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# Implications of Energy Ratings for Residential Real Estate Markets

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# Implications of Energy Ratings for Residential Real Estate Markets

## Executive Summary

**Timothy Riddiough and Todd Schatzki**[1]

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Given inaction at the federal level, state and local governments have stepped up efforts to address climate change. In particular, many areas have introduced or are considering the introduction of mandatory disclosure of energy ratings at the time a residential real estate property is listed for sale. These ratings typically measure a property's energy efficiency "performance" through a single metric, similar to product ratings developed by Consumer Reports.

In this paper we evaluate whether energy rating requirements used in conjunction with the residential property listing process are a useful policy tool to help mitigate environmental impacts or to achieve related policy goals. We find that while home sellers might sensibly provide energy ratings to complement other information of potential interest to possible homebuyers, mandating the use of such ratings is not, in general, warranted.

While requirements to disclose certain information during the listing process or at the time of house sale (title transfer) have existed for decades, these requirements are primarily aimed at addressing serious asymmetric information and bargaining problems between buyers and sellers, as well as problems between buyers, mortgage lenders, and other agents to the sales transaction. The rationale for such regulation is that home purchases occur infrequently over the life of the homeowner, but when they happen they come with large personal and financial consequences. In order to help protect buyers who have little practical experience with real estate transactions, legal requirements largely relate to the truthful disclosure of information regarding health and safety risks, closing costs, and mortgage financing terms. Mandatory information disclosure regarding energy efficiency, performance, and cost has not been required until recently, and only by certain localities. We note that information about household energy performance is different from transactional types of disclosure regulation, not directly affecting health and safety or having large relative financial effects. Indeed, many aspects of residential property energy use and efficiency are readily observable to prospective buyers. Moreover, buyers (and sellers) have multiple ways to obtain information regarding their own energy use and costs. Economic research suggests that buyers can, to a large degree, account for differences in expected energy expenditures between properties given available information.

Mandatory energy ratings do not directly address any of the market failures that contribute to excess energy use and its associated large-scale environmental impacts, particularly the excess use of energy that occurs when energy prices do not "internalize" the cost of these environmental impacts. Other market failures that may limit

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[1] Dr. Riddiough holds the James A. Graaskamp Chair and is a professor in the Department of Real Estate and Urban Land Economics at the University of Wisconsin - Madison. Dr. Schatzki is a Principal at Analysis Group. Support was provided by the Greater Boston Real Estate Board, but the opinions expressed are exclusively those of the authors. Research assistance was provided by Igor Karagodsky and Heather Banic. To request further information or provide comments, Dr. Schatzki can be reached at: todd.schatzki@analysisgroup.com.

household investment in energy efficiency, moreover, are not directly addressed by energy rates, either. Given these investment-related market failures, local or state governments sometimes subsidize energy audits intended to help homeowners identify cost-effective ways to lower energy use. Policy typically relies on a combination of subsidies and education rather than mandatory requirements because reliable audits are costly to undertake, among other factors.

Energy ratings are often generated by complex formulas, the inputs of which are various characteristics and attributes of the real property being scrutinized. This approach has been developed to economize on cost and to reduce the risk that certifiers may submit erroneous ratings. But formulaic approaches can be problematic: their inner workings can be opaque, misspecification can lead to inaccurate assessments, and ultimately they may provide limited information about actual energy efficiency and energy costs. Many ratings, for example, do not measure the financial and environmental consequences of engineering and structural information. Some ratings provide only an alphabetic (A to F) or ordinal (1 to 10) ranking of a property's performance relative to other properties. Such metrics do little to help a homebuyer estimate future energy expenditures. Moreover, the specification of an engineering model may not account for all relevant property features. In fact, because there is no industry consensus on the proper way to measure energy performance, variation in the choice and weighting of energy-efficiency factors leads to variation in ratings outcomes across engineering model specifications.

