

Do Homeowners Know How Efficient Their Homes Are?

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ABSTRACT

Information obtained from customers about the energy characteristics of a home can provide useful data for program design and targeting, as well as for program evaluation. A key concern about this “self-reported” data, however, is the technical accuracy of that information.

This paper will explore the results of a study that included over 400 telephone surveys with homeowners and over 100 home energy audits. The telephone surveys included homeowner ratings of the efficiency level of various home features as well as the entire house. The results of these telephone surveys will be compared to the results of energy audits that assessed the efficiency of these features at the same homes.

This paper will assess the presence and extent of statistically significant differences between the actual efficiency of home features for homeowners who report that a feature is energy efficient compared to homeowners who report that it is not efficient. In addition, we will estimate the proportion of owners who accurately report that their home is or is not energy efficient.

This paper will provide insight into the accuracy of homeowners’ perception of the efficiency of key features of their homes. With a clearer understanding of homeowner-reported information, programs may be able to improve their targeting of homes and measures, as well as homeowners who will successfully participate. In addition, this paper will be useful to evaluators by identifying what information may or may not be reliably collected via telephone surveys.

Introduction

Information obtained from customers about the energy characteristics of a home can provide useful data for program design and targeting, as well as for program evaluation. A key concern about this “self-reported” data, however, is the technical accuracy of that information.

For energy efficiency programs that target existing homes, the homeowners’ perception of the efficiency of their homes represents both an opportunity and an obstacle. Homeowner-reported information is used by programs, to varying degrees, to identify opportunities to improve energy efficiency. Accurate information presents clear opportunities for program savings while inaccurate information may lead to the ineffective use of program resources. In addition, homeowners who have an accurate understanding of their homes’ efficiency may be more likely to participate and then install recommended measures. By comparing the results of homeowner-reported efficiency with the results of energy audits, this paper will provide insight into the relationship between their perception and actual performance.

This paper will assess the presence and extent of differences between the actual efficiency of home features for homeowners who report that a feature is energy efficient compared to homeowners who report that it is not efficient. In addition, we will estimate, where possible, the proportion of owners who accurately report that home features are or are not energy efficient.

This analysis will explore the results of a study conducted in Vermont that assessed the market for existing single-family homes (NMR, RLW & Conant 2009). Existing homes are defined as homes five

years or older, according to the homeowners. In addition, single-family homes include the following types of homes:

- Detached single-family home
 - Constructed on-site using a foundation
 - Modular home that is built at a factory in separate units then assembled and set onto a foundation.
- Townhouse or duplex, with a wall separating the units from basement to roof, and with separate utilities for each unit

A variety of research tasks were undertaken in order to assess the single-family existing homes market in Vermont, including the following:

- Telephone surveys with 418 owners of single-family homes who live in their homes, conducted during October and November of 2007.
- On-site audits at 123 owner-occupied single-family homes conducted between December 2007 and April 2008. These homes were recruited from the pool of homes occupied by telephone survey respondents. The audits gathered detailed information on insulation, windows, HVAC systems, water heating, appliances, and lighting and included the measurement of building shell air leakage using a blower door test at 70 homes.

Overall Home Efficiency

Table 1 displays several measures of home efficiency from the on-site audits, including air infiltration levels and wall and ceiling insulation R-values, based on the owner’s perception of home efficiency (NMR, RLW & Conant 2009, 96). Compared to owner occupants who “agreed” or “strongly agreed” with the statement “My home is energy efficient”, owner occupants who “disagreed” or “strongly disagreed” have significantly less ceiling insulation (R-value of 22 vs. 29) and less wall insulation (R-value of 9 vs. 13). However, there is no significant difference in terms of air infiltration rates.

Table 1. Perception of Overall Home Energy Efficiency and Key Building Shell Characteristics

	Agree or Strongly Agree Home Is Energy Efficient	Disagree or Strongly Disagree Home Is Energy Efficient
Average R-value for Wall Insulation	13*	9*
Number of Homes	91	20
Average R-value for Flat Ceiling Insulation	29*	22*
Number of Homes with All Flat Ceilings	69	17
Average Air Infiltration ACH50	8.9	10.3
Number of Homes with Air Infiltration Data	53	14

*Significantly different from the comparison value at the 90% Confidence Level.

