Title

How Does Home Energy Score Affect Home Value and Mortgage Performance?

Authors

Pigman, Margaret

Deason, Jeff

Wallace, Nancy

et al.

Publication Date

2023-12-14

Electricity Markets & Policy
Energy Analysis & Environmental Impacts Division
Lawrence Berkeley National Laboratory

How Does Home Energy Score Affect Home Value and Mortgage Performance?

Margaret Pigman, Jeff Deason, Lawrence Berkeley National Laboratory
Nancy Wallace, Paulo Issler, Fisher Center for Real Estate & Urban Economics, UC Berkeley

August 2022

2022 ACEEE Summer Study on Energy Efficiency in Buildings proceedings printed with permission.

The U.S. Department of Energy's Building Technologies Office supported this work under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

How Does Home Energy Score Affect Home Value and Mortgage Performance?

Margaret Pigman, Jeff Deason, Lawrence Berkeley National Laboratory
Nancy Wallace, Paulo Issler, Fisher Center for Real Estate & Urban Economics, UC Berkeley

ABSTRACT

Energy-efficient homes save their occupants money through lower energy bills. These savings might be capitalized into higher home sale prices. They also improve the household's net cash flow, which might make households better able to pay mortgage debt. The U.S. Department of Energy (DOE)'s Home Energy Score (HES) assigns a 1-10 score to homes and estimates annual energy bills based on modeled energy consumption. In this paper we investigated the relationship between HES metrics and two housing market outcomes: home sale price and mortgage performance. We found that the relationship was only statistically significant in places with a mandatory HES assessment at the time of sale. Using a sample of 26,291 home sales that occurred after HES assessments, we found that a one-point increase in HES in these locations was associated with a 0.5% increase in sale price, and an increase in $100 of estimated annual energy bills was associated with a 0.4% decrease. This magnitude of effect is consistent with estimated magnitudes of home sale premiums for other green or energy-efficient home certifications in the literature. We also found that a one-point increase in HES was associated with a 5.5% reduction in the odds of a loan going 30 days delinquent if the loan originated after the assessment occurred. Similarly, we found that a $100 decrease in estimated annual energy bills was associated with a 2.3% decrease in the odds of a loan going delinquent if it originated after the assessment occurred. Our results suggest that HES provides a valuable signal for housing market transactions in specific situations.

Introduction

Energy efficiency is sometimes touted as a sound investment offering increased home values and lower energy bills to households that could improve mortgage performance. We investigated these assertions through a large-scale, national study, leveraging data on home sales and mortgage performance of homes rated by the U.S. Department of Energy (DOE)'s Home Energy Score (HES).

Our work builds upon studies investigating similar questions for HES and other home energy ratings or certifications, but is the first to analyze the full HES database. We considered the relationship between HES and two outcomes: home sale prices and mortgage delinquency. We studied the effect of two metrics that are produced during a HES assessment: the score itself and estimated annual energy bills. In the case of home value, the buyers and sellers see both metrics, and either or both could impact the purchase price. However, the HES is generally displayed more prominently than the estimated energy bills. For mortgage performance, there are two main reasons why loans on homes with lower energy consumption might be less likely to go delinquent. First, the home's energy bills may be lower than those of otherwise similar but less efficient homes, freeing up funds to make loan payments. Second, there might be a selection effect such that buyers of homes with higher HES or lower estimated bills are different from other buyers, for example being more likely to make consistent loan payments regardless of the home where they live. In the first case, we would expect estimated energy bills to have a clearer relationship with mortgage performance than HES. In the second case, either HES or estimated bills could have a clear relationship with mortgage performance but only for mortgages that originated after the assessment occurred. Because lenders can only take into account HES assessments that occur before mortgage origination, the performance of those loans is particularly important to understand.

What is Home Energy Score?

HES is a rating of a house's energy consumption developed by DOE as an analog for a miles-per-gallon rating for a car (DOE 2021). Homes are assigned a score of 1-10, with 1 indicating the most consumption and 10 the least. The scores are based on modeled source energy consumption for heating, cooling, and water heating after subtracting solar electricity generation.[1] The score calculation does not include energy consumed by appliances, plug loads, and lighting. Moreover, HES is an "asset rating" that does not consider occupant behavior. As such, HES does not capture all dimensions of household energy use and expenditures. However, the end uses the score captures represent 65% of U.S. residential energy consumption on average (EIA 2015). For more information on HES, see Glickman et al. (2014).