Energy ratings are costly to undertake, and at present there is no clear evidence that mandating their disclosure at the time of property listing reduces energy use or leads to investment in energy-efficient technologies. By contrast, many other policies targeting household energy use and investment have demonstrated efficacy from both an environmental and cost perspective. These other policies often try to influence consumer energy use or investment behavior directly. Given that the behavioral pathway by which energy ratings would affect energy use or investment decisions is indirect at best, established alternatives offer better policy approaches.

In addition to the substantial uncertainty about their efficacy, an energy rating requirement may have unintended consequences. In particular, their impact on property prices may exceed an adjustment consistent with the underlying differences in energy costs. Economic research confirms that energy ratings affect property values in the expected direction – that is, higher ratings lead to higher valuations ("premiums") and lower ratings lead to lower valuations ("discounts"). However, research has found that the magnitude of these premiums and discounts does not appear to accurately reflect the capitalized value of expected future energy expenditures. Instead, these premiums and discounts appear to *inflate* differences in expected future energy expenditures across properties with different ratings. The reason for this inflation of premiums and discounts is unclear. It could reflect overattention to future energy expenditures (perhaps due to the salience of the information provided) or personal preferences (e.g., the cachet of owning a highly rated home, or the stigma of owning a lower rated home). In any case, evidence to date indicates that mandatory energy ratings can lead to home-value effects that are incommensurate with the changes in energy costs that the policy was designed to incentivize. And economic research finds that these home-value effects could be large, with changes in property values potentially on the order of tens of thousands of dollars.

Energy ratings appear to have complex distributional consequences, with the nature of these impacts depending on the type of rating system adopted and characteristics of the local housing stock. Our empirical analysis indicates that energy ratings may vary widely across localized geographic areas, with variation reflecting a variety of factors, including socioeconomics (e.g., age and income), vintage of the housing stock, typical house sizes, and the homes' stock of physical amenities. Interestingly, we do not see a discernable relationship between income/wealth and energy ratings, on average. While properties owned by higher-income/wealth households tend to have a greater quantity of energy efficiency features that increase energy ratings, they also tend to have larger house sizes, which increases energy usage and lowers scores. Thus, these two factors – energy efficiency (on a per-square-foot basis) and house size – offset each other to some degree.

## Implications of Energy Ratings for Residential Real Estate Markets

**Timothy Riddiough and Todd Schatzki**[2]
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# I. Introduction

Residential households account for 22% of the energy use in the United States (US), a large fraction of this total reflecting energy uses that depend on housing size, condition, systems, age, and other qualities. For example, heating and air conditioning systems, window quality, wall and attic insulation, home design, and lighting systems are all known to affect energy use. At 22% of total US energy consumption, household energy use is an important contributor to various environmental problems, most notably climate change effects due to greenhouse gas (GHG) emissions.

Given growing concerns about climate change and environmental degradation, policymakers have begun to develop measures aimed at addressing these impacts. The suite of measures being considered is large, and includes policies that target the underlying environmental problem (e.g., GHG pricing through cap-and-trade), policies that mandate technology changes (e.g., renewable portfolio standards, low carbon fuel standards), and policies that target energy use and investment in energy efficiency (e.g., utility energy efficiency programs). Rather than pursue a single strategy, policymakers are often adopting a "belt and suspenders" approach that adopts multiple measures simultaneously.

This paper addresses one particular measure that is receiving increased attention: mandatory disclosure of building energy "ratings" for newly listed residential properties through an energy "scorecard."[3] An energy rating is a measure that attempts to communicate a property's energy efficiency or total energy use performance through a single metric – e.g., a numerical score or a letter grade – similar to product ratings provided by Consumer Reports. While methods underlying these rating metrics have been available for some time, discussions in the US about mandating their use is relatively recent. Indeed, as local and state regulators expand their lists of potential policy responses to global climate concerns, mandating residential household energy ratings has gained increasing favor among policymakers.