Table 2 displays, in the first column, the percent of homes with wall insulation of R-13 or above, ceiling insulation of R-30 or above, and air infiltration levels below 9.0 air changes per hour at 50 CFM (ACH50) for those owners who agreed that their home is energy efficient (NMR, RLW & Conant 2009, 97). Forty percent of these homes had R-13 or above wall insulation; R-13 fiberglass batt insulation is typical in 2x4 walls. In addition, 58% of these homes had R-30 or above ceiling insulation and 58% had air infiltration below 9.0 ACH50. Overall, 27% of the 41 homes with all flat ceilings, blower door test results, and where the owner agreed that the home was efficient meet all three of these criteria and thus appear to have reasonably efficient building shells for an existing home.

The second column displays the percent of homes with wall insulation at R-7 or below, ceiling insulation at R-19 or below, and air infiltration above 13.0 ACH50 for those owners who disagreed that their home is energy efficient. Of the 20 homes where the owners disagreed that their home is energy efficient, 30% have wall insulation equal to or below R-7. About two-thirds have flat ceiling insulation equal to or below R-19, and 21% have air infiltration above 13.0 ACH50. However, none of the eleven homes with all flat ceilings and blower door test results and where the owner disagreed that the home was efficient met all three criteria.

Table 2. Perception of Home Energy Efficiency and Percent of Homes with Building Shell Characteristics

Percent of Homes with	Agree or Strongly Agree Home Is Energy Efficient	Disagree or Strongly Disagree Home Is Energy Efficient
Wall Insulation equal to or above R-13	40%	
Wall Insulation equal to or below R-7		30%
Number of Homes	91	20
Flat Ceiling Insulation equal to or above R-30	58%	
Flat Ceiling Insulation equal to or below R-19		65%
Number of Homes with All Flat Ceilings	69	17
Air Infiltration below 9.0 ACH50	58%	
Air Infiltration above 13.0 ACH50		21%
Number of Homes with Air Infiltration Data	53	14

Efficiency of Home Features

In the homeowner telephone survey, respondents were asked if their home contained the following features:

- Windows
- Furnace or boiler
- Central Air Conditioning¹
- Room air conditioners
- Hot Water Heater
- Refrigerator
- Freezer
- Dishwasher
- Clothes Washer
- Insulation
- Lighting

If the homeowner reported that their home contained a given feature, then they were asked to rate the efficiency level of that feature using the following categories:

- ENERGY STAR qualified²
- Energy efficient (but not ENERGY STAR)²
- Average efficiency
- Not energy efficient
- Do not know

Because home features have different characteristics related to efficiency designations, we use different approaches to assess the homeowner's perception of energy efficiency. Features for which it is not always possible to accurately determine the ENERGY STAR status, such as insulation, windows, and furnaces/boilers, and for water heaters, for which there is no ENERGY STAR label, we compare the average efficiency levels between homeowners who rated the feature as 'ENERGY STAR' or 'energy efficient' versus those who rated the feature as 'average efficiency' or 'not energy efficient'. For appliances, which are more easily identified as ENERGY STAR, we compare the proportion of ENERGY STAR models for respondents who report the appliance is ENERGY STAR versus the percentage for those who do not.

¹ Because only two homes had central air conditioners installed, we do not present an analysis of homeowner perceptions of the efficiency of central air conditioners.

² Respondents were asked about ENERGY STAR only if they reported earlier in the survey that they were aware of the ENERGY STAR label. Of the 123 owners whose homes received on-site inspections, 90% were familiar with the ENERGY STAR label.

Insulation. The auditors determined the type and R-value of insulation through visual inspection where feasible; in the absence of visual inspection, the auditors assessed wall type and thickness or, lastly, relied on homeowner reports in the event that other methods were not possible. Table 3 compares the average R-value for wall insulation and flat ceiling insulation based on the homeowners' ratings of the efficiency level of their insulation from the telephone survey (NMR, RLW & Conant 2009, 95). Owners who rated their insulation as 'energy efficient' or 'ENERGY STAR' have significantly higher levels (at the 90% confidence level) of wall insulation than those homeowners who rated their insulation as 'average efficiency' or 'not energy efficient'; however, there is no statistically significant difference for flat ceiling insulation.

Table 3. Homeowner Rating of Insulation Efficiency and Insulation R-values

	Homeowner Rated Insulation as 'Energy Efficient' or 'ENERGY STAR'	Homeowner Rated Insulation as 'Average Efficiency' or 'Not Energy Efficient'
Average R-value for Wall Insulation	14*	10*
Number of Homes	59	30
Average R-value for Flat Ceiling Insulation	28	27
Number of Homes	42	21

*Significantly different from the comparison value at the 90% Confidence Level.

