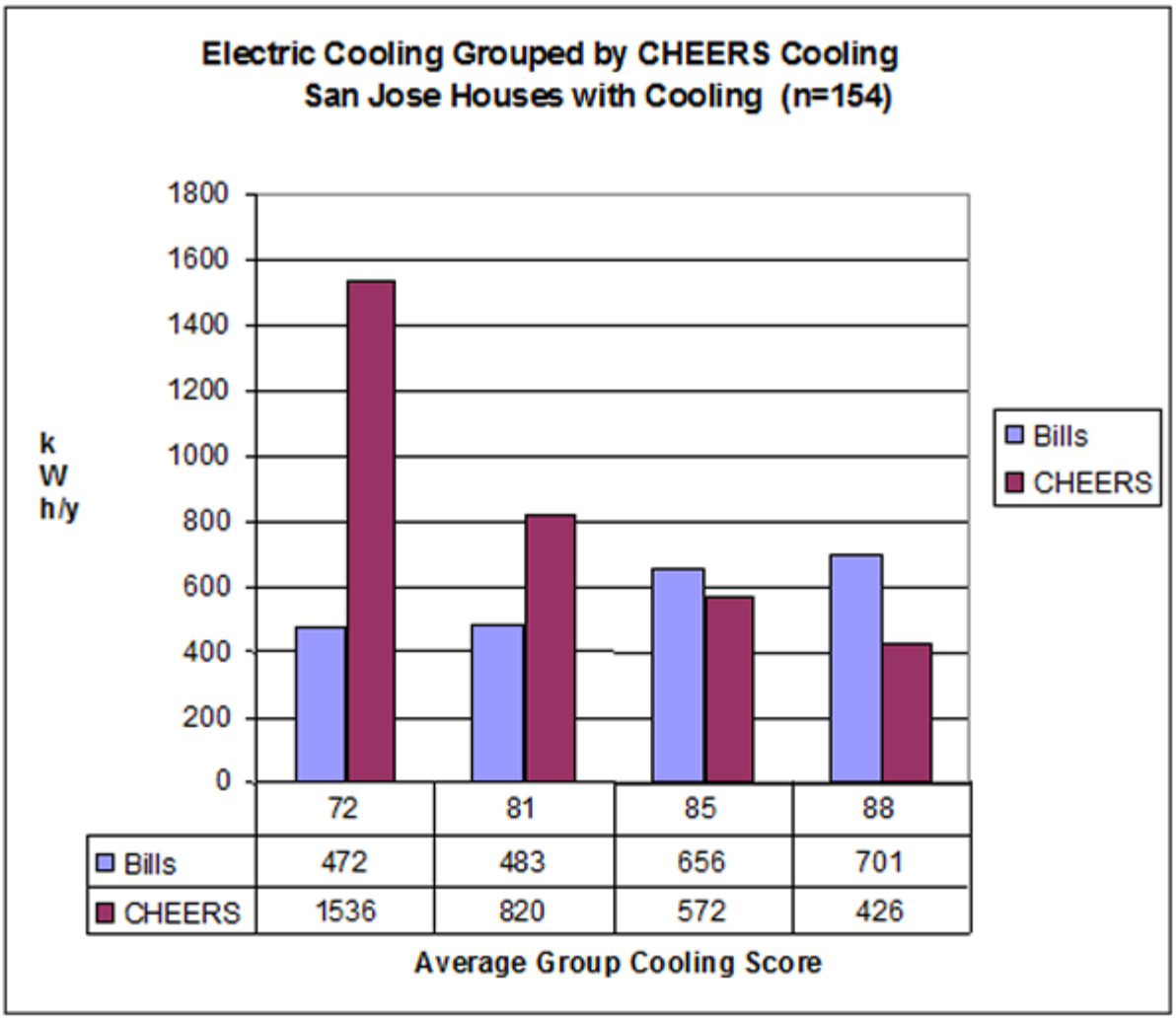


Figure 2 . Electric Cooling Bills vs. CHEERS Cooling Score

(Source: Wilcox)

Presumably this performance has been improved somewhat by the HERS calculations rules adopted by the Energy Commission that went into effect in 2010 (HERS II).

A study for the Energy Trust of Oregon compared the results of four modeling technologies: REM/Rate, Home Energy Saver-Mid (HESm), Home Energy Saver-Full (HESf), and SIMPLE. The four methods were applied to 190 homes and each method provided an estimate of the annual energy use of the houses. On average REM/Rate, HESm and HESf overpredicted the total energy use of the homes. For the HESm predictions 60% were off by more than 50%, for REM/Rate 32% of the predictions were off by more than 50% and for HESf 22% of the predictions were off by more than 50%. SIMPLE predictions were the closest to the actual total energy use and, on average underpredicted the use by 17%. It also exhibited only 8% of the predictions with an error greater than 50%.