Our paper evaluates the efficacy of policy responses that would require the use of residential energy ratings. We do this by analyzing the economics of both product information disclosure and environmental protection. The paper proceeds as follows. First, we discuss and evaluate potential rationales for regulation related to household energy ratings. Second, we consider the details of energy ratings, including the information provided by energy ratings,

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[2] Dr. Riddiough holds the James A. Graaskamp Chair and is a professor in the Department of Real Estate and Urban Land Economics at the University of Wisconsin - Madison. Dr. Schatzki is a Principal at Analysis Group. Support was provided by the Greater Boston Real Estate Board, but the opinions expressed are exclusively those of the authors. Research assistance was provided by Igor Karagodsky and Heather Banic. To request further information or provide comments, Dr. Schatzki can be reached at: todd.schatzki@analysisgroup.com.

[3] In this paper we do not consider energy rating requirements that target commercial and multifamily properties. For more information on these requirements, see Robert N. Stavins, Todd Schatzki, and Jonathan Borck, "An Economic Perspective on Building Labeling Policies," March 28, 2013 (hereafter "Stavins, Schatzki, and Borck, 2013"); and Natalie Mims et al., "Evaluation of U.S. Building Energy Benchmarking and Transparency Programs: Attributes, Impacts, and Best Practices," Energy Analysis and Environmental Impacts Division, Lawrence Berkeley National Laboratory, April 28, 2017.

how the information is generated, and the ratings' costs and impact on environmental outcomes. Third, using available data, we evaluate the potential impacts of using energy ratings on residential real estate market outcomes.

# II. Market Failures Associated with Household Energy Use

Generally speaking, from an economic perspective, the primary purpose of regulatory interventions is to remedy "market failures" that prevent markets from arriving at economically efficient outcomes. If a regulation can create net benefits, addressing the market failure without imposing excessive costs or significant unintended consequences, economic outcomes can be improved.

Several rationales have been offered to justify mandatory requirements for household energy ratings to be provided at the time a homeowner lists their house for sale. One rationale is that inadequate information on household energy efficiency is currently disclosed to potential buyers. From this perspective, the regulation might help protect consumers and improve real estate market efficiency. A second rationale is that energy ratings can help mitigate environmental impacts (negative "externalities"), particularly those related to global climate change, by reducing household energy use. We consider each rationale individually, below.

## A. Required Disclosure of Information on Residential Real Estate Properties

Disclosure of information on a product's quality may be required when inadequate information provision, asymmetric information, or asymmetric power relationships exist between buyers and sellers or between buyers and agents involved in a real estate transaction. In some circumstances, information problems or power relationships can diminish market efficiency. For example, automobiles with hidden defects ("lemons") may be hard for buyers to detect before purchase, which may reduce demand for all vehicles if buyers are fearful of purchasing a defective automobile. However, it is often the case that markets self-correct for these informational problems through the voluntary disclosure of information about product quality or by offering warranties.[4] In contrast to voluntary disclosure and other market-based solutions, mandatory requirements for information disclosure can introduce their own set of problems. Thus, when assessing whether disclosure requirements are beneficial from a societal standpoint, it is important to evaluate the particular circumstances and available remedies.

Residential real estate is a particularly heterogeneous good. Each property is unique, and the list of features that affect a property's market value is long, including structural features (interior space, number of bedrooms and bathrooms, built-in appliances, kitchen quality and vintage, etc.), property conditions (structural condition and defects, health and safety hazards, etc.), locational features (on-street traffic levels, proximity to public transportation, distance to schools, etc.), and neighborhood amenities (school quality, neighborhood housing quality, town services, etc.). Potential buyers thus have many different features to consider when assessing a property's value and desirability.

