RESEARCH REPORT

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Home Energy Efficiency and Mortgage Risks

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Executive Summary

In recent years, home energy efficiency has progressed from the margins to the mainstream. Builders large and small are now constructing homes to higher energy efficiency levels. Increasingly, remodeling projects include energy efficiency upgrades. Most importantly, consumer awareness and acceptance are high. Consumers understand that energy efficiency pays for itself over the lifetime of the building through lower heating and cooling costs.

Despite these trends, the market has not reached its full potential. Financing obstacles prevent many moderate- and middle-income homebuyers and owners from enjoying the benefits of energy efficiency. An important way to encourage greater adoption of residential energy efficiency measures is for mortgage pricing or underwriting flexibility to reflect the savings that come as a result of energy efficiency. Lenders and investors have been reluctant to do so, in part because they lack reliable loan performance data on which to base underwriting decisions.

The study indicates that default risks are on average 33 percent lower in energy-efficient homes, controlling for other loan determinants.

Many have theorized that energy-efficient homes should have lower default risks than standard homes because the former are associated with lower energy costs, which leaves more money to make the mortgage payment. However, few empirical studies have been conducted due to limited data availability.

This study examines actual loan performance data obtained from CoreLogic, the lending industry's leading source of such data. To assess whether residential energy efficiency is associated with lower default and prepayment risks, a national sample of about 71,000 ENERGY STAR- and non-ENERGY STAR-rated single-family home mortgages was carefully constructed, accounting for loan, household, and neighborhood characteristics.

The study finds that default risks are on average 33 percent lower in energy-efficient homes, controlling for other loan determinants. This finding is robust, significant, and consistent across several model specifications. A borrower in an ENERGY STAR residence is also one-quarter less likely to prepay the mortgage. Within ENERGY STAR-rated homes, default risk is lower for more energy-efficient homes. The lower risks associated with energy efficiency should be taken into consideration when underwriting mortgages.

Financing Energy Efficiency

Making homes energy efficient often requires higher upfront costs, but financing mechanisms can help offset them. Investments in residential efficiency often produce rates of return well above interest rates or other investment opportunities. Still, market failures, such as transaction costs and information asymmetries, prevent rapid and widespread adoption of energy efficiency. To succeed, public- and private-sector efficiency programs must overcome these barriers.

The U.S. housing stock is valued at about $14.5 trillion, according to the Federal Reserve System. Even 2% devoted to energy efficiency improvements would require capital outlays of nearly $300 billion. That amount exceeds any funding we could realistically expect from the government or utility sector. A variety of funding mechanisms exist today, such as, state and local energy efficiency loan funds, on-bill repayment, and PACE bonds. But their scale is vastly lower than what is required.

By far, the most widely used mechanism is direct borrowing. Most energy improvements for existing homes can be financed through consumer loans, a home equity loan secured by property, or a traditional or specialized mortgage. Such financing usually requires that consumers have substantial equity in their existing homes, the financial reserves to pay any added costs out-of-pocket, or larger down payments for a home purchase. For many first-time homebuyers and moderate-income borrowers who do not have these financial resources, energy-efficient mortgages (EEM) offer a solution. EEMs offer lenders flexibility in the debt-to-income and other underwriting considerations so that borrowers can qualify for larger loans or lower interest rates.

Conceptually, EEMs and other mortgage-based products present a number of advantages as energy efficiency financing tools, since they allow consumers to finance efficiency features at mortgage rates, as opposed to high commercial credit rates. However, these products have received little market uptake to date, largely because of the transactional complexity, poorly developed lender guidance, limited benefits for lenders, and lack of consumer information. Few lenders currently offer them except for Federal Housing Administration (FHA) and Veterans Administration mortgages, even in states with the largest numbers of new ENERGY STAR homes.

The limited availability of EEMs may be due in large part to the market's tighter mortgage qualification rules, which do not recognize energy efficiency, as well as a lack of information about their default risks. If, indeed, mortgages on energy-efficient homes have lower risks than those on less efficient homes, then good credit policy would merit more flexible underwriting standards or even consideration in loan-level price adjustments. In addition, with more accurate information on risks, lenders may be able to develop and tailor mortgage products that better meet the needs of both consumers and investors.

An important way to encourage greater adoption of residential energy efficiency measures is for mortgage pricing or underwriting flexibility to reflect the savings that come as a result of energy efficiency.

Policy Implications

Because the findings are consistent across different model specifications and types of subsamples, we can derive a number of implications for policy and lending practices.

First, lenders may want to require information about energy costs and encourage an energy audit or energy rating during the process of mortgage underwriting. In the same manner that appraisals calculate the value of the home, an energy-rating determination could inform other important characteristics of the loan, including the debt-to-income ratio. Utilizing energy audits as part of the mortgage underwriting process would help homeowners make informed decisions about energy efficiency investments and likely promote long-term efficiency of the housing stock.

Second, lenders and secondary market investors should take into account the energy efficiency of the home used as collateral for the loan in an underwriting decision. For instance, they may allow for a higher debt-to-income ratio and a higher appraisal value to offset the modest increase in cost-of-energy improvements. This and similar approaches would allow borrowers to obtain the underwriting flexibility needed to cover the modest additional cost of energy efficiency features and increase affordability for many moderate- and middle-income borrowers.

In summary, the findings demonstrate that energy efficiency and the degree of energy efficiency matter. The lower risks associated with energy efficiency should be taken into consideration when underwriting mortgage risks. Major market stakeholders, such as FHA, Freddie Mac, and Fannie Mae, could encourage underwriting flexibility for mortgages on energy-efficient homes as well as promote energy efficiency to consumers in concert with their lending partners. Finally, Congress should consider the findings in its deliberations of current and proposed legislation to improve the accuracy of mortgage underwriting used by federal mortgage agencies, by ensuring that energy costs are considered in the underwriting process.