The development of HERS procedures continues to be hampered by lack of data to validate energy calculations in older homes. Most current energy use data is derived from utility bill analysis, surveys, and monitoring in occupied homes in which the presence and behavior of occupants precludes detailed monitoring. To date, there has been no facility that provides the opportunity to collect detailed data under controlled conditions in older California homes.

[EAI] Earth Advantage Institute, Energy Performance Score 2008 Pilot Findings and Recommendations Report, for the Energy Trust of Oregon, August 2009.

The Central Valley Research Homes (CVRH) project is addressing this lack of data. The project team leased four unoccupied homes in Stockton, California to serve as laboratories where energy use and energy efficiency is being scientifically studied over the course of three years. In the first phase of the CVRH project, the researchers arranged for six different HERS Raters to perform HERS inspections of each home, in order to compare HERS inspection and rating results against the real performance of these homes in a controlled environment where occupants do not affect the outcome. The results are intended to form part of a basis for judging the accuracy, consistency and reliability of HERS ratings for use in efficiency programs.

This interim report compares the heating and cooling use estimates obtained from the six HERS Raters with the actual heating and cooling use in the research homes. The HERS Raters are identified by numbers 1 through 6. The houses are identified by the name of the street they face: Grange, Mayfair, Fidelia, and Caleb.

Methodology

Ratings and Energy Use Estimates

The project team identified four unoccupied homes in Stockton, CA suitable for carrying out the experiments, and arranged to lease the homes and keep them unoccupied for several years. The homes range in vintage from 1948 to 2005, and vary in their foundation type, size and number of stories. The energy issues presented by the homes cover the spectrum of typical existing houses in California. Glazing ranges from single-pane steel casement windows to double-pane low-E windows in the newest home. Similarly, ceiling insulation R-value ranges from R-5 to R-30. The quality of air sealing, duct

location and insulation amounts, and HVAC system types and efficiencies provided similar ranges of energy performance issues.

The project team attempted to carry out a blind comparison of the four homes with several HERS Raters who would each supply normal ratings for the same homes. We obtained a list of HERS Raters active in California's Central Valley. A member of the research team who is an architect contacted Raters on the list and said that he had a client who was interested in obtaining HERS ratings on the four homes. The architect asked for a standard HERS rating on each home and paid the rate requested by each Rater.

The HERS Raters were not told that this activity was part of a research project, that the State of California was involved or that other Raters would be asked to rate the same homes. Rater visits were scheduled to avoid Raters encountering each other and every effort was made to make the process seem ordinary. There were inevitable glitches, including the fact that some Raters were able to see from the HERS Provider registry that other Raters were active at the same homes. We had no contact with the HERS provider. Overall we believe that the process was largely successful and that we obtained ratings and energy use estimates that were as well prepared or better than normal.

The six HERS Raters all used version 5.1.6.7 of Energy Pro, a software program that estimates home energy use based on user inputs to create a model of the building being analyzed. A total of 24 ratings and estimates were obtained. All the Raters measured the house air leakage with a blower door and duct leakage with a Duct Blaster™.

Monitoring Actual Energy Consumption

We installed monitoring and control systems in each home. The systems control the operation of the HVAC and internal gain. We heavily instrumented the research homes to provide hourly and minute by minute data. The monitoring equipment also controlled the humidifiers and heaters that simulated latent and sensible heat gain from typical occupancy.

The monitored data points were read every 20 seconds and the average (or sum as appropriate) was recorded every minute. The monitored points are listed in Table 1.

Category	Item
Energy Used	Total House kWh
Energy Used	House AC Condensing Unit kWh
Energy Used	House AC Inside Unit kWh
Energy Used	House Furnace Natural Gas (ft^3)
Energy Used	Reference AC Condensing Unit kWh

Category	Item
Energy Used	Reference AC Inside Unit kWh
Energy Used	Reference Heating kWh
Occupancy Simulator	Latent kWh
Occupancy Simulator	Sensible kWh
Whole House Fan	Inside Outside Temp Differential
Whole House Fan	status (on/off)
Ambient	Outdoor Ambient T (3 locations)
Ambient	Outdoor Ambient Humidity
Ambient	Wind Speed
Ambient	Horizontal Solar Radiation
Heating and Cooling	Thermostat Set Point
Heating and Cooling	Active System (House or Reference)
House AC	Evaporator Saturation T
House AC	Evaporator Saturation T (run time avg.)
House AC	Suction Line T
House AC	Suction Line T (run time avg.)
House AC	Condenser Saturation T
House AC	Condenser Saturation T (run time avg.)
House AC	Liquid Line T
House AC	Liquid Line T (run time avg.)
House AC	Return Air T
House AC	Return Air humidity
House AC	Return Air T (run time avg.)
House AC	Return Air humidity (run time avg.)

