Valuing Green Home Designs: A Study of ENERGY STAR® Homes

Authors Bryan Bloom, MaryEllen C. Nobe, and Michael D. Nobe

Abstract A number of researchers have attempted to isolate the incremental effect of energy efficiency on home value; however, few studies have benefited from the availability of a comprehensive and continuous indicator of home energy efficiency such as the ENERGY STAR® program. This case study builds on past research by comparing original sale prices between ENERGY STAR qualified homes and non-ENERGY STAR qualified homes in Fort Collins, Colorado. Sale prices were analyzed using hedonic regression analysis. Results indicate that ENERGY STAR homes originally sold for $8.66 more per square foot than non-ENERGY STAR homes.

Homebuyers in the United States play a significant role in reducing fuel consumption and the resulting carbon emissions. ‘‘The housing sector provides a number of opportunities to address two urgent national goals—reducing greenhouse gases and U.S. foreign oil dependence,’’ (Fernald, 2009). Total energy consumption, including both primary energy and renewable energy, in the U.S. residential sector has averaged 18.093 quadrillion Btu between 1980 and 2005 according to the U.S. Energy Information Administration (EIA, 2010). Residential energy consumption was 15.759 quadrillion Btu in 1980; by 2005, it had increased 37% to 21.659 quadrillion Btu (EIA, 2010). In comparison, the commercial sector averaged 14.105 quadrillion Btu and the transportation sector averaged 23.249 quadrillion Btu per year between 1980 and 2005 (EIA, 2010). In 2005, the majority of residential energy consumption was for space and water heating (Elliot, Langer, and Nadel, 2006).

Beyond the impact of residential energy consumption on total U.S. energy consumption, the level of energy efficiency designed into a home also has a direct bearing on homeownership costs. According to the Consumer Expenditure Survey, 34% of homeowners’ average annual expenditures were on housing in 2009 (Bureau of Labor Statistics, 2010). Of the amount spent by homeowners on their housing, 21.5% went to pay for utilities. In comparison, 13% of household annual expenditures were on food and 16% were for transportation costs in 2009. Since housing expenditures comprise such a significant portion of the average household budget, any reduction in operating and maintaining of homes will have direct benefits to homeowners in terms of reducing the overall cost of housing. By choosing to place more value on unseen amenities such as added insulation, infiltration reduction, duct sealing, or high efficiency furnaces versus other more visible amenities (i.e., marble flooring and granite counters), homeowners can realize significant reductions in utility requirements necessary to heat and cool their homes (NAPEE, 2011). For example, homes designed and built to ENERGY STAR® standards are at least 15% more energy efficient than homes built to the 2004 International Residential Code, while many are 20%–30% more efficient than standard homes (‘‘Features and Benefits’’, n.d.; NAPEE, 2008). The result is both reduced homeownership costs and reductions in U.S. residential energy consumption and carbon emissions (Elliott, Langer, and Nadel, 2006; Fernald, 2009).

Although it is evident that energy-efficient homes can play a significant role in reducing U.S. energy consumption, greenhouse gas emissions, and home ownership expenses, widespread adoption and incorporation of energy-efficient designs and construction practices have been slow. Currently, energy-efficient homes only account for 21% of U.S. new home construction (2009 ENERGY STAR Qualified New Homes, 2010). Researchers have identified numerous reasons for this lack of implementation, including transaction costs, lack of information, uncertainty of energy savings, split incentives, and initial capital investment (Elliott, Langer, and Nadel, 2006; Fuller, 2009). Significant to this study are homebuilders’ perceptions that initial capital investments for increased energy efficiency will not be recaptured through energy savings or capitalization of these investments when the home is sold (Galuppo and Tu, 2010). As long as these perceptions persist among homebuilders, they will remain reluctant to invest in these systems and the residential market will continue to be a significant contributor to U.S. greenhouse gas emissions (Lande, 2008). Ultimately, the value consumers place on energy-efficient residential design either encourages or hinders further incorporation of energy-efficient features into homes (Galuppo and Tu, 2010).

Compounding this issue is the relatively short periods for which U.S. homeowners own their homes. On average, U.S. homeowners tend to sell their home every eight years (Dacquisto, Emrath, Laquatra, and Laitner, 2001; Lande, 2008). Generally, for homeowners to justify additional design and construction costs related to increasing energy efficiency from an economic stand point, they must believe that they will recoup the added capital investments either through (1) reduced utility bills during the time they own their home, (2) an increased sales price, or (3) some combination thereof (Lande, 2008). Because payback periods for many energy efficient upgrades can easily exceed the duration homeowners typically own their homes, and little evidence exists to give them confidence that these costs will be capitalized into the sales price, many homeowners rationally conclude that added construction costs for increased energy efficiency are not economically justifiable.