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Introduction

Over the last few decades, even while houses are becoming more energy efficient, energy costs per household and the total energy used in the residential sector are rising. Many people are living in smaller households but in larger houses, with increasing reliance on space conditioning and appliances, which result in higher energy consumption per household (Kaza 2010). In turn, higher energy costs leave households with less income to meet other needs, such as housing-related expenses. If these trends are going to change anytime soon, greater adoption of energy efficiency measures is needed. An important way to encourage such adoption is for mortgage pricing or underwriting flexibility to reflect the savings that come as a result of energy efficiency. Keoleian et al. (2000) argue that while an energy-efficient house recoups any additional premium in sales prices, the mortgage underwriting process does not account for these savings, contributing to lower adoption rates of energy-efficient measures. In this study, we focus on other reasons why the mortgage underwriting process should account for energy efficiency.

In their study of California homes, Kok and Kahn (2012) find that there is an average premium of $34, 800 (~9%) for green-rated homes. Green-rated homes, such as those certified by Leadership in Energy and Environmental Design (LEED) or GreenPoint Rated, conserve energy and materials both in the operation and the construction phases. Presumably, these premiums are paid back through the operational savings over a lifetime. However, as Jaffe and Stavins (1994) argue, the non-rapid adoption of energy efficiency measures indicates that the present valuation of savings is less important to consumers than other market and non-market barriers. These include transaction costs, uncertainty and cost of the initial investment, and information asymmetries, all of which are still poorly understood.

With regard to energy efficiency and mortgage risks, the paucity of information is surprising because the potential relationship between the two can be easily explained. Burt, Goldstein, and Leeds (2010) theorize that mortgages on energy-efficient houses should have lower risks than those on standard houses because the savings from residential energy and transportation costs leave more income available in case of emergencies or unexpected events. Using proxy measures for transportation energy costs such as Walk Score™, Rauterkus, Thrall, and Hangen (2010) find that transportation energy savings are associated with lower mortgage delinquency risks in high-income areas but higher risks in low-income areas. Increased vehicle ownership for households, as a proxy for higher transportation costs, increases the delinquency risks. These results contradict the earlier study by Blackman and Krupnick (2001), who find that location efficient mortgages do not have any significant effect on delinquency risk compared to conventional mortgages.[1] Empirical studies on this and related issues have reached suggestive, inconclusive, and even contradictory findings in large part due to the reliance on proxy measures to capture important variables.

In this study, we address some of the limitations of prior work and examine whether residential energy efficiency is associated with lower mortgage risks. More narrowly, we use a national sample of 71,000 loans from CoreLogic (38 states and the District of Columbia) and examine whether energy efficiency and the degree of energy efficiency are associated with lower default and prepayment risks. In this particular study, we focus on household energy consumption, leaving the effect of transportation energy burden for future work.

The structure of the paper is as follows. We first describe the different financing mechanisms for residential energy efficiency. Next, we provide an overview of the mortgage risk literature. Then, we describe the research design and

1 This study is limited to Federal Housing Administration (FHA) loans in Chicago, Ill. Because the mandate of FHA is to increase home ownership among poor people, the results from this study may not be generalizable.

methods to examine the effects of energy efficiency on mortgage risks. Finally, we discuss the results and derive implications for future research and policy.

Household Energy Efficiency

According to the Energy Information Administration's 2009 Residential Energy Consumption Survey (RECS), households spend around $230 billion each year on energy (not including transportation). The residential sector accounts for 20% of the total energy consumed in the United States (Energy Information Administration 2011). A widely cited study by McKinsey & Company suggests that energy efficiency in the residential sector has a potential to save $41 billion annually (Granade et al. 2009). It is, thus, not a surprise that building energy efficiency is considered the "fifth fuel" and is actively promoted through government policy and voluntary action.

One of the widespread ways of promoting residential energy efficiency in the United States is the U.S. Environmental Protection Agency's (EPA) ENERGY STAR program for appliances, commercial and industrial buildings, and new home construction. The market penetration of the ENERGY STAR label in new housing construction is noteworthy—25% of new U.S. housing starts were ENERGY STAR-certified in 2011.[2] Homes awarded the ENERGY STAR label are at least 15%-20% more energy efficient than the typical new home and must meet rigorous guidelines for a high-efficiency thermal enclosure (windows, insulation etc.), Heating Ventilation and Air Conditioning (HVAC) system, and appliances, as well as a comprehensive water management system.

To earn an ENERGY STAR rating, homes must undergo an inspection by a certified home energy rater who examines construction plans and conducts post-construction evaluations, including a blower door test (to test the envelope infiltration) and a duct infiltration test. The rater uses this data to assign the home a relative performance score, called a HERS Index Score. The index is normalized to the climatic zone, size, and type of the house. A home built to current market standard (2006 International Energy Conservation Code standard) is given a rating of 100.[3] Lower HERS ratings for a house indicate higher efficiency; i.e., a HERS rating of 60 means that the house is 40% more energy efficient than a similar one that is constructed to the current market standards. A score of 0 corresponds to a net-zero energy home. A standard resale house has a rating of 130. Typically, a HERS rating of 85 is required to achieve ENERGY STAR certification. Residential Energy Services Network (RESNET) is a standard-making body that certifies the raters as well as the procedures and is responsible for ensuring consistency and quality in certification.