[4] See David Dranove and Ginger Zhe Jin, "Quality Disclosure and Certification: Theory and Practice," *Journal of Economic Literature* 48(4): 935-963, December 2010; Sanford Grossman, "The Informational Role of Warranties and Private Disclosure about Product Quality," *Journal of Law and Economics* 24(3): 461-483, 1981; and Paul R. Milgrom, "Good News and Bad News: Representation Theorems and Applications," *Bell Journal of Economics* 12(2): 380-391, 1981.

Potential buyers have many ways of acquiring information about properties available on the market, including property listings on the multiple listings service (MLS), information individually supplied and tailored by the seller, responses to requests for additional information by the buyer, and home inspections. Home inspections, typically included as a contingency by the buyer once an offer to purchase has been accepted by the seller, are a standard part of the home sale process. A home inspection, with an outside expert assessing the property's physical condition, provides an opportunity to uncover material defects. Potential buyers are in a position to control the scope of home inspections and focus on particular areas of concern, including energy efficiency. Using information gained through a home inspection, buyers can bargain further over price, request remedies to any identified defects, or opt to withdraw their offer.[5]

Because there are many options available to potential buyers to acquire information about individual properties, mandatory information disclosure requirements have been limited to address certain types of issues. While the law can be complex (and potentially ambiguous), a common requirement is that information disclosure be truthful. This requirement is meant to mitigate adverse selection problems and misrepresentation of the true condition of the home.[6] To promote the truthful disclosure of information, state real estate agent associations have developed disclosure forms to be filled out by sellers. Disclosure statements typically include some information about energy systems.

A second type of information problem relates to property-specific health and safety risks, which can be difficult to identify (e.g., past structural defects not observable to an inspector).[7] Disclosure can allow buyers to avoid these risks, which may be more severe for particular populations (e.g., children). Examples related to property specific health and safety risks include the disclosure of lead paint or radon gas.[8]

Finally, disclosure requirements have been imposed to reduce the asymmetric balance of power that can exist in a real estate sales transaction. These requirements have been adopted to address concerns about certain practices (e.g., undisclosed kickbacks between intermediaries), which can inflate costs to buyers. The Real Estate Settlement Procedures Act is a prominent example of a regulation adopted to protect buyers through timely and clear disclosure of the costs and terms of various financial aspects of the real estate transaction.[9]

At first blush, it might appear that a home's energy efficiency does not to rise to the same level of social concern as the issues we just discussed. Perhaps most importantly, from a buyer's standpoint, a home's energy efficiency can be understood through voluntary disclosures or information obtained from public records or inspection. In **Section III**, we assess energy ratings in further detail, considering whether disclosure of information related to

[5] In particularly competitive markets, some prospective buyers may opt to forgo such inspections to differentiate their offers from other bidders' offers.

[6] For example, see *REALTOR Magazine*, "10 Essential Disclosure Rules," 2009, at https://magazine.realtor/law-and-ethics/law/article/2009/04/10-essential-disclosure-rules.

[7] States have also passed regulations releasing the seller from disclosure of certain information that is determined *not* to impose a risk. For example, in Massachusetts the seller must notify the buyer of any known hazards of lead in paint and plaster, but does not need to disclose the fact of a prior death, felony, or parapsychological phenomenon.

[8] States with requirements related to lead include Connecticut, Massachusetts, Maryland, New Hampshire, and Ohio, while states with requirements related to radon include Arizona, Connecticut, Delaware, Florida, Kansas, Massachusetts, Montana, New Hampshire, and New Jersey.

[9] Consumer Financial Protection Bureau, "CFPB Consumer Laws and Regulations, RESPA," https://files.consumerfinance.gov/f/201503_cfpb_regulation-x-real-estate-settlement-procedures-act.pdf.

household energy performance suffers from a market failure that creates barriers to efficient market outcomes, and whether *mandated* disclosure of a household energy rating would generate net benefits by mitigating that market failure. To preview our conclusion, we find that from the standpoint of consumer information disclosure, there is no clear rationale for mandating energy ratings. Buyers have various means of obtaining information on household energy performance, and economic research suggests that they make use of this information when making offers. Further, as we discuss below, energy ratings can have a number of unintended consequences.