Ultimately, homebuyers play a significant role in determining what role the residential sector will play in addressing U.S. energy consumption, greenhouse gas emissions, dependence on foreign oil, and home ownership costs. Through their purchasing behaviors, homebuyers either support or hinder progress within the residential sector in meeting the aforementioned objectives. If homebuyers are not willing to realize the capitalization of increased energy efficiency in the purchase of a home, builders will remain reluctant to include energy-efficient design and strategies in their projects. For energy-efficient building practices to become more prevalent, it must be established that homebuyers are willing to pay more for energy-efficient homes, which is consistent with basic economic theory (Laquatra, Dacquisto, Emrath, and Laitner, 2002; Lande, 2008).

Incorporation of energy-efficient designs and construction techniques offer have the potential to offer immediate cash-flow benefits on monthly or yearly returns. As a result, buyers should be willing to pay more for homes with lower utility bills in anticipation of savings on future costs of operation, and consequently, sellers should attempt to charge more for homes with energy efficient features Laquatra, Dacquisto, Emrath, and Laitner, 2002). Mandell and Wilhelmsson (2011) found that homeowners are willing to pay for increased energy efficiency. Other studies, however, that have sought to provide empirical evidence that homebuyers are in fact paying more for energy-efficient homes have suffered from the challenges inherent in quantifying energy efficiency in a manner that is recognized in the marketplace (Dacquisto, Emrath, Laquatra, and Laitner, 2001). Homes are complex commodities; finding historical and observable data to support the hypothesis that energy efficiency positively impacts housing values is difficult, especially when numerous other aesthetically-pleasing features exist that presumably take precedence over utility bills. Previous research studies attempting to capture and report the incremental value of energy efficiency have not had the benefit of utilizing a comprehensive measure of home energy efficiency. Not until recently has an assessment tool existed that allows researchers to easily identify which homes are more energy efficient. When the Environmental Protection Agency (EPA) extended its ENERGY STAR rating to homes, it created an easily identifiable metric of residential energy efficiency based on a Home Energy Rating System (HERS) index. The purpose of this study is to extend previous research to approach a more accurate answer to the question of whether or not and to what extent housing markets capitalize the value of energy efficiency using ENERGY STAR labeling.

The research question guiding this study is: Do homes constructed with more energy-efficient building systems, as qualified by the ENERGY STAR labeling program, have higher market values than non-ENERGY STAR qualified homes? If so, how much more are they worth?

Based on this question, the following hypothesis was developed:

H_1: ENERGY STAR rated homes will have higher sales prices than comparable non-ENERGY STAR rated homes in the study area.

Review of Literature

The literature review focuses on prior studies of capitalization of energy efficiency within the residential markets. Although this topic has received considerable attention in the commercial real estate sector (both in the U.S. and internationally), there has been considerably less research relevant to this study conducted in the residential section. In 2001, the EPA sponsored a comprehensive analysis of published research literature titled *The Value of Energy Efficiency in Housing:*

Review and Analysis of the Literature (Dacquisto, Emrath, Laquatra, and Laitner, 2001). The report presents a review of published research on the capitalization of energy efficiency in housing over a 20-year history. Their report focused primarily on using past applications of hedonic regression analysis and, to a lesser extent, willingness-to-pay surveys to determine if energy efficiency is reflected in home values.

Sopranzetti (2010) explains hedonic regression as an analytical process that allows for the deconstruction of home prices into their component parts to determine how individual components contribute to the overall value. Similarly, Meese and Wallace (1997) define hedonic regression as a way of estimating the value of a complex commodity with a bundle of attributes, such as a house, by modeling the price of that commodity as a function of the particular set of attributes it possesses. Each attribute is valued independently and contributes its individual value to the overall value of the commodity, making it easier to observe the market value of each attribute by itself. For example, appraisers can use hedonic regression to determine the value of house attributes such as structural characteristics (e.g., square footage, number of rooms, number of bathrooms, and known defects), neighborhood characteristics (e.g., quality of the school system and/or neighborhood), or location within a given market (Sopranzetti, 2010). Energy efficiency, the attribute of most interest to this study, can also be identified and included as an analysis component in hedonic regression to determine its contribution to overall home value.