Within the United States, there are other comprehensive, but smaller or regional, programs that promote energy efficiency in new housing construction, such as LEED for Homes, the National Association of Home Builders' Green Building Standard, EarthCraft (in the Southeast), Earth Advantage Label (in the Pacific Northwest), and GreenPoint Rated certification (in California).[4] These rating systems generally exceed the building performance of ENERGY STAR and promote comprehensive green building technologies and materials.

Almost all rating systems rely on some version of modeled and hypothetical energy use. While the construction is tested for leakage and other inefficiencies, the rating systems do not account for actual post-occupancy energy use.[5] Household energy consumption, while dependent on building envelope and appliances, is also crucially dependent on occupants' behavior and use patterns. As Stein and Myer (2000) point out, while ENERGY STAR certification is a useful predictor of a home's relative energy efficiency, the difference between a homeowner's expected/modeled and realized energy savings may vary. This consideration plays an important role in qualifying the conclusions drawn in this study. Nevertheless, ENERGY STAR-certified houses are, on average, expected to save energy compared to conventional homes.

Financing Energy Efficiency in the Residential Sector

Promoting energy efficiency in the residential sector

2 http://www.energystar.gov/index.cfm?fuseaction=qhmi.showHomesMarketIndex (Accessed February 5, 2013)

3 Fairey et al. (2000) provides a historical overview of the development of HERS ratings in the United States.

4 By 2012, only about 15,000 U.S. homes were LEED certified. On average, about 400,000 new homes are constructed every year in the United States. (See http://www.usgbc.org/ShowFile.aspx?DocumentID=2683, http://www.census.gov/construction/nrc/)

5 This is true for the residential sector. ENERGY STAR ratings for the non-residential sector rely on building performance by comparing the actual energy use to other buildings of similar type in that year.

requires providing mechanisms to offset the higher upfront cost generally associated with energy efficiency measures. While many of these measures have a reasonable payback period, some barriers, such as transaction costs and information asymmetries, prevent rapid and widespread adoption of energy efficiency (Gillingham, Newell, and Palmer 2009). Part of the challenge for both public- and private-sector programs is to provide mechanisms, including innovative financing mechanisms, that will overcome these barriers. The value of the U.S. housing stock is about $14.5 trillion.[6] If we assume that 2% of this value is required for efficiency improvement in the residential sector, public and private outlays add up to $300 billion.

One of the ways in which energy efficiency is financed is through grants geared towards energy efficiency retrofits. A well-known and long running program is the Weatherization Assistance Program (WAP) that offers grants to qualified low-income families for the purpose of weatherization. State-sponsored energy efficiency loan funds are also in vogue. They, too, have grown recently through funding from the American Recovery and Reinvestment Act (ARRA) of 2009. The National Association of State Energy Officials (NASEO) tracks 66 such funds that are available in 34 states. The total amount of funding dedicated to state energy revolving loan funds covered in their database is over $925 million.[7]

However, residential energy efficiency is predominantly funded by the rate payer. Total spending on U.S. rate-payer-funded energy efficiency initiatives more than doubled in the latter half of the past decade—from $2 billion in 2006 to $4.8 billion in 2010. However, two-thirds of the total was concentrated in only 10 states, with California, New York, New Jersey, Massachusetts, and Washington as leaders (Barbose, Goldman, Hoffman, and Billingsley 2013; Barbose, Goldman, and Schlegel 2009). One such initiative, "on-bill financing" (OBF) is provided by the utilities as part of their efficiency efforts. Utilities provide zero- (or near-zero) interest loans for qualified customers, which are then recouped through a line item in the utility bill. However, most of these programs are targeted primarily at non-residential customers rather than homeowners due to the complexity of collection and resistance on the part of utilities (Fuller 2009). In 2011, New York State authorized residential on-bill loans, which are currently being implemented by the New York State Energy Research Authority (NYSERDA) in cooperation with New York utilities (Henderson 2012).

Property Assessed Clean Energy (PACE) bonds are a financing mechanism that uses locally issued tax bonds to fund residential energy improvement activities. The funds are paid back gradually (over 20 years or so) through special taxation placed on the property through a lien. In the event of resale, new property owners take on the responsibility of special taxes. Because of the first lien placed on the property, secondary market institutions have been reluctant to embrace mechanisms such as PACE bonds, thus limiting their widespread adoption to date.

By far, the most widely used mechanism is direct borrowing. Most energy improvements for existing homes can be financed through consumer loans, a home equity loan secured by property, or by traditional or specialized mortgages. Although not widely available, energy improvement mortgages (EIM) allow the homeowner to fold the costs of energy improvements into the mortgage. By contrast, energy-efficient mortgages (EEM) allow lenders to have flexibility in the debt-to-income ratio and other underwriting considerations so that borrowers can qualify for larger loans or obtain a lower interest rate. Both these specialized programs are relatively small because of the transactional complexity and lack of information (USEPA 2010). Furthermore, very few lenders currently offer them, except for Federal Housing Administration and Veterans Administration mortgages. For example, there are only three such lenders for the state of Texas and two in Arizona, the two states with the largest number of new ENERGY STAR residences in 2011.[8]

The above programs and financing options have grown and show promise, but at less than $6 billion in aggregate are far below the need. Of all these mechanisms, EEMs and EIMs have the greatest potential to encourage energy efficiency because they rely on the mainstream financial system. Their limited availability and appeal may be due in large part to the uncertainty and lack of information about their inherent risks. If, indeed, mortgages on energy-efficient homes have lower risks than those on less-efficient homes, a lower pricing or more flexible underwriting

6 Replacement cost value of U.S. housing stock: Federal Reserve Board's Flow of Funds Accounts, December 6, 2012, Table B.100 (line #43). This figure includes homes with and without underlying mortgages.