The simulated energy consumption for a house is placed into one of 10 bins corresponding to each of the 10 scores. The energy consumption cutoffs between these bins vary by the particular weather station used in the simulation of each house. For example, if two houses have the same modeled energy consumption, the one in a mild climate may have a lower score than the one in a very cold climate. The bin cutoffs for each score are designed to place approximately 10% of the housing stock in each bin based on data from the 2009 Residential Energy Consumption Survey (RECS). Because the cutoffs are determined by household energy consumption rather than consumption per square foot, larger homes will have lower scores all else equal.

In addition to the score, a HES report includes energy consumption by fuel, carbon footprint, and energy costs. Unlike the score itself, these metrics include an estimate of energy consumed by appliances, plug loads, and lighting. The carbon and cost calculations also incorporate local emissions factors and utility rates.

Households generally receive a HES assessment for one of two reasons. First, many households receive assessments when they participate in certain utility retrofit programs. Specific programs represent significant shares of scored homes. For example, about 33% of HES-rated homes in our dataset are in Connecticut, where Energize CT's Home Energy

[1] Solar generation was added to the calculation in 2017, so the scores of homes assessed prior to 2017 do not account for solar generation.

Solutions program requires a HES assessment. Second, a small but growing number of locations require a HES assessment and disclosure prior to or during a home sale. Berkeley, CA started requiring HES at the point of sale in 2015, and Portland, OR instituted this requirement in 2018. 20% of the HES-rated homes in our dataset are in Portland. Because of these location-specific programmatic and disclosure drivers, homes with HES are concentrated in certain geographic regions.

Literature Review

Home value. Several previous studies in the U.S. have found that homes with green ratings command a premium in the housing market. These studies vary in the geography they cover, the rating systems analyzed, and the methods used. Taken together, there is strong evidence that green ratings are associated with increased home value (Table 1). Of the rating systems mentioned, only ENERGY STAR® is strictly an energy certification; the others consider additional non-energy green features. Other studies outside of the U.S. (for example Brown and Watkins (2016) and Zancanella, Bertoldi, and Boza-Kiss (2018)) have also found a premium.

Table 1. Summary of home value literature in the U.S.

Rating system	Premium	Location	Source
ENERGY STAR	2.7% 0-2% 0-4.8% 2-5%	National Portland, OR; Austin, TX; NC triangle area Portland, OR; Western WA; Boise, ID Maryland	Argento, Bak, and Brown (2019) Walls et al. (2017) Watkins & Associates et al. 2015 Yuan and Cohen (2017)
Multiple	6% 2-5%	Austin, TX California	Hallman (2017) Kahn and Kok (2014)
Earth Advantage	4% 0%	Portland, OR Portland, OR	Walls et al. (2017) Watkins & Associates et al. 2015
Other local system	8-9% 4.5-4.8%	Austin, TX (Austin Green Building Program) Western WA (Built Green)	Watkins & Associates et al. 2015 Watkins & Associates et al. 2015

Mortgage performance. Two U.S. studies have looked at the association between Home Energy Rating System (HERS) rating and mortgage performance. HERS compares the modeled energy consumption of a home built to that of one built to the 2006 International Energy Conservation Code (IECC); a score of 100 indicates that the consumption is the same as a home built to code, and a score of 0 indicates a zero net energy home. HERS rating is a common method for determining ENERGY STAR qualification. Both studies found that better a HERS rating was associated with lower mortgage risk in at least some circumstances. Kaza, Quercia, and Tian (2014) studied the loans on with homes with HERS ratings that were conducted between 2000-2010. They found that a one-point decrease in HERS rating was associated with a 4% decrease in the odds of default and a 2% decrease in the odds of prepayment. The study found that homes with HERS ratings that qualify for ENERGY STAR certification had 32% lower odds of default and 25% lower odds of prepayment than homes that would not qualify for certification. Argento, Bak, and Brown (2019) studied loans on homes with HERS ratings conducted more recently, between 2013-2017. They found that HERS rating had no statistically significant effect on mortgage performance in general. However, among houses with a high debt-to-income ratio (>45%), rated houses had lower delinquency rates (1.70 percentage points) than unrated.

Methods

Data Sources

We assembled data from three sources: HES for energy and building characteristics, ATTOM for building characteristics and sale information, and McDash for mortgage information.

The HES dataset, provided by DOE, contains information on all assessments conducted through June 2021. This includes the score and estimated annual utility bills as well as a variety of building characteristics such as floor area and the number of bedrooms.

The ATTOM dataset contains publicly available data from county assessor[2] and recorder[3] offices describing property characteristics and transactions for more than 3,000 counties in the United States starting before the first HES assessments. We merged the HES and ATTOM data through geocoding latitude and longitude.