Hedonic Regression Studies

The literature on hedonic house price models reviewed for this study dates back two and a half decades and includes many different methodologies. A summary of studies reviewed is provided in Appendix A. The collective results of these studies (Exhibit 1) indicate varying levels of capitalization of energy efficiency when homes are sold (Nevin and Watson, 1998; Dacquisto, Emrath, Laquatra, and Laitner, 2001); yet, the body of research as a whole suffers from challenges associated with identifying levels of residential energy efficiency. This shortcoming hinders integration of these findings into property appraisals; as a result, homebuilders are reluctant to trust that additional cost for increased energy efficiency design/construction will be capitalized in the future.

Some consistency is evident in the studies among the attributes identified for inclusion in the hedonic regression analysis (see Appendix A for a summary table), although considerable variations are also apparent and worthy of review. While all studies reviewed attempted to control for the various factors contributing to home value, all did so to a different degree. Furthermore, the studies reviewed included a wide range of sample sizes and variables in an effort to best identify the incremental market value of energy efficiency (Laquatra, 2002). An overview of the methodologies utilized in the studies is provided in Appendix B. In total, eight studies were reviewed. All but one were limited to small geographic markets and short periods of time. Sample sizes for these studies ranged from 67 to more than 15,000; the majority of studies had sample sizes between 81 and 505.

Exhibit 1 | Key Results From Hedonic Studies

Reference	Key Findings	R^2
Halvorsen (1981)	The 1974 spike in relative cost of fuel oil raised price differential between gas- and oil-heated houses to $761 in 1974, and up to $4,597 in the first half of 1975.	0.75
Corgel (1982)	Value of energy-efficient homes (with lower structural heat loss) was $3,248 higher than inefficient homes.	0.73
Johnson (1983)	Home value increased by about $20.73 for every $1 in annual fuel bills.	0.80
Longstreth (1986)	A one inch increase in wall insulation increased home value by $1.90 per square foot; a one inch increase in ceiling insulation increased home value by $3.37 per square foot; high quality (energy efficient) windows increased home value by $1.63 per square foot.	0.43
Laquatra (1989)	Home value increased by $2,510 for each one-point decrease in thermal integrity factor.	0.67
Dinan (1989)	Home value increased by $11.63 per $1 decrease in fuel expenditures needed to maintain a home at 65 degrees F in average heating season.	n/a
Horowitz (1990)	Home value increased by about $12.52 per $1 decrease in electric bills, consistent with home buyers discounting savings at after-tax mortgage interest rate.	0.86
Nevin (1998)	Home value increased by about $20 for every $1 reduction in annual fuel bills.	0.41

Note: The sources are Nevin and Watson (1996) and Dacquisto, Emrath, Laquatra, and Laitner (2001).

Additionally, some of the samples looked strictly at new or nearly-new homes, some looked only at resale values, and others looked at all sales data within a given marketplace (Dacquisto, Emrath, Laquatra, and Laitner, 2001). Following is an overview of the variables used in each study reviewed.

Structural Variables. Structural variables account for the physical characteristics that contribute to home value (Sopranzetti, 2010). All of the studies reviewed included square footage as a structural variable while also controlling for property age to some degree. Additional structural variables most often included in the models were number of bathrooms, lot size, fireplaces, and garages. Only two of the eight studies reviewed account for all of the aforementioned variables. In some cases, the absence of certain variables may be the result of data limitations. Nevertheless, these variables have been found to have significant effects in the other regression analyses; failure to include these variables would compromise internal validity.

Neighborhood and Locational Variables. Neighborhood and locational variables represent the locational quality of a property within a community (Sopranzetti, 2010). The handling of neighborhood and locational variables differed significantly across the reviewed studies. These factors are not binary variables; they are not *have* or *have-not* items. As a result, it is not easy to quantify them on a numerical scale, unlike *size* and *age*, making it difficult to measure the impact of their exclusion or mistreatment in a regression study. All but two of the reviewed studies included some degree of locational effects. For example, one study used distance to the central business district, while another used distance to the nearest interstate ramp. In smaller sample sizes with relatively few subdivisions, it may be easier to control for locational effects and more simplified criteria may suffice.