Category	Item
House AC	Thermostat Call Status (each zone)
House AC	Condensing Unit status (on/off)
House AC	# Cycles
House Air Handler	status (on/off)
House Air Handler	# Cycles
House Furnace	Thermostat Call Status (each zone)
House Furnace	# Cycles (each zone)
House Furnace	status (on/off)
House Furnace	# Cycles

From July 2012 to April 2013, we operated all four houses with their as found envelopes and HVAC systems to generate baseline data sets. Analysis of this data provides heating and cooling loads, their dependency on outdoor conditions and indoor thermostat settings, as well as HVAC efficiency.

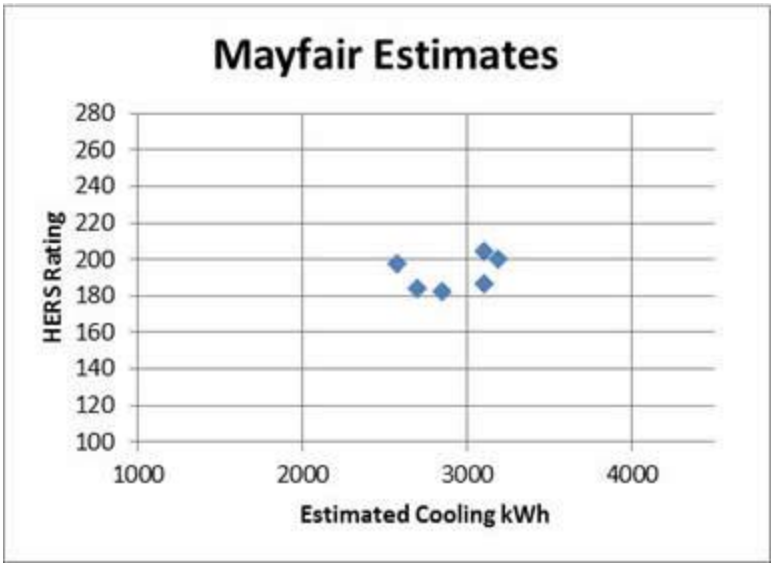
Results

Range of HERS Estimates

To the degree that the goal of HERS ratings is to accurately project the energy use of a structure, the results from different raters on the same house should be within a narrow range of values. Table 1 shows the results of the ratings. The percentages are the ratio of the difference between the maximum estimate and the minimum estimate divided by the minimum estimate.

Table 1 . Range of HERS Ratings and Heating and Cooling Estimates

House	HERS Rating		Estimated Heating (therms/yr)		Estimated Cooling (kWh/yr)	
	Range	Difference	Range	Difference	Range	Difference
Caleb	121 to 159	31%	238 to 572	140%	1403 to 3163	125%
Fidelia	129 to 179	39%	339 to 430	27%	1999 to 4364	118%
Mayfair	182 to 204	12%	451 to 604	34%	2574 to 3190	24%
Grange	182 to 269	48%	214 to 521	143%	2025 to 4491	122%



The Mayfair house has what we would characterize as reasonable agreement among the six Raters. The other three homes have cooling energy estimates that vary by over 100% (a two to one ratio). These three homes also have HERS ratings that vary by excessive amounts.

A plot of Mayfair's estimated cooling consumption and its HERS ratings shows the data falling into a fairly tight cluster (Figure 3).

HERS Estimates Compared to Monitored Results

To the degree that the goal of HERS ratings is to accurately project the energy use of a structure, the results should come within a reasonable range of the actual usage of such a house that is controlled to function as specified within the HERS models. Some of the specific items that need to be controlled or accounted for in the experiment are: thermostat set points, internal gains, no interference from occupants, and outdoor conditions. The CVRH experiment controlled for all the above except outdoor conditions. The outdoor conditions are obviously out of experimental control so they were intensively monitored. The monitored energy consumption was correlated with the outdoor temperatures and the

correlation was applied to the same weather file as used for the HERS ratings. The HERS heating and cooling estimates are compared to the monitored results in the tables and graphs below.