## B. Mitigation of Excess Environmental Impacts

Household energy use results in various impacts to others called externalities. Negative externalities from energy consumption and production reflect impacts to natural resources such as air, water, and land. For example, health and environmental impacts arise from local and regional emissions of particular matter, nitrogen oxides, and sulfur dioxide that occur when fossil fuels are combusted to generate electricity or heat homes. Other consequences include climate change arising from GHG emissions and contamination of water by energy production and mining waste.

One policy rationale for energy ratings is that they provide a means of mitigating these negative externalities. Information about energy performance does not provide any direct incentive for households to change their energy use. In contrast to carbon pricing, which directly affects homeowners' incentives to consume energy by internalizing the cost of externalities into energy prices, the availability of information about a home's energy performance does not directly affect financial outcomes. Energy ratings may, however, indirectly affect homeowner behavior, although the direction of this impact is ambiguous. Energy ratings could cause some homeowners to lower energy use if those with low ratings become more aware of energy costs, although ratings could also cause some homeowners to increase energy use if those with high energy ratings use more energy than they otherwise would (the so-called "rebound effect").[10]

Proposals for mandatory energy ratings are also motivated by market and behavioral failures related to occupants' energy technology investment. The central issue here is the *apparent* failure of households (as well as businesses) to adopt cost-effective, energy-efficient technologies, leading to the so-called "energy paradox."[11] This apparent phenomenon has motivated policies directed toward increasing investment in energy-efficient technologies, including the creation of energy rating programs, which are the subject of this paper. Many economic factors may impede the adoption of cost-effective energy-efficient technologies, including *market failures* that prevent markets on their own from achieving an efficient allocation of resources, *behavioral failures* that lead people's actual decisions and choices to differ systematically from economically "rational" decisions, and *market barriers* that impede the adoption of new technologies or investment in energy efficiency.[12] Policymakers have aimed to address these factors in a number of ways, including subsidization of energy audits and energy-efficient investments, low-cost financing of energy-efficient investments, and education and communications regarding the

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[10] Kenneth Gillingham et al., "The Rebound Effect and Energy Efficiency Policy," *Review of Environmental Economics and Policy* 10(1): 68-88, January 2016.

[11] See Stavins, Schatzki, and Borck, 2013; Adam Jaffe and Robert N. Stavins, "The Energy Efficiency Gap: What Does It Mean?" *Energy Policy* (1994) 22:804-810; and Adam Jaffe, Richard Newell, and Robert N. Stavins, "The Economics of Energy Efficiency," in *Encyclopedia of Energy,* Cutler J. Cleveland, editor; Amsterdam: Elsevier, pp. 79–90.

[12] Stavins, Schatzki, and Borck, 2013.

potential gains from energy-efficient investments. From this vantage point, energy rating requirements are a new approach in a long history of policy interventions.

Mandating energy ratings may, however, do little to encourage homeowners to make investments in energy efficiency. An energy rating provides the homeowner with no information on what types of actions would improve a home's performance. Pertinent information about cost-effective investment in energy efficiency generally requires an *energy audit,* performed by a qualified energy assessor. Because there are potential efficiencies to securing an energy rating and an energy audit at the same time, energy scorecards often include both an energy rating and the findings of a cursory energy audit.

It is beyond the scope of this paper to evaluate the complex set of issues associated with energy audits, particularly in light of the substantial programmatic experience with audits and the past efforts to expand voluntary audit participation. However, we can make several observations regarding audits and audit requirements in relation to mandatory requirements for energy ratings.