7 http://www.naseo.org/resources/selfs/ (Accessed February 7, 2013)

8 http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.locator (Accessed January 13, 2012).

standard is likely to result in an increased demand for these products. In addition, with more accurate information on risks, lenders may be able to develop and tailor these mortgage products more effectively.

Estimating Mortgage Default and Prepayment Risks

Mortgage lending, then, can play an important role in promoting energy efficiency. For this reason, it is important to understand the risks inherent in such lending. Fortunately, many insights have been gained from a large number of mortgage termination studies that can be applied to better understand the relationship between energy efficiency and risks. Previous studies focus on two aspects of mortgage risks: default and prepayment. Mortgage default occurs when mortgage borrowers stop making scheduled payment and certain conditions required by law occur.[9] Prepayment occurs when borrowers pay off loans prematurely. From a lender perspective, prepayment can be considered a risk because when borrowers pay off the loan prematurely, often when interest rates fall, the expected stream of payment and return are not realized. Both default and prepayment can lead to a loss to lenders, although given the relative size of the loss, researchers and practitioners tend to focus more on default (Quercia and Stegman 1992).

Two complementary frameworks have been advanced to explain these two risks. One has focused on the financial benefit of options (Foster and Van Order 1984; Kau, Keenan, Muller, and Epperson 1992). This group of studies treats default and prepayment as financial options. The framework assumes that borrowers make constant evaluations about the financial benefits of these options and will exercise them once those options become beneficial. For instance, with regard to default, borrowers are expected to consider their equity position: borrowers who owe to the lender more than the house is worth, net of costs, are expected to be more likely to default than those with positive equity positions. This explanation, though powerful in explaining certain key aspects of mortgage performance, does not seem to explain fully why borrowers stop making their mortgage payments. Over the last two decades, a complementary view has emerged in which most borrowers are said to evaluate their equity position (or option) only in the event of a crisis or trigger event, such as job loss or divorce (Vandell 1995). Most recent studies of default use a combination of these frameworks.

Empirically, researchers have found evidence supporting the complementary views of the option-based and adverse trigger-event frameworks. The loan-to-value ratio, the value of the prepayment option, and the local unemployment rates have been found to have consistent impacts on both mortgage default and prepayment. Also, certain characteristics of the borrower and the financial and servicing institutions have a consistent effect. For instance, Quercia, Pennington-Cross, and Tian (2012) find support for the importance of current loan-to-value ratio, borrower credit, income, and unemployment. As a rule, ability to pay (captured by debt-to-income ratio) has been omitted from most loan termination studies due to methodological considerations.[10] Consistent with prior work, we use three months late in payments (90 days delinquency) to model the default decision.

The savings resulting from energy efficiency, as discussed previously, can be viewed as a cushion to unanticipated crisis or adverse events that could make mortgage repayment more difficult. It is also likely that homeowners in the market for efficient homes weigh the long-term savings derived from energy efficiency against the short-term higher costs, thus reflecting a higher degree of financial savvy. On the basis of the mortgage termination literature, we expect mortgages on energy-efficient homes to have a lower probability of default than those on less efficient ones.

Research Design and Methods

Researchers often apply hazard analysis in mortgage evaluation to deal with the right censoring issue or the fact that borrowers may terminate their mortgage after the period under consideration. In such an analysis, researchers estimate the conditional event probability (hazard), i.e., the probabilities of default and prepayment, conditional on surviving to date, as defined statistically. Default and prepayment are considered competing risks because when borrowers act on one they preclude action on the other. In the context of this competing risk model, consider two termination risks: default *(D)* and prepay *(P)*. The hazard $\lambda_i^r\left(t \middle| X_i(t), \beta_r, \theta_r\right)$ for an individual *i,* risk $r = D, P$ given characteristics $X_i(t)$, parameters, β_r, and unobserved

9 In the United States, laws governing the conditions of default and foreclosure can differ by jurisdictions (See e.g. Cutts & Merrill, 2008).

10 Two exceptions include Quercia, Pennington-Cross, and Tian (2012) and Berkovec et al. (1998).

heterogeneity parameter θ_r is defined as

$$\lambda_i^r\left(t|X_i(t),\beta_r,\theta_r\right)=\lim_{\Delta t\to 0}\frac{Pr\left(t<T_i^r<t+\Delta t|T_i^r\geq t,X_i(t),\beta_r,\theta_r\right)}{\Delta t}$$

With a discrete time assumption, a multinomial logit model is often used to estimate the above equation.

We use a treatment control research design to estimate the differences in mortgage termination risks. We use the loan information for ENERGY STAR (treatment) and non-ENERGY STAR (control), supplemented with information about factors that contribute to household energy consumption. We adopt the competing risk framework of mortgage terminations and estimate the impact of prepayment and mortgage default simultaneously (Quercia and Spader 2008). A multinomial logit model is used to quantify these risks relative to one another and tests whether risks of loans of energy-efficient homes are different from those of energy-inefficient homes:

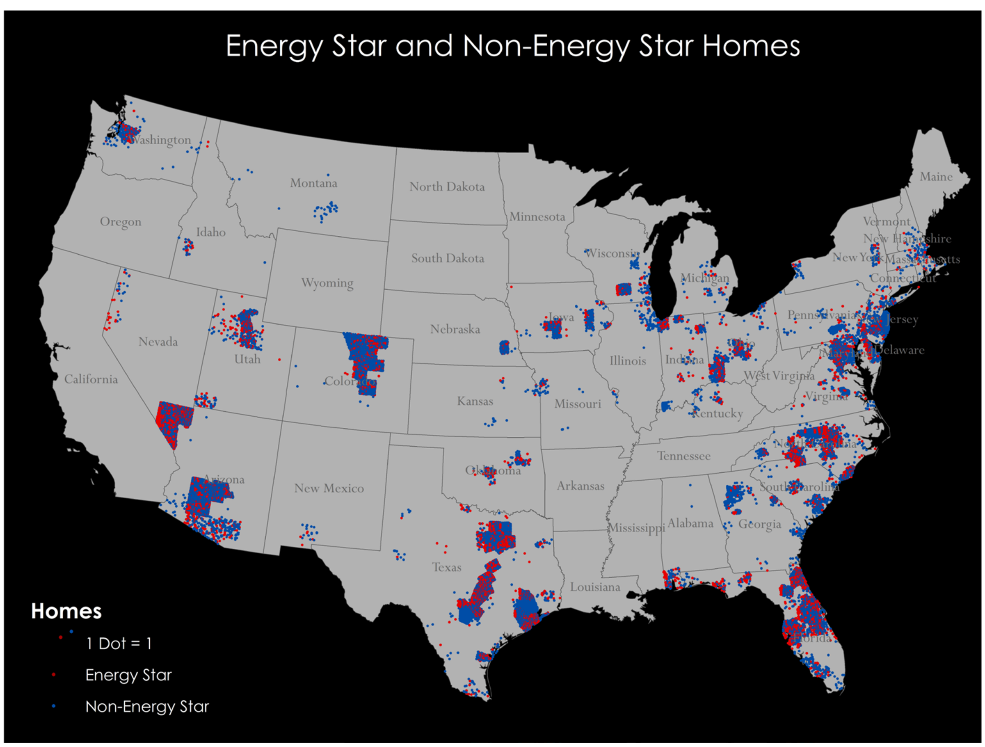
$$\ln\frac{Pr\left(Y_i=D\right)}{1-Pr\left(Y_i=D\right)}=\alpha_D+\beta_D'\boldsymbol{E}+\gamma_D'\boldsymbol{X}+\delta_D C$$

$$\ln\frac{Pr\left(Y_i=P\right)}{1-Pr\left(Y_i=P\right)}=\alpha_P+\beta_P'\boldsymbol{E}+\gamma_P'\boldsymbol{X}+\delta_P C$$

where Pr is the probability, $\boldsymbol{E}$ is a set of variables of the house that relate to energy consumption (such as square feet and climate) and $\boldsymbol{X}$ is the standard set of explanatory variables from the mortgage termination literature (such as LTV, unemployment rate, age of the loan indicator variables, etc.). C is an indicator variable referring to the treatment (ENERGY STAR/regular). δ are the estimates of interest.

In order to understand whether the extent of energy efficiency matters, we compare the risks of default of mortgages on ENERGY STAR homes for which a HERS Index Score is available. These HERS ratings are included in the model as a continuous variable (0-85), thus allowing us to examine whether better energy efficiency (lower HERS rating) is associated with lower mortgage risks. Thus, instead of an indicator variable for treatment we use a HERS rating variable. Because the HERS model primarily compares the loan performance of ENERGY STAR residences, the results may be interpreted as an argument for considering the degree of energy efficiency in the mortgage underwriting process.

Figure 1: Geographical Distribution of the Sample (ENERGY STAR and Non-ENERGY STAR Residences)



Data Description

The study uses a carefully constructed sample of loans across the nation. First, we obtained addresses of 226,962 HERS-rated homes from RESNET's database and directly from individual HERS providers. These houses obtained a HERS rating from 2000-2010. Because of data privacy restrictions,[11] inconsistent addresses, and low numbers market share of HERS-rated homes, the states of Alaska, Arizona, California, Louisiana, Maine, Minnesota, North Dakota, Oregon, South Dakota, Tennessee, West Virginia, and Wyoming are excluded from the sample (Figure 1).

Each of the addresses is matched to addresses in CoreLogic's loan level database. For each of these matched records within the zip code, loan information of approximately three other loan records was also included in the sample. It is assumed that these houses are not energy efficient and are considered part of the "control" group. Furthermore, the sample is restricted to single-family owner-occupied houses whose loans originated from January 2002 and loans that were used for purchase only.

All the loan level variables including payment stream were provided by CoreLogic. Prepayment is defined as loans being paid off prematurely. Consistent with prior work, 90 days delinquency is used to capture mortgage default. Similarly, the key risk determinants at origination are included in the model: borrower credit score (FICO), loan-to-value ratio, loan type (conventional/government and non-profit organizations backed), local unemployment rate, neighborhood income, house value relative to the area median value, debt-to-income ratio, size of the house, and age of the house (Table 1).

We constructed the neighborhood level variables from multiple sources. CoreLogic's MarketTrends database was used to include variables such as the number of foreclosures and the number of properties own by lenders (REOs) in the area. Unemployment rate, median housing value, and household income were retrieved from the 2006-2010 Census American Community Survey at the census-tract level. Geographic weighting was used to aggregate the data to the zip-code level.

In addition to the ENERGY STAR and HERS rating, we included a number of other energy-use-related variables in the analysis, including the number of cooling days, number of heating days, electricity prices, and area of the house. Weather data, such as average annual (over the last decade) cooling degree days and heating degree days, are obtained from the National Climatic Data Center. Each weather station is assigned to a block group and then data were aggregated to zip-code level through geographic weighting. Electricity prices are used as a proxy for cost

11 While energy-efficient homes enjoy a large market share in California, consumer privacy restrictions prevented the access to address and rating data for California HERS-rated homes.