Mortgage data were provided by Black Knight's McDash[4] dataset. This nationwide dataset is sourced by the top U.S. mortgage servicers covering about 70% of all mortgage transactions. The data include mortgages pooled for securitization by Fannie Mae, Freddie Mac, Ginnie Mae, and private label issuances, as well as those kept on the mortgage originator's balance sheet.[5] We used a crosswalk, previously developed by the University of California, Berkeley, Real Estate & Financial Markets Lab, to join the ATTOM and McDash data.[6] The McDash-ATTOM crosswalk covers ATTOM transactions and McDash mortgages originated before January 2020. Mortgage status history runs through January 2021.

---

[2] https://www.attomdata.com/data/property-data/assessor-data/

[3] https://www.attomdata.com/data/property-data/recorder-data/

[4] http://www.bkfs.com/CorporateInformation/NewsRoom/Pages/20180221.aspx

[5] McDash collects data from participating mortgage servicers from this broad range of sources, accounting for 70% of U.S. mortgages. However, as we do not observe the other 30% of mortgages, we cannot speak directly to representation of the McDash data for all mortgages.

[6] The crosswalk links property mortgage transactions (lien records) and subsequent events, such as new mortgages and distresses, recorded in ATTOM to mortgage origination and termination events described in McDash. It uses the following information for deriving matching scores between McDash and ATTOM transactions: time of origination, loan amount, type of interest rate (fixed or variable), type of transaction (purchase or refinance), property value when the transaction is a purchase, time of loan termination, and status of loan termination (distressed, paid out, or current). The matching score is used as a metric for identifying, for each McDash mortgage, the 25 nearest neighbor transactions in ATTOM. In the last step, the approach employs a stable marriage algorithm to resolve competing McDash mortgages matching the same ATTOM transaction.

Table 2 summarizes these data sources and the specific variables from each that we employed in our analysis.

Table 2. Summary of data sources and variables

Name	Description	Variables employed
HES	All HES assessments conducted through June 2021	Assessment date, score, simulated utility bills, floor area, number of bedrooms, year built
ATTOM	Building characteristics and sales data from property tax assessors and recorders	Sale date, sale amount, building type, lot size
McDash (mortgage analysis only)	Mortgage characteristics and status through January 2021 Mortgages originated before January 2020	Monthly loan status, origination date, amount, interest rate, borrower credit score at loan origination, loan type

We lost some observations in each step in the process of merging the datasets. We started out with 150,804 HES ratings, some of which were conducted on the same home. After geocoding the addresses and merging with the ATTOM data, we had 130,755 ratings on 114,305 properties. We removed homes with outlier values for sale price and floor area by requiring the cost per square foot to be between $50 - 2,000/sq.ft. We also excluded houses with estimated energy bills over $10,000/year.

To study home sale impacts, we considered only homes that were sold after being rated. The final sample size for this portion of the analysis is 26,291 home sales of 24,694 homes. (Some homes sold more than once after being rated, and we included each of those sales in our dataset.)

For the mortgage performance analysis, we filtered down to the homes with a match in the McDash dataset that had an active mortgage loan after the assessment. In some cases, the loan originated before the assessment. In those cases, we studied only the performance of the portion of the loan that post-dated the assessment. The final sample size for this portion of the analysis is 42,071 first mortgages[7] on 37,694 homes.

[7] If multiple loans were active during the same time, we designated the one that originated first as the first mortgage. If they originated on the same date, we designated the largest one as the first mortgage. We did not consider loans that only overlap for one month to be active at the same time.

Statistical Models

Home value. To estimate the impact of HES on home value, we ran multivariable regressions predicting the natural log of home sale price, as shown in Equations 1 and 2.[8] Because of this transformation, the coefficients can be interpreted as the percent increase in sale price associated with increasing the HES by one score or annual energy costs by one dollar.

We distinguished between assessments that occurred in cities where HES was mandated at the time of sale (Portland, OR after 2017 and Berkeley, CA) and cities where it was not. We represented this in the regression equation as an interaction term between the HES variable and a binary variable indicating whether the assessment was mandated.

$$\ln(sale\ price) = b_1 \cdot HES + b_2 \cdot HES \cdot mandated + b_3 \cdot X_3 + \cdots + b_n \cdot X_n + b_0 \qquad (1)$$
$$\ln(sale\ price) = b_1 \cdot bills + b_2 \cdot bills \cdot mandated + b_3 \cdot X_3 + \cdots + b_n \cdot X_n + b_0 \qquad (2)$$

where b_1 and b_2 are the coefficients of interest, *mandated* is a binary variable indicating that the sale occurred in a city where HES was mandated, and X_3 through X_n are the control variables.

We estimated models with a variety of control variables, including floor area, year sold, and zip code where the home is located. We present full regression tables in the next section showing all control variables.