Windows. U-values are typically listed on the National Fenestration Rating Council sticker attached to new windows. However, these stickers are removed after installation, thus we estimated window U-values based on the type of glazing (single-paned, double-paned, etc), frame type (wood, vinyl, metal, etc), glass coating (low-E), and presence of storm window, using the default window U-values specified in the Vermont Residential Building Energy Standards manual.³ There is no statistically significant difference in the average U-value for owners who rated their windows as 'energy efficient' or 'ENERGY STAR' versus those homeowners who rated their windows as 'average efficiency' or 'not energy efficient' (Table 4).

Table 4. Homeowner Rating of Window Efficiency and Window U-values

	Homeowner Rated Windows as 'Energy Efficient' or 'ENERGY STAR'	Homeowner Rated Windows as 'Average Efficiency' or 'Not Energy Efficient'
Average U-value	0.54	0.54
Number of Homes	75	37

³ Vermont Residential Building Energy Code Handbook, Edition 2.0, November 2004. Table B-1, Page 59.

Heating Systems. The annual fuel utilization efficiencies (AFUE) for heating systems were not typically visible during the on-site audits, therefore Table 5 displays estimated efficiency ratings (NMR, RLW & Conant 2009, 93).⁴ Owners who rated their oil or natural gas heating systems as ‘energy efficient’ or ‘ENERGY STAR’ have significantly higher efficiency units (at the 90% confidence level) than those homeowners who rated their heating systems as ‘average efficiency’ or ‘not energy efficient’.

Table 5. Homeowner Rating of Heating System Efficiency and Rated Efficiency

	Homeowner Rated Heating System as ‘Energy Efficient’ or ‘ENERGY STAR’	Homeowner Rated Heating System as ‘Average Efficiency’ or ‘Not Energy Efficient’
Average Efficiency of Oil Heating Systems	0.83*	0.80*
Number of Homes	37	19
Average Efficiency of Natural Gas Heating Systems	0.87*	0.83*
Number of Homes	24	10

*Significantly different from the comparison value at the 90% Confidence Level.

⁴ Auditors generally collected the data according to a hierarchy with AFUE first, manufacturer rated efficiency next and input over output last. About one-quarter of units had AFUE ratings posted, another one-quarter had manufacturers efficiency on the nameplate, and about one-third had only input and output capacity ratings available. The remainder did not have enough information to determine the unit efficiency. It is important to distinguish the rated efficiencies reported in this study from operating efficiencies. Units that are not periodically checked and tuned may operate at reduced efficiencies; auditors found that a little over one-half of the heating systems had been checked by a service technician within the last five years or so. Most of those with service tags on them indicated post tune-up operating efficiencies close to the rated efficiencies, as determined by the flue gas temperature and CO2 tests performed.

Water Heaters. Because energy factors for water heaters were not available in most homes, the energy factors were estimated using different methods. Energy factors for indirect-fired tanks were estimated by multiplying the boiler efficiency by 0.92; energy factors for tankless coil systems were estimated based on the number of bedrooms.⁵ There is no statistically significant difference in the average energy factor for owners who rated their water heaters as ‘energy efficient’ or ‘ENERGY STAR’ versus those homeowners who rated their water heaters as ‘average efficiency’ or ‘not energy efficient’ (Table 6).

Table 6. Homeowner Rating of Water Heater Efficiency and Water Heater Energy Factor

	Homeowner Rated Water Heater as ‘Energy Efficient’ or ‘ENERGY STAR’	Homeowner Rated Water Heater as ‘Average Efficiency’ or ‘Not Energy Efficient’
Average Energy Factor	0.70	0.64
Number of Homes	71	28

Appliances. Auditors recorded the ENERGY STAR status and model numbers for refrigerators, freezers, clothes washers, and dishwashers during the on-site audits; the ENERGY STAR status of these models was validated at http://www.energystar.gov/index.cfm?c=appliances.pr_appliances. Because model numbers have a variety of configurations (due to differing colors, features, etc), an exact match is required to positively identify a model as ENERGY STAR. In addition, model numbers are not always visible on appliances; for these units, we relied on the auditor’s original designation of ENERGY STAR status.

Because about three-quarters of the 50 room air conditioners were estimated to be less than five years old, we compared the recorded Energy Efficiency Ratio (EER) to the current minimum EER required by ENERGY STAR (http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac) in order to determine the ENERGY STAR status of room air conditioners.

⁵ Vermont Residential Building Energy Code Handbook, Edition 2.0, November 2004. Table B-3, Page 60.