Energy Efficiency Variables. Energy efficiency variables represent different measures of energy conservation resulting from home design/construction. In the studies reviewed, significant differences existed on the approach used to identify energy efficiency. Some treated energy efficiency as a binary variable while others used utility bills as proxies for energy efficiency. For example, in one study energy efficiency was based solely on the type of fuel (natural gas or oil) that was used to heat the house. Another study based energy efficiency on roof temperatures as measured using infrared aerial photographs. All of these studies ignored other contributing factors to home energy efficiency, which is reflective of the difficulty inherent in identifying a single measure of energy efficiency. Because energy efficiency is clearly not a simple either-or phenomenon, it will be difficult to generalize results from studies employing this sort of methodology.

Other studies reviewed by Dacquisto, Emrath, Laquatra, and Laitner (2001) identify energy efficiency as the sum of four attributes: inches of wall insulation, inches of ceiling insulation, presence of storm windows and/or thermopane glass, and presence of wood/vinyl window frames. In these studies, separate coefficients are assigned to represent the implicit price of each of these features. A major limitation of this approach is that information on specific physical features contributing some level of energy efficiency may not be available in many data sets.

One particularly relevant study reviewed by Dacquisto, Emrath, Laquatra, and Laitner (2001) is the Laquatra (1986) study (Appendix B). Laquatra constructed a continuous variable called the ‘‘Thermal Integrity Factor’’ (TIF) to represent varying levels of energy efficiency. TIF assesses the annual heating load as measured in Btu per square foot of heated floor space per heating degree day, although it does not adjust for equipment efficiency, duct and distribution system losses, differences in fuel type, and energy usage for water heating, cooling, and other purposes. All of these deficiencies could result in differences in utility bills for houses with the same TIF and floor area (Dacquisto, Emrath, Laquatra, and Laitner, 2001). Application of this approach is also limited by the ability to obtain the data needed to calculate the TIF variable.

Based on the review of these studies, a minimal level of consistency can be identified with respect to which structural, neighborhood, and locational variables should be included in hedonic regression analysis of home values. Prior measures of energy efficiency, however, vary considerably. It is clear from the studies reviewed that identifying a usable measure of energy efficiency has been problematic. As a result, replication and application of study results have been limited, as evidenced by a general lack of application within the appraisal industry.

The measures of efficiency utilized in these studies were based on information that is simply not easily accessible to appraisers.

Improving Methodology

Despite the limitations of research investigating how housing markets capitalize the value of home energy improvements, it still remains consistent with economic theory that such a phenomenon occurs to some degree. Improved methodologies are needed to enable more reliable and implicit conclusions; hedonic regression models seem to be the most effective way of achieving these conclusions (Dacquisto, Emrath, Laquatra, and Laitner, 2001; Sopranzetti, 2010). While each regression study possesses its own set of weaknesses, the ones reviewed here do take significant steps toward employing a reliable analysis. Taken together, all of the models provide a seemingly comprehensive list of explanatory variables that should encourage future studies to include as many of them as possible. The challenge remaining is to incorporate better identifiers of energy efficiency that are also accessible to appraisers.

Since these studies were conducted, better measurements of energy efficiency have become available, such as ENERGY STAR labeling for homes, LEED for Homes, and the National Green Building Standard. Third-party ratings of homes as either green or energy efficient provides a paper trail for appraisers to incorporate into appraisals. This paper trail provides the documentation necessary to support the analysis of a high performance home and measurements of contributory value (Admoatis, 2010).

Green Home Assessment Tools

The green building industry has grown substantially in the last few decades. At the same time, several green home assessment tools have entered the residential market, providing consistent assessments of varying levels of energy efficiency and essentially creating a branding for energy-efficient homes that is readily identifiable. Current assessment tools for the residential market include the Environmental Protection Agency's (EPA) ENERGY STAR rating, the U.S. Green Building Council's LEED for Homes, and the National Association of Home Builders' National Green Building Standard. Each of these assessment tools sets forth various criteria to ensure that the homes certified met a minimum level of increased energy efficiency compared with more common building designs and construction practices. While each assessment tool has its strengths and weaknesses, it is not the purpose of this paper to provide an in-depth review of these assessment tools and the comparable levels of energy efficiency between assessments. Rather, the purpose is to access the impact of energy efficiency branding on the ability to isolate increases in home value as a result of increased energy efficiency. Since consumers are likely to be more familiar with the ENERGY STAR rating system, which has been in existence longer than the other two rating systems, this system was chosen for use in this study.