Mortgage performance. We modeled two binary outcome variables derived from the loan's payment history. The first takes on a value of one if a mortgage was ever 30 days (or more) delinquent after the HES assessment was conducted, and zero otherwise; the second is defined similarly but for 120-day (or more) delinquency. 30-day delinquency is the earliest observed delinquency, while 120-day delinquency typically triggers mortgage default proceedings. Most mortgages that reach 120-day delinquency eventually "cure," returning to current status or being paid off; however, actual foreclosures and short sales were too infrequent in our data to analyze.

We distinguished between mortgages that originated before and after the assessment was conducted because mortgage lenders can only take HES into account when setting their loan terms if the assessment occurred prior to loan origination. Also, we expected to see a stronger relationship between HES and loan performance for loans that originated after the assessment if there is a selection effect on the type of buyers who purchase more and less efficient homes.

Because these are binary variables, we modeled them with a logistic regression as shown in Equations 3 and 4.

$$\text{logit}(ever\ delinquent) = b_1 \cdot HES + b_2 \cdot HES \cdot originated\_before\_assessment + b_3 \cdot X_3 + \ldots + b_n \cdot X_n + b_0 \qquad (3)$$
$$\text{logit}(ever\ delinquent) = b_1 \cdot bills + b_2 \cdot bills \cdot originated\_before\_assessment + b_3 \cdot X_3 + \cdots + b_n \cdot X_n + b_0 \qquad (4)$$

[8] We conducted this transformation because the residuals of the fit are more normally distributed as required by the assumptions of linear regression, the goodness of fit indicators are much higher, and this is the approach taken in the literature.

where b_1 and b_2 are the coefficients of interest, *originated_before_assessment* is a binary variable indicating that the loan originated before the HES assessment occurred, and X_3 through X_n are the control variables.

Results

Summary Statistics

Figure 1 shows the geographic distribution of the data. Although HES is a national system with rated homes in 45 states (including D.C.), the home sales and mortgages are clustered in a handful of locations. In particular, about 65% of the sales that occurred after a HES assessment were in Oregon, reflecting the point-of-sale HES requirement in Portland. The next most common location was Connecticut, which had 14% of sales that occurred after a HES assessment. Mortgages that were active after an assessment were also heavily clustered in Oregon (30%) and Connecticut (34%). Because the unit of the analysis is the sale or the mortgage loan, rather than a building, the characteristics of the same home are included multiple times in the summaries if it was sold multiple times or had more than one primary mortgage after assessment.

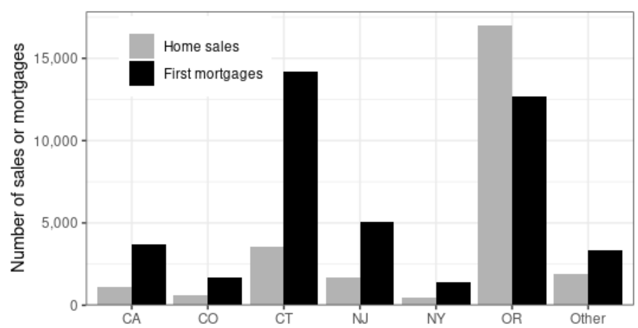

Figure 1. Locations of sales and mortgages

Figure 2 shows the distribution of HES of the home sales and first mortgages in our sample. We have good coverage of the full range of HES, with all ten scores being represented.

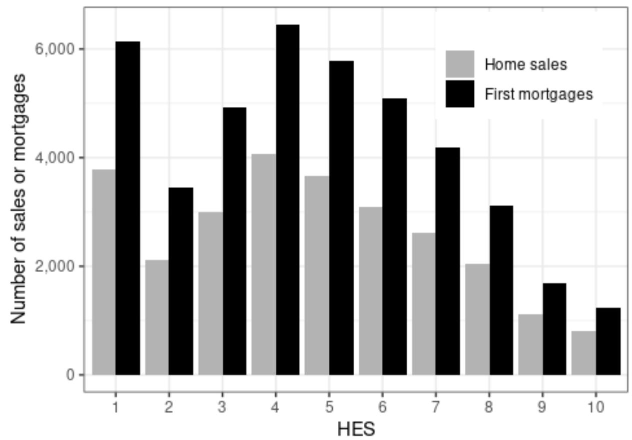

Figure 2. Distribution of HES of sales and mortgages

Table 3 shows a summary of the characteristics of the home sales and mortgage samples. Compared to the sample of sales, the sample of loans contains homes with slightly higher energy bills and slightly larger floor area but a similar distribution of HES and assessment dates.