Figure 1 displays the proportion of ENERGY STAR appliances found during the on-site audits for owners who rated their appliance as ‘ENERGY STAR’ versus those who did not rate the appliance as ENERGY STAR (NMR, RLW & Conant 2009, 94). For all types of appliances, owners tend to substantially overestimate the presence of ENERGY STAR models. Only one-quarter to one-third of the refrigerators, clothes washers, and dishwashers that survey respondents thought were ENERGY STAR were confirmed as ENERGY STAR models; none of the six freezers that homeowners thought were ENERGY STAR were confirmed as ENERGY STAR models. In addition, between 5% and 9% of these appliances that respondents thought were *not* ENERGY STAR were in fact ENERGY STAR models.

For room air conditioners (RAC), five of the ten homes where owners rated their RACs as ENERGY STAR contained at least one ENERGY STAR model, compared to 38% of the 16 homes where the owner did not rate their RAC as ENERGY STAR qualified. Because the audits were performed in the winter and early spring, RACs were not always accessible in homes.

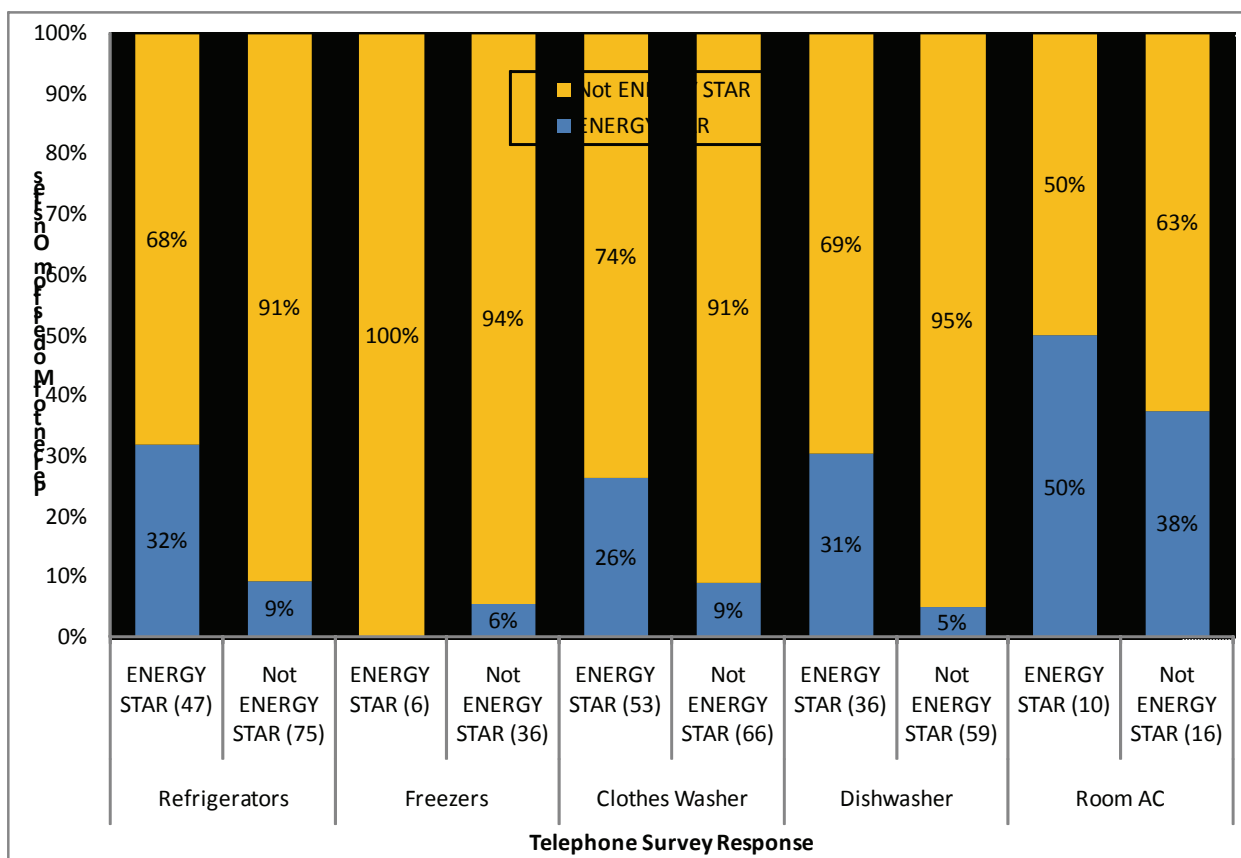


Figure 1. Homeowner Perceptions of ENERGY STAR Appliances and Actual Status

Lighting. Of the seventeen homes whose homeowners rated their lighting as ‘ENERGY STAR’, sixteen (94%) were found to have at least one CFL installed. Of the 87 homes whose homeowners did not rate their lighting as ‘ENERGY STAR’, 85% were found to have at least one CFL installed. These results may understate the percentage of homeowners who know they have ENERGY STAR lighting because some homeowners may have rated their lighting as ENERGY STAR only if they thought that all their lighting was ENERGY STAR and others may have said their lighting was ENERGY STAR if they knew that at least some of their lighting was ENERGY STAR. Also, not all CFLs are ENERGY STAR labeled, though many are.

Summary

The comparison of homeowner survey results to the findings of on-site inspections in Vermont suggests the following about homeowners:

- Homeowners appear to have some ability to generally characterize their home’s overall efficiency. Compared to owner occupants who “agreed” or “strongly agreed” their home was energy efficient, owner occupants who “disagreed” or “strongly disagreed” have significantly less ceiling insulation (R-value of 22 vs. 29) and less wall insulation (R-value of 9 vs. 13) in their homes; however, there is no significant difference in terms of air infiltration rates. On the other hand, there were still many cases where the homeowner perceptions regarding energy efficiency were not well founded. Overall, only 27% of the 41 homes with all flat ceilings, blower door test results, and where the owner agreed that the home was efficient, appear to have a reasonably efficient building shell for an existing home, with ceiling insulation equal to or above R-30, wall insulation equal to or above R-13, and air infiltration below 9.0 ACH50.