ENERGY STAR. In an attempt to reduce the emission of greenhouse gases, the EPA introduced the ENERGY STAR program in 1992. The purpose of this voluntary program was to identify and promote energy-efficient products designed to reduce greenhouse gas emissions. The ENERGY STAR label was initially listed only on items such as major appliances, office equipment, lighting, and home electronics. It has since expanded to include the construction of new homes, taking on a whole-house approach to measure energy efficiency. To qualify as ENERGY STAR labeled, a home must (a) meet the appropriate Home Energy Rating System (HERS) Index, (b) be verified and field-tested in accordance with the Residential Energy Services Network (RESNET) Standards by a RESNET-accredited provider, and (c) meet all applicable codes (''The Performance Path,'' n.d.).

Methodology

A sample of 300 homes in Fort Collins, Colorado were selected to test the research question and related hypothesis guiding this study. The sample consisted of 150 ENERGY STAR qualified homes and 150 non-ENERGY STAR qualified homes. While this sample selection limits the application of the results to a broader population, it is within the range of sample size commonly utilized for similar studies. Sample homes were identified using energy rating data available through E-Star Colorado and the county assessor's records. For each ENERGY STAR home included in the data set, a comparable home in the surrounding area was identified. To control for the considerable effect of location on home price, comparable homes were identified as close to the ENERGY STAR homes as possible based on address information. Generally comparable homes were at most 2–3 miles from the ENERGY STAR homes. It should be noted that although Fort Collins is a college town, all of the homes included in the study were in newer subdivisions that were located away from the campus community. Further, the study is delimited to single-family detached homes constructed during or after 1999 since newer homes have presumably higher levels of energy efficiency. Delimiting the study to nearly new homes also avoids the challenges of evaluating efficiency across homes of vastly different ages (Adomatis, 2010). Sales for all homes occurred between 1999 and 2005. When selecting comparable properties, it was also important to ensure that these properties were not infarct ENERGY STAR homes. To control for this, the builder name listed in the county assessor's records was cross-checked with the list of participating ENERGY STAR builders as listed on the ENERGY STAR website.

Data and Analysis

Consistent with related literature on hedonic regression, the regression used in this study contains several independent variables (Exhibit 2). Original sale price per square foot is the dependent variable. The expected relationship between each independent variable and the dependent variable is indicated under the heading *Expected Relationship* (Exhibit 2). All of the model variables, with the exception of *BaseFin*, *Quality*, *CovProch*, and *ENERGYSTAR*, are scale variables. Variables appearing with a subscript ''d'' are considered dummy variables. These variables were measured in binary terms, whether or not a feature is present. For dummy variables, a value of 1 was given if the feature was present and 0 if the feature

Exhibit 2 | Independent Variables and Expected Sign of Coefficient

Variable	Description	Expected Relationship
Age	Age of home in years	−
TotalSF	Total finished square feet of home	+
LotSF	Size of lot in square feet	+
BaseSF	Total basement square feet	+
$BaseFin_{(d)}$	Whether or not home has finished basement	+
Stories	Number of stories	+/−
Bedrooms	Number of bedrooms	+
Bathrooms	Number of bathrooms	+
$Quality_{(d)}$	Superior quality of construction	+
$CovPorch_{(d)}$	Whether or not home has covered porch	+
GarageSF	Total garage square feet	+
$ENERGYSTAR_{(d)}$	Whether or not home is ENERGY STAR® qualified	+

Note: A subscript *d* represents a dummy variable.

Exhibit 3 | Regression Coefficients and *P*-Values

Variable	Coeff.	*p*-Value
Age	−3.981***	<.001
LotSF	0.002***	.001
TotalSF	−0.038***	<.001
BaseSF	0.018***	<.001
$BaseFin_{(d)}$	0.395	.912
Stories	−6.594	.069
Bedrooms	−0.065	.969
Bathrooms	4.765	.057
Quality	5.830**	.013
$CovPorch_{(d)}$	−3.141	.362
GarageSF	0.043***	<.001
$ENERGYSTAR_{(d)}$	8.664**	.005
R^2	73.5%	

Notes: A subscript *d* represents a dummy variable.
*$p < .05$
**$p < .01$
***$p < .001$

was absent. The variable *Quality* is based on the quality indicator included in the county assessor's records.