Table 3. Median characteristics of home sales and first mortgage samples

	Home sales	**First mortgages**
Estimated energy bills ($/yr)	1,664	2,046
Assessment date	10/1/18	4/20/18
Floor area (sq.ft.)	1,809	1,894
Sample size	26,291	42,071
Number of homes	24,694	37,694

Table 4 shows a summary of the additional characteristics of home sales that we used in the home value analysis. The homes in the analysis sold for more than the U.S. average, likely due to the fact that many of the rated homes are in high home value areas (e.g., Connecticut and Portland, OR).

Table 4. Characteristics of home sales

Median Sale price	Median Date sold	Median Lot size (sq.ft.)	Median bedrooms	Median year built	Share single family
$425,000	8/2/19	6,424	3	1957	96%

Table 5 shows a summary of the loan characteristics that we used in the mortgage performance analysis.

Table 5. Characteristics of first mortgages

Ever 30+ days delinquent after assessment	12%
Ever 120+ days delinquent after assessment	4%
Median months of payment history before assessment	19
Median months of payment history after assessment	23
Loan originated before 2009	7%
Median date of loan origination	6/1/16
Went delinquent before assessment	7%
Median loan amount	$270,000
Median interest rate	4%
Fixed interest loans	94%
Loan for purchase	55%
Median credit score at mortgage origination	758
Mortgage type	
Conventional without mortgage insurance	63%
Conventional with mortgage insurance	17%
Federal Housing Administration Residential	12%
Veterans Administration Residential	4.4%
Other	1.9%

Home Value

Table 6 shows the regression results for both HES and predicted bills. The coefficients of the control variables behave reasonably. Larger homes with more bedrooms on larger lots were more valuable, as were detached single-family homes.[9] Homes sold more recently (the "quarter sold" variable) sold for higher prices all else equal.

We found that the HES variables were only statistically significant for sales in cities where assessment is mandated at point of sale. In those cases, we found that an increase in one level of HES was associated with a 0.5% increase in purchase price, and an increase of $100 of estimated annual energy bills was associated in a 0.4% decrease in purchase price. These results are consistent across multiple model specifications tested. Model specifications that do not distinguish between sales in cities with and without HES did not show a statistically significant relationship between the HES variables and sale price.

[9] Here we are comparing detached single-family homes with duplexes and townhomes, the other home types that HES covers.

Table 6. Home value regression results

	Score		Estimated energy bills	
Score (mandated)	0.0051	***		
Score (not mandated)†	-0.0017			
Bills (mandated)			-3.63E-05	***
Bills (not mandated)†			-9.20E-06	
HES not mandated	0.10	***	0.028	***
Floor area (sq. ft.)	2.25E-04	***	2.32E-04	***
Lotsize (sq. ft.)	4.03E-10	***	4.08E-10	***
Number of bedrooms	0.039	***	0.40	***
Year built	6.33E-04	***	6.19E-04	***
Single family	0.22	*	0.22	***
Quarter sold	1.06E-04	***	1.02E-04	***

Significance codes: '***' $p < 0.001$; '**' $p < 0.01$; '*' $p < 0.05$
Zip-code-level fixed effects; robust standard errors clustered at the state level.
† Coefficient and p-value calculated using the interaction term.

The positive correlation between HES and sale price in HES-mandated locations is consistent with the finding in the literature that homes with better energy ratings command a sale premium. It is difficult to compare the magnitude of the effect because other studies typically compare certified to non-certified homes, and the certifications are not mandated anywhere. HES is a system that gives scores even for homes with high energy consumption, and we find that it only has a statistically significant effect in cities with mandates. This is consistent with Sussman et al.'s experimental finding that potential buyers preferred energy efficient homes only when information about inefficient ones was also disclosed (2020). In terms of effect size, we can approximate a certified vs. uncertified comparison by leveraging the fact that HES scores represent deciles of home performance. We define a home with a HES of 5 as a "typical" home and a home with a HES of 10 as a "certified" home for purposes of this approximation. We find a 2.5% increase in sale price between a HES 5 home and a HES 10 home in cities with mandated assessment, all else equal, which is in line with the common estimates in the literature for certified vs. uncertified homes (see Table 1). The lack of mandate for a certification may be less important for its effect on sale price because a certification may be more likely to be disclosed without a requirement.

Mortgage Performance

Table 7 shows the regression results from three models relating HES and 30-day delinquency. Model (1) includes all of the data; models (2) and (3) contain subsets of the data based on whether or not the mortgage is on a house that was rated in Berkeley or Portland after

2017 ("mandated" vs. "unmandated"). Table 8 contains the analogous results for estimated energy bills.