For Mayfair, the cooling estimates from the raters was nicely clustered, however the actual annual usage based on monitored data shows the cooling use is only 25% of the clustered estimates.

Table 2 Results – Cooling Estimates vs. Monitored Cooling Use

House	HERS Estimated Heating (kWh/yr)						Monitored
	Rater 1	Rater 2	Rater 3	Rater 4	Rater 5	Rater 6	
Caleb	2784	3163	2835	1403	1781	2702	1159
Fedelia	2471	4364	2874	3146	2588	1999	1377
Mayfair	2574	3100	2694	3190	2849	3010	731
Grange	4491	3077	2810	3731	2025	2276	678

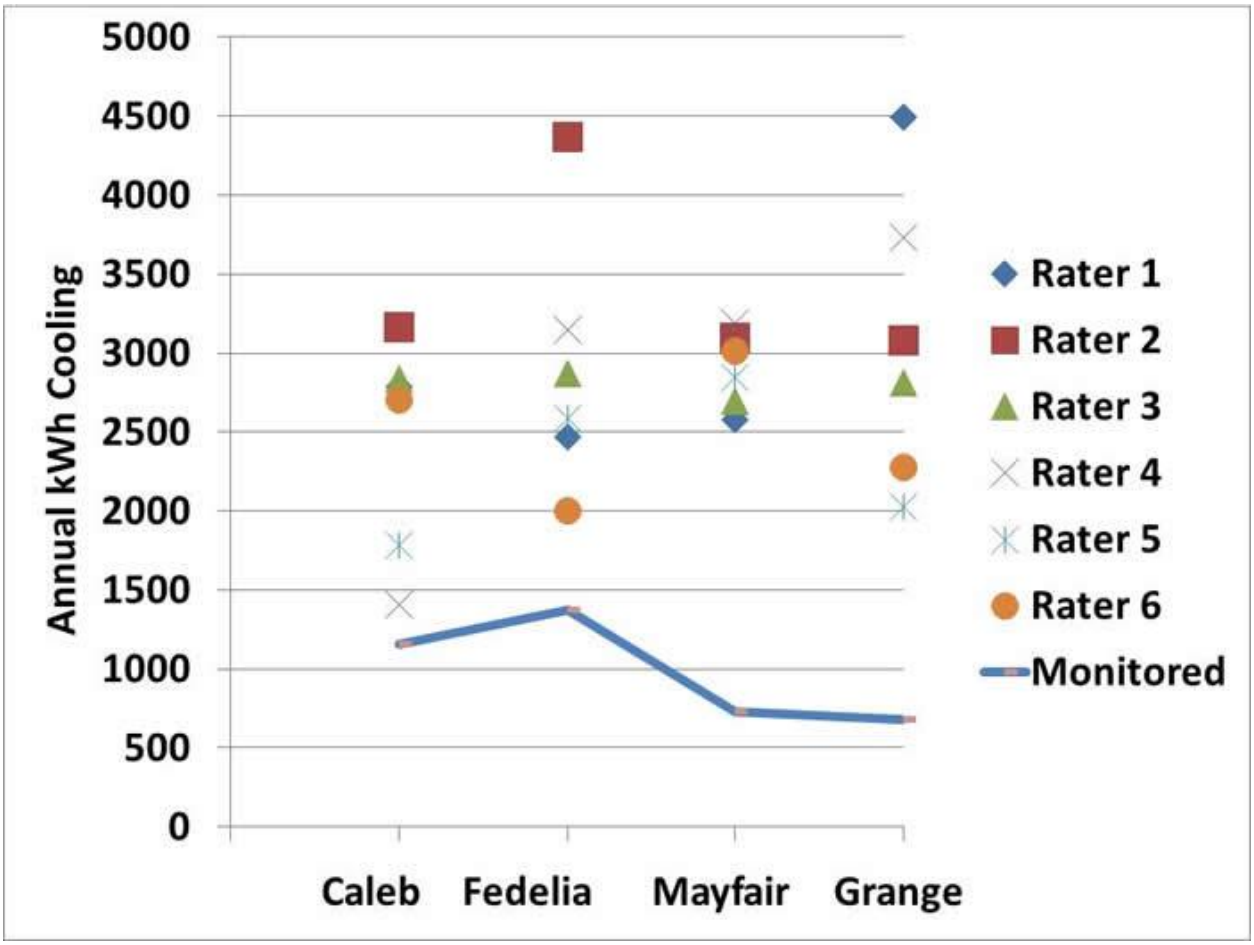


Figure 5. Annual Heating therms Estimates and Monitored Gas Use