Independent variables with a positive *Expected Relationship* are expected to increase house value as buyers are expected to pay more for houses with these amenities. *Age*, the only variable with a negative coefficient, is expected to have a negative effect on house value as buyers are expected to pay less for older homes (Exhibit 3). *Number of stories* does not have a predictable coefficient as the decision to buy a ranch or two-story house is presumably a decision of preference, not superiority. The *quality* variable is a seemingly subjective judgment of home construction, yet it is expected to be a strong indicator of home value. Quality ratings were provided within the county assessor's data. Homes could be rated as poor, average, or good. All of the homes in the data set were rated as being either of average or good quality.

Results

The result of the regression analysis for the independent variables identified in Exhibit 2 and the dependent variable *sales price* was statistically significant at $p < .01$. The R^2 value was .735, indicating that 74% of the market valuation variation could be explained by the model. The effect size for the model was large ($r = .857$) and it had good internal reliability as evidenced by a Cronbach's alpha of .317. The absolute coefficient (β) values for the independent variables included in the model ranged from a low of 0.018 to a high of 8.664. Independent variables with beta approaching zero essentially have minimal effect on the *sales price*, while variables with larger beta have a greater impact on *sales price*.

Almost all of the non-energy coefficients have the expected signs with the exception of *TotalSF* and *Bedrooms*; the latter of which is not statistically significant ($p = .969$). The coefficient of the *ENERGYSTAR* variable was statistically significant at $p < .01$. The beta of the *ENERGY STAR* variable is 8.664, higher than any other predictor variable.

TotalSF, one variable that would seem to be a strong predictor of home value, had a surprisingly negative coefficient, as well as a significant *p*-value. This may be because *TotalSF* is strongly correlated with other variables (e.g., *LotSF* and *Quality*) and that there might be a diminishing point of return for additional square footage (Nevin and Watson, 1998). Another possible reason for this result is that homebuyers that are more aware of the environmental impact of buildings may place more value on a smaller home that uses less materials and is more energy efficient. *Bedrooms* did not have a significant effect on sale price, even though this is typically a significant factor in residential pricing. Again, this may be due to inefficiency in recognizing collinearity. Future studies might benefit from considering and testing for collinearity and providing an approach to account for such correlation.

Two important limitations of these results were the exclusion of a location variable and the use of only ENERGY STAR rated homes. The model used in this study did not address locational effects on home price. The data set used did not include quantifiable information on the market effect of locational variation. Instead, the researchers controlled for locational impacts by identifying comparables homes based proximity to ENERGY STAR certified homes. Had a locational variable been included in the data set, it is expected that the beta for *ENERGYSTAR* would be lessened but would not change from a positive to a negative relationship. Additionally, it would be expected that a significant amount of collinearity would exist between a locational variable and the *ENERGYSTAR* variable (and possibility *AGE*) since all of the homes were located in fairly new neighborhoods. It is recommended that future studies include a locational variable.

Further, employing the ENERGY STAR label and accompanying home energy rating as the determinant and measure of home energy efficiency does not take into account that homes without the ENERGY STAR label may have an equal or greater degree of energy efficiency. The purpose of focusing on ENERGY STAR homes was simplify the identification of energy efficient homes as this was identified as a significant challenge in previous studies. Additionally, identification of energy-efficient homes without third-party certification by either homebuyers or appraisers would require thorough understanding of design and construction strategies by homebuyers (or appraisers) as homes may be marketed as energy efficient when in fact they are not (Adomatis, 2010). Therefore, this study focused only on ENERGY STAR labeled homes. The purpose of this study, however, was to test the impact of third-party certification of home energy efficiency on market prices paid by consumers. In the area where this study was conducted, the results provide further support for added contributory value in the assessment of a certified energy-efficient home.

Conclusion

Although significant awareness exists on the impact of energy consumption by the U.S. residential sector, adoption of energy-efficient residential designs has been slow. Of most concern to homebuilders is the perception that the added costs related to increased energy-efficient design and construction will not be recognized when the home is sold (Galuppo and Tu, 2010). This concern has persisted even though prior studies have provided empirical evidence of consumers who recognize the contributory value of increased energy efficiency. These past studies, however, used measures of energy efficiency that were not easily replicable or recognizable by homebuyers, appraisers, or homebuilders. In recent years, several third-party certifications have become available that can be used to address this shortcoming of prior studies. Third-party certification can be used to document the incorporation of design and construction techniques (Adomatis, 2010). One well-established certification is the EPA’s ENERGY STAR labeling for homes. By incorporating ENERGY STAR certification into a hedonic regression analysis of sales prices for homes in Fort Collins, Colorado, this study provides a much needed update on homebuyers’ willingness to pay for increased energy efficiency.