Table 1: Average Values for ENERGY STAR and Non-ENERGY STAR Homes in the National Sample

Variables	Non-ENERGY STAR Homes	ENERGY STAR Homes
n	46,118	24,944
Age of House	13.2	4.2
Area (sq.ft.)	2,183	2,283
Origination LTV	0.91	0.93
FICO Score	706.1	705.3
Zip Code Average Income	$73,741	$73,550
Zip Code Unemployment	6.4	6.4
Time to Default	30.6	29.9
Sale Price	$218,461	$ 221,919
Cooling Degree Days	1,486	1,494
Heating Degree Days	1,308	1,199
Electricity Price (¢/kWh)	12.2	12.1

of energy. Prices at the zip-code level are obtained from Open Energy Info[12] and compiled by NREL and Ventyx for both investor-owned utilities (IOU) and non-IOU utilities. Approximately 1,300 zip codes were without data. They were estimated from neighboring zip codes and through manual lookup. These zip-code level neighborhood variables were then added to the address-level loan information. The addresses were then de-identified and the analysis conducted on this dataset.

Overall, the final analysis file for the baseline model includes information on about 71,000 loans. This number results from limiting the sample to 30-year fixed-rate mortgages,[13] the first five years after origination, loans with original loan-to-value ratios between 50% and 150%, and excluding cases with missing values in key determinants. All 71,000 loans are included in our baseline model estimation. Only the ENERGY STAR homes (~35% or 21,000) are included in the model that examines the relationship between the extent of energy efficiency and mortgage termination risks.

Descriptively, ENERGY STAR homes show lower incidences of default and prepayment. About 23% of the ENERGY STAR home loans prepaid compared with 33% for the non-ENERGY STAR group. Similarly, while mortgages on only 8% of ENERGY STAR homes have experienced default (on average after 29.9 months), about 15% of mortgages on the non-ENERGY STAR homes group did (on average, after 30.8 months). Other notable differences include the fact that ENERGY STAR houses are newer than other homes and, while the average ENERGY STAR house is larger, the price per square foot is remarkably similar between the two groups (~$106/sq. ft.). As for the rest of the key variables, both treatments and control groups have similar characteristics.[14]

Energy Efficiency Associated with Lower Mortgage Risks

Overall, the findings are consistent with prior work and expectations (Table 2).

In the baseline model, we examine the relationship between ENERGY STAR rating and the mortgage risks (Table 3), i.e., when *C* is the indicator variable that represents whether a home has ENERGY STAR certification. To further examine, the effect of relative efficiency on mortgage risks, we examine the subsample of ENERGY STAR-certified houses for which we have a HERS rating (Table 4). In addition to the variables included

12 http://en.openei.org/wiki/Gateway:Utilities (Accessed September 2012).

13 Adjustable-rate mortgages (ARM) and other types of loans require panel data that tracks the payment schedule and time-arying attributes. Such data are not available and the models used in the study are not suitable to study such mortgages, but should be considered in future work.

14 To account for the distributional differences in age, we also restricted the sample to houses that were built in the last decade. The findings are similar in direction and significance as those presented here. Refer to the Appendix for findings when restricting the sample to post-2000 homes (Table 3B).

Table 2: Summary of Findings

	BASELINE MODEL		HERS RATING SAMPLE	
	Default	Prepayment	Default	Prepayment
ENERGY STAR Certification	--	--	N/A	N/A
HERS Rating	N/A	N/A	++	++
FICO Score	--	++	--	++
Origination Loan-to-Value Ratio	++	--	+	--
Age of the House	--	--	-	--
Loan Type	++	++	++	++
Neighborhood Unemployment Rate	++	--	+	--
Neighborhood Income	++	++	++	+
House Value/ Area Median Sale Price	--	++	--	+

Note: ++, -- represent statistically significant results and +, - represent insignificant results.

Table 3: Base Model (All Data)

	DEFAULT				PREPAY			
Variable	Estimate	Std. Err.	Sig	Odds Ratio	Estimate	Std. Err.	Sig	Odds Ratio
Intercept	8.91	0.37	***		1.94	0.26	***	
FICO Score	-0.01	0.00	***	0.99	0.00	0.00	***	1.00
Loan Origination After 2006	-2.92	0.05	***	0.05	-3.03	0.04	***	0.05
Original Loan to Value Ratio	0.79	0.17	***	2.20	-1.51	0.12	***	0.22
Loan Type	1.31	0.04	***	3.72	0.33	0.03	***	1.39
Zip Code Average Unemployment	0.03	0.01	***	1.03	-0.04	0.00	***	0.96
Zip Code Average Income	0.00	0.00	***	1.00	0.00	0.00	***	1.00
House Price Relative to Zip Code Sale Price	-0.13	0.03	***	0.87	0.16	0.02	***	1.18
Age of the House	-0.01	0.00	***	0.99	-0.01	0.00	***	0.99
ENERGY STAR Certification	-0.39	0.03	***	0.68	-0.32	0.02	***	0.73

n=71,062. Log likelihood=-52,007.6
*** $p <= 0.001$, ** $p <= 0.01$, * $p <= 0.05$, · $p <= 0.1$

in the baseline model, the HERS model incorporates additional variables that capture local energy use characteristics. These include cooling degree days, heating degree days, electricity price and area of the house.