The coefficients for the control variables consistently behaved as expected in terms of the direction of the relationship. The more seasoned a loan was before an assessment, the less likely it was to go delinquent; this is consistent with the general shape of loan performance curves, as many loans that go delinquent do so relatively quickly (see, e.g., Deason, Leventis, and Murphy 2022). More months of payment history post- assessment were associated with higher delinquency simply because the loan had more opportunity to go delinquent. Loans that had gone delinquent before the home was rated were more likely to go delinquent after the assessment. Loans with higher loan-to-value ratios (LTV) or interest rates were more likely to go into delinquency, all else equal. Borrowers with higher credit scores were less likely to go delinquent, and loans with longer terms were more likely to go delinquent. Relative to conventional loans that do not require mortgage insurance, all other mortgage types were more likely to go delinquent.

We found that mortgage loans on certain homes with higher HES were less likely to go 30 days delinquent. This was true of loans that (a) originated after the assessment and (b) were made on homes in locations with a mandated HES assessment.[10] We estimate that an increase of one in the HES decreases the odds of delinquency by 5.5%.[11]

To understand the magnitude of the effect among this subset of loans, we once again defined the difference in HES between a "certified" and a "typical" home to be 5 points. This implies that a loan on a "certified" home had a 28% decrease in the odds of going delinquent compared to a "typical" home. Alternately, the average marginal effect[12] of a one-point increase in score was a 0.2 percentage point decrease in the likelihood of 30-day delinquency. Again using our 5-point HES increase for a "certified" vs. a "typical" home, this implies a 1 percentage point decrease in the likelihood of delinquency. These effect sizes are not out of line with those found in the literature: a 30% decrease in the odds of 90-day delinquency for ENERGY STAR certification and a 1.70 percentage point decrease in 60-day delinquency for HERS-rated homes with a high debt-to-income ratio (Kaza, Quercia, and Tian 2013; Argento, Bak, and Brown 2019). Note that in both of those cases the authors used a higher delinquency threshold than our 30 days.

Similarly, we found that the relationship between 30-day delinquency and estimated energy bills was only significant for loans that originated after the HES assessment and on homes in a place where that assessment was mandated. In this case, a $100 increase in estimated annual energy bills was associated with a 2.3% increase in the odds of the loan going delinquent. Alternately, a $100 increase in the estimated annual energy bills was associated with a 0.02 percentage point increase in the likelihood of 30-day delinquency.

---

[10] The coefficient for the model using all of the data was statistically significant, but this is because it includes the loans with mandated assessments.

[11] In other words, if a home with a HES of 5 has a 12% chance of delinquency, an otherwise identical home with a HES of 6 would have an 11.34% chance (12*(1-.055)).

[12] Conceptually, the average marginal effect is the average of the slope of the logistic curve with respect to a single variable for every data point in the dataset; it can be interpreted in the same manner as the coefficient from a linear regression.

Table 7. Mortgage performance logistic regression results – score

	(1) All	(2) Unmandated	(3) Mandated
Score (originated after assessment)	-0.038 **	-0.024	-0.057 **
Score (originated before assessment) †	4.1E-04	2.3E-03	-5.1E-03
Originated before assessment	-0.50 ***	-0.46 ***	-0.34
Months loan originated before assessment	-4.3E-03 ***	-4.2E-03 ***	-5.8E-03 **
Went delinquent before assessment	1.93 ***	1.74 ***	2.71 ***
Months of payment history after assessment	0.025 ***	0.024 ***	0.055 ***
Loan originated before 2009	0.103	0.12	0.35
Floor area (sq. ft.)	3.8E-05	3.0E-05	6.9E-05
Original LTV	0.49 ***	0.58 ***	0.19
Original interest rate	11.60 ***	13.66 ***	-3.11
Loan type (base level: fixed)			
ARM	-0.10	-0.13	-0.087
unknown	-0.010	0.30	-11.70
Original credit score	-5.0E-03 ***	-4.9E-03 ***	-5.3E-03 ***
Original term	1.5E-03 ***	1.7E-03 ***	-3.9E-04
Product type (base level: conventional without PMI)			
Conventional with PMI	0.17 **	0.10	0.35 **
FHA residential	0.78 ***	0.76 ***	0.76 ***
Other	0.42 ***	0.38 ***	0.59
VA residential	0.25 **	0.21 *	0.31
(Intercept)	-0.39	-0.62 *	-0.84 **
Number of loans	42,071	28,813	13,258

Significance codes: '***' $p < 0.001$; '**' $p < 0.01$; '*' $p < 0.05$
† Coefficient and p-value calculated using the interaction term.
The magnitudes of the coefficients from logistic regression are not intuitive since they represent changes in the logarithm of the odds of going delinquent. Still, their signs and statistical significance can be interpreted as usual.