- Homeowners appear to most accurately characterize the efficiency level of heating systems and wall insulation. Homeowners who rate their heating systems, through the telephone survey, as ‘energy efficient’ or ‘ENERGY STAR’ have significantly higher steady state efficiency levels than those homeowners who rate their heating system as ‘average efficiency’ or ‘not energy efficient’ (0.83 vs. 0.80 for oil, 0.87 vs. 0.83 for natural gas). Owners who rate their insulation as ‘energy efficient’ or ‘ENERGY STAR’ have significantly higher levels of wall insulation (R-14 vs. R-10) than those homeowners who rate their insulation as ‘average efficiency’ or ‘not energy efficient’; however, there is no statistically significant difference for flat ceiling insulation.
- Homeowners’ characterizations of window and water heater efficiency appear to be of limited value. There is no statistically significant difference in the average window U-value or the average water heater energy factor for owners who rated their windows or water heaters as ‘energy efficient’ or ‘ENERGY STAR’ versus those homeowners who rated their windows or water heaters as ‘average efficiency’ or ‘not energy efficient’.
- Homeowners tend to substantially overestimate the presence of ENERGY STAR appliances. Only one-quarter to one-third of the refrigerators, clothes washers, and dishwashers that survey respondents thought were ENERGY STAR were confirmed as ENERGY STAR models. In addition, between 5% and 9% of these appliances that respondents thought were *not* ENERGY STAR were in fact ENERGY STAR models.

- Homeowners may not link the term “ENERGY STAR lighting” with CFLs. Of the seventeen homeowners who rated their lighting as ‘ENERGY STAR’, sixteen (94%) were found to have at least one CFL installed. Of the 87 homes that did not rate their lighting as ‘ENERGY STAR’, 85% of homes were found to have at least one CFL installed.

Overall, these results suggest that homeowners can generally identify the relative efficiency level of their entire home, their heating systems, and wall insulation. However, their reporting of efficiency regarding ceiling insulation, windows, and water heaters does not yield useful information. In addition, they have a widespread lack of awareness of the energy efficiency of their appliances, and a very strong tendency to over-estimate the presence of high-efficiency models. While this research was conducted in Vermont, there is no apparent reason why these results should be unique to that state. One might expect that similar limitations on this type of data would be likely elsewhere, but it would be desirable to see research findings from other regions.

These results provide insight into the accuracy of homeowners’ perception of the efficiency of key features of their homes. With a clearer understanding of homeowner-reported information, program designers and evaluators can better identify which information may or may not be reliably collected via telephone surveys. In addition, program designers can better understand which measures homeowners tend to overestimate the efficiency of, thereby yielding insight into the targeting of specific measures that may provide greater energy savings than portrayed by the homeowner.

References

Nexus Market Research (NMR), RLW Analytics (RLW), Dorothy Conant. 2009. Overall Report for Existing Homes in Vermont – Final. Vermont Department of Public Service. June 8.