ENERGY STAR certification is associated with substantial and significant reduction in the default and prepayment risks (Table 4). The odds of a mortgage default on an ENERGY STAR residence, *ceteris paribus*, are one-third less than those on a home in the control group. A mortgage on an ENERGY STAR residence is also one-fourth less likely to be prepaid. With regard to whether the extent of energy efficiency matters (HERS rating), the findings are consistent with expectations (Table 4). Controlling for other factors, more efficiency, measured by a point decrease in the HERS score, is associated with a decrease in the risk of default by 4% and in that of prepayment by 2%. This suggests that mortgages on more efficient homes exhibit even lower mortgage risks than those on their less-efficient but still ENERGY STAR-rated counterparts.

As a rule, the other predictors in both models exhibit the expected effects. Borrower credit score (FICO) is significantly and positively associated with prepayment and negatively associated with default in both the baseline and HERS models. Original loan-to-value (OLTV) ratio exhibits significant and positive effects on default and negative effects on prepayment. Controlling for the state-fixed effects, the effect of OLTV is insignificant in the HERS model for default, though increasing OLTV reduces the prepayment risk. In this dataset, conventional loans have higher default and prepayment risks compared to government-backed (include Fannie Mae and Freddie Mac) and nonprofit loans, probably because the loans tend to carry more favorable terms and servicing. Local unemployment rates are positively associated with default risks in the baseline model and negatively associated with prepayment risks in both models. While higher neighborhood incomes increase the default and prepayment rates, the effects are substantively small. This result is likely due to the coarseness of the neighborhood that evens out any spillover effects. Older houses are both less likely to default and prepay. Finally, houses with values higher than the neighborhood mean exhibit lower default and higher prepayment propensities, reflecting the underlying income effect.

Energy prices do not seem to have an effect on the default likelihood but do negatively affect prepayment risks within ENERGY STAR homes (Table 4), i.e., higher energy costs reduce the risk of prepayment. Controlling for the relative price of the house, larger houses have higher prepayment and default risks. Age of the loan is included as a set of dummies in the models. The higher the age of the loan, the more likely the risk of default. Dummies for the state are also used in the models to control for the state-fixed effects, and are almost all statistically insignificant in the baseline models.[15] These model results are qualitatively consistent with other specifications and hence the results are robust.

15 They are not presented in the tables for brevity. A complete set of results is available from the authors.

Implications for Public Policy and Research

As the Great Recession has made painfully obvious, the mispricing of mortgage risks can have serious implications. Similarly, the mispricing of risks can have serious negative implications in the recovery. Efficiency will be hurt when credit decisions do not take into consideration important risk information. The models suggest that mortgages on energy-efficient housing loans have significantly lower risks than those on less efficient homes, yet mortgage underwriting practices do not reflect this fact. We find that mortgages on energy-efficient homes are associated with lower mortgage risks. Default risks on these mortgages are about one-third lower than those in the control group. We also find that the extent of energy efficiency matters: the more energy efficiency, the lower the risks.

Table 4: HERS Model (Only with ENERGY STAR Homes)

	DEFAULT				PREPAY			
Variable	Estimate	Std. Err.	Sig	Odds Ratio	Estimate	Std. Err.	Sig	Odds Ratio
Intercept	10.25	1.19	***		-0.49	0.74		
FICO Score	-0.02	0.00	***	0.98	0.00	0.00	***	1.00
Loan Origination After 2006	-3.76	0.18	***	0.02	-2.29	0.15	***	0.10
Original Loan-to-Value Ratio	0.30	0.44		1.35	-1.19	0.25	***	0.30
Loan Type	0.58	0.09	***	1.78	0.22	0.06	***	1.24
Zip Code Average Unemployment	0.02	0.01		1.02	-0.05	0.01	***	0.95
Zip Code Average Income	0.00	0.00	***	1.00	0.00	0.00	.	1.00
House Price Relative to Zip Code Sale Price	-0.18	0.08	*	0.83	0.10	0.04	*	1.11
Cooling Degree Days	0.00	0.02		1.00	-0.07	0.01	***	0.93
Heating Degree Days	-0.04	0.02	*	0.96	0.00	0.01		1.00
Electricity Price	0.01	0.01		1.01	-0.02	0.01	***	0.98
Area of the House	0.01	0.00	*	1.01	0.02	0.00	***	1.02
Age of the House	-0.01	0.02		0.99	-0.07	0.01	***	0.94
HERS Score	0.04	0.01	***	1.04	0.02	0.00	***	1.02

n=21,094, Log likelihood=-12,822.26

*** p <= 0.001, ** p <= 0.01, * p <= 0.05, . p <= 0.1

Because the findings are consistent among different model specifications and different types of subsamples, we can derive a number of implications for policy and lending practices. First, lenders may want to require an energy audit or energy rating during the process of mortgage underwriting. In the same manner that appraisals calculate the value of the home, an energy-rating determination could define other important characteristics of the loan, including the debt-to-income ratio. Requiring energy audits as part of the mortgage underwriting process would help homeowners make informed decisions about energy efficiency investments and likely promote long-term efficiency of the house rather than a single-time certification. This alone is likely to increase the energy performance of housing stock.

Second, lenders and secondary market investors should take into account the energy efficiency of the home used as collateral for the loan in the underwriting decisions. For instance, they may allow for a higher debt-to-income ratio, lower FICO score, or a reduction in the interest rate. Relaxing the residual income standards for some types of mortgages that will account for the degree of efficiency of the house may be another option. Any of these approaches would allow borrowers to obtain larger loans. This would increase affordability for many borrowers, especially in high-cost areas. Loan-level price adjustments (LLPAs) could also be used to account for mortgages on energy-efficient homes. Moreover, when possible, lenders should consider a HERS or similar rating that accounts for degrees of energy efficiency in a unit as well.