Table 8. Mortgage performance logistic regression results – estimated energy bills

	(1) All	(2) Unmandated	(3) Mandated
Bills (originated after assessment)	4.3E-05	1.9E-05	2.3E-04 *
Bills (originated before assessment) †	-1.1E-05	-6.0E-06	-1.1E-04
Originated before rating	-0.19	-0.26 *	0.43
Months loan originated before assessment	-4.4E-03 ***	-4.2E-03 ***	-5.8E-03 **
Went delinquent before assessment	1.93 ***	1.74 ***	2.72 ***
Months of payment history after assessment	0.025 ***	0.024 ***	0.056 ***
Loan originated before 2009	0.11	0.12	0.36
Floor area (sq. ft.)	4.3E-05	3.3E-05	6.3E-05
Original LTV	0.50 ***	0.58 ***	0.18
Original interest rate	11.75 ***	13.68 ***	-3.21
Loan type (base level: fixed)			
ARM	-0.10	-0.13	-0.086
unknown	-7.2E-03	0.30	-11.74
Original credit score	-5.0E-03 ***	-4.9E-03 ***	-5.4E-03 ***
Original term	1.5E-03 ***	1.7E-03 ***	-3.8E-04
Product type (base level: conventional without PMI)			
Conventional with PMI	0.17 **	0.10	0.36 **
FHA residential	0.78 ***	0.76 ***	0.77 ***
Other	0.42 ***	0.38 ***	0.59
VA residential	0.25 **	0.21 *	0.32
(Intercept)	-0.72 *	-0.80 *	-1.46 *
Number of loans	42,071	28,813	13,258

Significance codes: '***' $p < 0.001$; '**' $p < 0.01$; '*' $p < 0.05$
† Coefficient and p-value calculated using the interaction term.
The magnitudes of the coefficients from logistic regression are not intuitive since they represent changes in the logarithm of the odds of going delinquent. Still, their signs and statistical significance can be interpreted as usual.

We also tested models predicting 120-day delinquency but did not find consistent statistically significant associations with either HES rating or estimated bills. Per Table 5, 120-day delinquency is considerably less common in our data, so we may lack sufficient statistical power in our dataset to observe any differences that might exist.

Conclusion

In our dataset, HES metrics were significantly associated with home value and mortgage performance in places with point-of-sale assessment mandates.[13]

In terms of home value, we found that homes with higher HES or lower estimated energy bills commanded a higher sale price, all else equal. Improving a home's HES by one was associated with about a 0.5% increase in sale price, and reducing estimated annual energy bills by $100 was associated with a 0.4% increase in sale price. These results were statistically significant at conventional significance levels and robust to model specification. The magnitude of the effect we observed is consistent with estimated magnitudes of home sale premiums for other green or energy-efficient home certifications in the literature. The fact that we observe this effect only in locations with mandatory scoring and disclosure suggests that these mandates are important for communicating a home's level of efficiency to prospective buyers. In other locations, buyers may not know to look for the scores, or sellers may not provide the information in the first place.

In terms of mortgage performance, we found statistically significant effects of HES on the performance of mortgages originated after the assessment, but not on mortgages originated prior to the assessment. This suggests that selection is at least partially responsible for this effect – that there is something different about people who buy homes with lower energy consumption. It could be that they are more conscientious and careful about their finances in general, or that they are more frugal with their energy use than average, which would amplify the bill savings from the lower-energy house. That said, while we do no observe a statistically significant relationship between HES and mortgages originated prior to assessment, the point estimate is in the expected direction. It is possible that a statistically significant relationship would emerge for these homes with a larger sample size – which would suggest that the lower energy cost of these homes is also part of the explanation for stronger mortgage performance.

Our analysis showed an association between HES and home sale price and mortgage performance but does not prove a causal relationship. If factors we cannot control for that are correlated with high HES also affect home value, the association we observed could be in part due to those factors. For example, certified buildings might also tend to be newer or have more amenities, particularly because many certifications require features that are not directly related to energy consumption. Some observers have raised these concerns with existing studies of the value of energy efficiency certification. We feel these concerns are less of an issue for HES, which is an energy-only rating mostly applied to existing homes.

Our results add to the evidence in the literature that home energy ratings provide value to the real estate market. However, our results suggest some differences between HES and other ratings and certifications studied in the literature. None of the other ratings or certifications are mandated in some places but not others. Moreover, because other ratings and certifications

---

[13] There are very few HES assessments in California and Oregon outside of the mandated areas, we cannot directly test whether other characteristics of those places, in addition to the fact that scores are mandatory, are contributing to the effects. The difference in HES's effect on home value in these places is sharp enough, however, that we believe the mandates are the most likely driver.

mostly only apply to energy efficient or green homes, it is in the seller's best interest to advertise the rating or certification. HES is a consumption rating rather than an efficiency one, and it is applied to homes with high and low consumption. It was only associated with a sale premium when it was mandated at the point of sale, which means that buyers are able to compare HES across houses and can see the rating even for high-consumption homes.