The model tested in this study and which incorporated ENERGY STAR certification had an R^2 of 74%, consistent with the range of R^2 values for similar models (see Exhibit 1), which ranged from a low of 0.41 to a high of 0.86. These results support the hypothesis that ENERGY STAR rated homes will have higher sales prices than comparable non-ENERGY STAR homes in the study area. Results indicate that ENERGY STAR homes originally sold for $8.66 more per square foot than non-ENERGY STAR homes in the study area.

This study provides additional empirical evidence that homebuyers recognize the contributory value of increased energy efficiency. There is also evidence that the use of a third-party certification such as the ENERGY STAR rating system is valued by residential consumers. As similar assessment tools of residential energy efficiency (e.g., USGBC's LEED for Homes or the NAHB's National Green Building Standard) become more prevalent, similar cost premiums will be found for those homes as well. Further analysis, however will be needed to verify these predictions across other residential energy assessment tools. As additional studies are conducted, their combined results should strengthen the market for energy-efficient homes that are third-party certified. This, in turn should result in an increased percentage of new homes that are designed and constructed to be more energy efficient and an overall reduction in the energy consumption of the U.S. residential sector.

Appendix A

Review of Hedonic Studies

Study	Market Area, Time Period, and Types of Homes Included	Sample Size	Age of Homes in Sample
Halvorsen, R. and H.O. Pollakowski. The Effects of Fuel Prices on House Prices. *Urban Studies*, 1981, 18, 2, 205–11.	Oil and gas heated homes in Greenwood neighborhood in Seattle, Washington sold from 1970 to 1975.	269	Mean age not given
Corgel, J.B., P.R. Goebel, and C.E. Wade. Measuring Energy Efficiency for Selection and Adjustment of Comparable Sales. *The Appraisal Journal*, 1982, January, 71–8.	Single-family homes in Lubbock, Texas sold from 1978 to 1979.	100	Mean age not given
Johnson, R.C. and D.L. Kaserman. Housing Market Capitalization of Energy-saving Durable Good Investments. *Economic Inquiry*, 1983, 21, 374–86.	Electricity or natural gas-heated, single-family detached homes in Knox County, Tennessee sold in 1978.	1,317	Mean = 14 years Standard Deviation = 13 years
Longstreth, M. (1986). Impact of Consumers' Personal Characteristics on Hedonic Prices of Energy-conserving Durables. *Energy,* 1986, 11:9, 893–905.	Gas-heated, single-family detached homes in Columbus, Ohio SMSA sold from 1971 to 1978.	505	Mean = 22 years Std. Dev. = 15 years
Laquatra, J. Housing Market Capitalization of Thermal Integrity. *Energy Economics*, 1986, 8, 3, 134–38.	Newly built "Energy Efficient Housing Demonstration Program" homes in Minneapolis, Minnesota from 1980 to 1981.	81	New homes only

Appendix A (continued)

Review of Hedonic Studies

Study	Market Area, Time Period, and Types of Homes Included	Sample Size	Age of Homes in Sample
Dinan, T.M. and J.A. Miranowski. Estimating the Implicit Price of Energy Efficiency Improvements in the Residential Housing Market: A Hedonic Approach. *Journal of Urban Economics*, 1989, 25, 52–67.	Single-family detached homes in Des Moines, Iowa sold from January 1982 to June 1982.	234	Mean = 30 years Std. Dev. = 22 years
Horowitz, M.J. and H. Haeri. Economic Efficiency v. Energy Efficiency—Do Model Conservation Standards Make Good Sense? *Energy Economics*, 1990, 122–31.	42 nearly-new, electrically-heated homes in Tacoma City Light service district in Seattle, Washington built to the Model Conservation Standards (MCS) resold from 1983–1985, and 25 nearly new, electrically-heated control homes in the same area resold from 1983 to 1985.	67 (45 MCS and 25 control)	Nearly new homes
Nevin, R. and G. Watson. Evidence of Rational Market Values for Home Energy Efficiency. *The Appraisal Journal*, 1998, 401–09.	Electrically, piped gas or fuel oil-heated, single-family homes in American Housing Survey (AHS) national data from 1991, 1993, and 1995, and AHS metropolitan data from 1992 to 1996.	15,000+	Mean age not given

Note: The source is Dacquisto, Emrath, Laquatra, and Laitner (2001).