According to a study by the Joint Center for Housing Studies at Harvard University, two-fifths of home remodeling spending is for building envelope replacements and system upgrades (including electrical and HVAC systems).[16] Given that this was a $275 billion market in 2011, this represents about $100 billion investment by consumers that can be geared towards energy efficiency. One of the ways to promote these energy efficiency investments is to consider the underwriting rules for the home improvement loans by factoring in the decreased risk associated with energy-efficient homes. Another is to find mechanisms to encourage time-of-sale improvements on energy-efficiency measures. In particular, this is likely to help lower-income borrowers, who tend to purchase older homes that are often less energy efficient than those built in more recent years. The U.S. Environmental Protection Agency should encourage more lenders to join the ENERGY STAR program to broaden the consideration of energy efficiency in mortgage underwriting. The low numbers of lenders associated with the ENERGY STAR program should be addressed.

One of the criticisms of the ENERGY STAR program[17] in the green building community is that the standards of the program are too low to merit incentives (Hassel, Blasnick, and Hannas, 2009). One possible way of promoting energy efficiency is to move towards performance-based metrics rather than design-based certifications. Most of the narrowing gap between the utility savings of ENERGY STAR and those without that rating can be attributed to overall energy efficiency improvements in more recently built housing. While this study does not directly use the realized energy savings in mortgage performance, other studies show that standards for ENERGY STAR could be tightened, including moving towards more performance-based approaches. Future studies could examine this more thoroughly.

Future work needs to address a number of issues associated with this research. It needs to address the so-called endogeneity issue common in most mortgage performance studies. Mortgage borrowers who reside in energy-efficient homes may simply be more financially able than those who own less efficient homes. Panel data that tracks the borrower's income and market conditions is not available that will allow us to tease these effects. Future research also needs to examine additional measures of energy efficiency. While HERS can predict average energy costs in general, individual ratings, especially for older houses, are largely uncorrelated with the energy costs (Stein and Meier 2000). Therefore, better measures of energy savings could be considered in future studies to capture more fully its impact on mortgage risks. Future research should use a broader sample to study the effect on risk. Furthermore, other rating systems that promote more comprehensive green building strategies could also be examined for their effect on mortgage risk. However, overall, we believe the findings in this paper are robust and consistent enough across different model specifications to warrant further examination.

16 http://www.jchs.harvard.edu/sites/jchs.harvard.edu/files/harvard_jchs_remodeling_report_2013.pdf (Accessed February 20, 2013)

17 A recent General Accounting Office report found that the ENERGY STAR certification process for products can also be strengthened (USGAO 2010).

In general, the findings suggest that energy efficiency and the degree of energy efficiency matter. By reducing the household energy burden, the models suggest that owners of efficient homes are more likely to continue to meet their mortgage obligations. The lower risks associated with energy efficiency should be taken into consideration when underwriting mortgage risks. As such, Congress should consider the findings in their deliberations of the SAVE Act, the bill proposed to improve the accuracy of mortgage underwriting used by federal mortgage agencies by ensuring that energy costs are included in the underwriting process. Similarly, market stakeholders, such as Fannie Mae and Freddie Mac, could encourage underwriting flexibility for mortgages on energy-efficient homes, for instance by adjusting LLPAs or their equivalents accordingly. These measures have potential to dramatically increase the adoption of efficiency, contribute to reduction of the energy burden, and increase the quality of life for households across the United States.

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Appendix

Table 1B: Average Values for ENERGY STAR and Non-ENERGY STAR Homes for Houses Built after 2000

Variables	Non ENERGY STAR Homes	ENERGY STAR Homes
n	33,001	24,915
Age of House	5.8	4.1
Area (sq.ft.)	2,311	2,283
Original Loan to Value Ratio	0.91	0.93
FICO Score	706	705.3
Zip Code Average Income	$ 74,181	$ 73,550
Zip Code Unemployment	6.53	6.35
Time to Default	30.8	29.9
Sale Price	$ 226,708	$ 221,699
Cooling Degree Days	1,573	1,494
Heating Degree Days	1,184	1,198
Electricity Price	12.2	12.1

Table 3B: Base Model (Houses Built after 2000)

	DEFAULT				PREPAY			
Variable	Estimate	Std. Err.	Sig	Odds Ratio	Estimate	Std. Err.	Sig	Odds Ratio
Intercept	11.32	0.45	***		3.21	0.32	***	
FICO Score	-0.01	0.00	***	0.99	0.00	0.00	***	1.00
Loan Origination After 2006	-2.96	0.06	***	0.05	-3.06	0.06	***	0.05
Original Loan to Value Ratio	0.29	0.20		1.34	-1.72	0.14	***	0.18
Loan Type	1.25	0.04	***	3.48	0.23	0.03	***	1.26
Zip Code Average Unemployment	0.02	0.01	***	1.02	-0.05	0.01	***	0.95
Zip Code Average Income	0.00	0.00	***	1.00	0.00	0.00	***	1.00
House Price Relative to Zip Code Sale Price	-0.26	0.04	***	0.77	0.15	0.02	***	1.16
Age of the House	-0.24	0.01	***	0.79	-0.16	0.01	***	0.85
ENERGY STAR Certification	-0.65	0.03	***	0.52	-0.52	0.03	***	0.60

n=56,787. Log likelihood=-40,447.8
*** p <= 0.001, ** p <= 0.01, * p <= 0.05, . p <= 0.1

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