We are expanding on the analysis described in this paper in ongoing work. In particular, we plan to conduct analysis on data from more than two million HERS-rated homes,[14] which gives us a much larger sample size that will allow us to detect smaller effect sizes than this HES sample does. We will also study tens of thousands of homes that have received one of several green certifications, including National Green Building Standard (NGBS) certification, Florida Green Building Coalition's green home certification, and Leadership in Energy and Environmental Design (LEED). Different ratings and certifications measure somewhat different things and are used for different purposes, so results may vary. Taken collectively, however, our data will enable the most thorough exploration to date of the relationships between energy efficiency, home ratings and certifications, home value, and mortgage performance in the U.S.

References

Argento, R., X.F. Bak, and L.M. Brown. 2019. *Energy Efficiency: Value Added to Properties and Loan Performance*. Washington, DC: Freddie Mac. https://sf.freddiemac.com/content/_assets/resources/pdf/fact-sheet/energy_efficiency_white_paper.pdf.

Brown, M. and T. Watkins. 2016. *The "Green Premium" for Environmentally Certified Homes: a Meta-Analysis and Exploration*. http://dx.doi.org/10.13140/RG.2.1.1468.1368.

Deason, J., G. Leventis, and S. Murphy. 2022. *Long-Term Performance of Energy Efficiency Loan Portfolios*. Berkeley, CA: Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/long-term-performance-energy.

Department of Energy (DOE). 2021. *Home Energy Score Scoring Methodology*. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Home_Energy_Score_Methodology_Paper.pdf.

Energy Information Administration (EIA). 2015. *Residential Energy Consumption Survey*. https://www.eia.gov/consumption/residential/

Glickman, J., P. Kappaz, and G. Khowailed. 2014. "What's the Score? Lessons Learned from the U.S. Department of me Energy Score. ACEEE Summer Study on Energy Efficiency in

[14] Note that HERS and HES are significantly different in a number of ways, and we should not necessarily expect to observe the same effect from each. For one, HERS-rated homes are mostly new homes, while HES-rated homes are not (Argento, Bak, and Brown 2019). For another, HERS ratings account for house size and therefore measure efficiency, while HES measures total consumption.

Buildings. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/HomeEnergyScore_ACEEE%20Summer%20Study%202014%20Paper.pdf

Hallman, G. 2017. *The Value of LEED Homes in the Austin-Round Rock Real Estate Market*. Prepared for the U.S. Green Building Council. Retrieved from: https://www.usgbc.org/resources/value-leed-homes-austinround-rock-real-estate-market.

Kahn, M.E. and N. Kok. 2014. "The Capitalization of Green Labels in the California Housing Market." *Regional Science and Urban Economics*, 47. http://dx.doi.org/10.1016/j.regsciurbeco.2013.07.001.

Kaza, N., R.G. Quercia, and C.Y. Tian. 2014. *Home Energy Efficiency and Mortgage Risks.* Retrieved from: https://www.imt.org/wp-content/uploads/2018/02/IMT_UNC_HomeEEMortgageRisksfinal.pdf.

Sussman, R., C. Kormos, C. Park, and E. Cooper. 2020. *Energy Efficiency in Real Estate Listings: A Controlled Experiment*. Washington, DC: American Council for an Energy-Efficient Economy. https://www.aceee.org/research-report/b2002.

Walls, M., T. Gerarden, K. Palmer, and X.F. Bak. 2017. "Is Energy Efficiency Capitalized into Home Prices? Evidence from Three U.S. Cities." *Journal of Environmental Economics and Management*, 82. https://doi.org/10.1016/j.jeem.2016.11.006.

Watkins & Associates, SEEC LLC, and Earth Advantage. 2015. *The Market Valuation of Energy Efficient and Green Certified Northwest Homes*. Prepared for: The Northwest Energy Efficiency Alliance (NEEA). Retrieved from: https://www.earthadvantage.org/assets/documents/NEEA_Home_Valuation_Report-FINAL.pdf.

Yuan, M. and J. Cohen. 2017. *ENERGY STAR New Homes and the Impact of Certification on Maryland Home Prices*. Retrieved from: https://www.icf.com/insights/energy/energy-star-certification-on-home-prices.

Zancanella, P., Bertoldi, P., and B. Boza-Kiss. 2018. *Energy efficiency, the value of buildings and the payment default risk*. European Commission Joint Research Centre Science for Policy Research Report. Retrieved from: https://apo.org.au/sites/default/files/resource-files/2018-12/apo-nid212371.pdf