Appendix B

Variables Used in Hedonic Studies

Reference	Halvorsen & Pollakowski (1981)	Corgel, Goebel, & Wade (1982)	Johnson & Kaserman (1983)	Longstreth (1986)	Laquatra (1986)	Dinan & Miranowski (1989)	Horowitz & Haeri (1990)	Nevin & Watson (1998)
Dependent Variable	*Sale Price*	*Sale Price*	*Sale Price*	*Sale Price/Sf*	*Sale Price*	*Sale Price*	*Sale Price*	Occupant-Estimated Market Value
Independent Variables	—	*Area* (sf) *Age* (yrs) *# of bathrooms* *2-car garage* (D) *Central air conditioning* (D) *Date* (month of sale = 100–112) *Fireplace* (D) *Brick veneer* (D) *Cedar roof* (D) *Infra* (D)	*Util* ($/yr, ending) *Size* (sf) *Age* (yrs) *# of bathrooms* *Ranch* (D) *Split foyer* (D) *2-Story* (D) *Brick* (D) *Carport* (D) *Garage–1car* (D) *Garage–2car+* (D) *Patio* (D) *Deck* (D) *Paved drive* (D) *Fireplace* (D) *Unit air* (D) *Central air* (D) *A index* (D) *Census increase from 78% black within census tract* *Population density* *City lot* (sf)	*House size* (sf) *# of bathrooms* *# of stories* *House age* (yrs) *Distance to central business district* *Pupils per teacher* *Sale year* *Ceiling insulation* *Wall insulation* *Wood or vinyl window frames*	*Area* (sf) *Lot size* (sf) *Duplex* (D) *Attached* (D) *Thermal integrity factor* *Median house value for census tract* *Per pupil expenditure* *Mean commute for census tract* *Distance to interstate ramp*	*Floor area* (sf) *# of bedrooms* *# of bathrooms* *Family room* (D) *Dining room* *Lot* (100 sf) *Dishwasher* (D) *Central air conditioning* (D) *Window air conditioning* (D) *Garage–1 car* *Garage–2 car* *Garage* (D) *Fireplace* (D) *Age* (yrs) *Census income* *Basement* (D) *Miles from central business district*	*Floor area* (sf) *Heat pump* (D) *# of bathrooms* *Fireplace* (D) *Wood/tile roof* (D) *Note: A second regression with different sample used to estimate electricity use:* *Model Conservation Standards* (D) *Floor area* (sf) *Household size* *Household income* *Wood stove* (D) *Electric blanket or bed heaters* (D) *Central thermostat* (D) *Dishwasher* (D) *Electric dryer* (D) *# TVs/computers* *Electric water for tub/sauna* (D)	*Unit* (sf) *Lot size* (sf) *Age* (years) *# of rooms* *Total utilities* (all fuels) *Lot size* *Unit size times total utility* *# of rooms times total utility* *Garage* (D) *Porch* (D) *Central air conditioning* (D) *South* (D) *West* (D) *Midwest* (D) *Urban* (D) *Rural* (D)

Appendix B (continued)

Variables Used in Hedonic Studies

Reference	Halvorsen & Pollakowski (1981)	Corgel, Goebel, & Wade (1982)	Johnson & Kaserman (1983)	Longstreth (1986)	Laquatra (1986)	Dinan & Miranowski (1989)	Horowitz & Haeri (1990)	Nevin & Watson (1998)
Dependent Variable	*Sale Price*	*Sale Price*	*Sale Price*	*Sale Price / Sf*	*Sale Price*	*Sale Price*	*Sale Price*	Occupant-Estimated Market Value
Method of Measuring Energy Efficiency	Fuel type used to heat home (natural gas or oil)	Existence of either a cold roof (energy efficient) or a warm roof (not energy efficient)	Utility bills	Inches of insulation, presence of storm windows and / or thermopane glass, presence of wood / vinyl window frames	Thermal Integrity Factor = annual heating load for the house, measured in Btu / sf of heated floorspace / heating degree day	Utility bills / sf	Construction to meet Model Conservation Standards	Utility bills

Notes: The source is Dacquisto, Emrath, Laquatra, and Laitner (2001).
sf = square feet
yrs = years
D = Dummy, or indicator variable

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Bryan Bloom, Colorado State University, Fort Collins, CO 80523.

MaryEllen C. Nobe, Colorado State University, Fort Collins, CO 80523 or Mary.Nobe@colostate.edu.

Michael D. Nobe, Colorado State University, Fort Collins, CO 80523.