First, requirements that households undertake audits are uncommon. One reason for this is that the cost of a reliable audit is non-trivial, and an audit requirement would introduce costs for homeowners that have no intention of acting on audit recommendations. Instead, policies typically aim to encourage households to undertake audits voluntarily. But even under these circumstances, follow-through on audit recommendations is often limited. Thus, an on-going challenge of effective energy efficiency program design is increasing follow-through on audit recommendations. We have no reason to believe that mandating energy ratings at the time of property listing would necessarily enhance audit program effectiveness, particularly given other policy options such as making audits available when new owners sign up for electric and gas utility service.

Second, some argue that energy ratings serve as a complement to energy audits by drawing attention to audit findings. For voluntary audits, including an energy rating could increase attention to energy performance, making it more likely that property owners act on opportunities to invest in cost-effective energy technologies that are identified by an audit. But, decision to use energy ratings within a voluntary energy audit is separate from the decision about whether to mandate energy ratings or audits, rather than keep audits (with or without ratings) voluntary.

Third, there are assertions that energy ratings improve homeowners' ability to credibly convey information about energy performance to potential buyers, thus increasing their ability to recover the costs of investments in energy efficiency through higher sale prices or rents. But if sellers want to ensure that buyers are aware of the cost efficient features, they can convey information on energy efficiency improvements voluntarily. Such information may include features that are not immediately visible (e.g., wall and attic insulation, high efficiency windows and energy systems), as well as features that are easily visible (e.g., new double-paned windows). Given the value inherent in conveying such information, sellers have the incentive to disclose it voluntarily, and it should be unnecessary to mandate such disclosure.

Below, as we evaluate the details of residential household energy ratings, we also consider whether energy ratings address market failures related to household energy efficiency investment. To preview, we find that there is little evidence that energy ratings address the potential market and behavioral failures identified above.

# III. Residential Household Energy Ratings

An energy rating integrates information about housing structure and energy systems into a single metric.[13] If an energy rating is required at the time of a sale listing, in principle it can help a potential buyer assess future energy expenditures. A more energy-efficient home will have lower utility bills, making the home more valuable, all else equal. Thus, with this information, an interested buyer can adjust the offer to reflect expected future utility costs. Energy ratings may also influence a potential buyer's valuation if he or she has a preference to live in a "green" home.

Different energy rating methods have emerged over the years, but to date there is no consensus standard. In an effort to control for differences in current occupants' usage patterns, methods generally utilize an engineering algorithm or formula to translate information about a property and its systems and structures into a summary score. Some scores yield an ordinal ranking (e.g., 1 to 10 or A to F), while others produce a more technical measure (e.g., energy use based on industry metrics). Examples of rating systems include the Home Energy Rating System (HERS) developed by the US Department of Energy (US DOE), the Energy Performance Score (EPS) used in several state pilot programs (including Massachusetts), the energy performance certificates (EPC) used in the United Kingdom (UK) and Denmark, and the building energy rating certificate (BER) used in Ireland.

Another type of energy performance rating is recognition that a minimum energy efficiency quality standard has been met. This is sometimes called a "green label."[14] To date, green labels have only been used through voluntary programs that provide homeowners the opportunity to demonstrate that their homes meet certain "green" standards.

As discussed above, absent an energy rating, potential buyers have many other means of obtaining information on a property's energy performance. Existing disclosures may include information related to a property's energy efficiency or energy performance. Disclosure forms include information related to a property's energy systems (e.g., type of HVAC systems, age of systems) and actions taken to conserve energy (e.g., type of wall and ceiling insulation, if any). In addition, potential buyers can openly observe the property's physical structure (e.g., type of windows, apparent age, and type of energy systems), obtain information through a home inspection, and request utility bills.

There is strong evidence that buyers use this information when making offers to purchase houses. Research shows that real estate transaction prices reflect expected future energy costs, which is consistent with the conclusion that current sources of information allow buyers to account for energy cost effects.[15] One recent study

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[13] The US Department of Energy (US DOE) writes that an energy rating "lets the homeowner understand how efficient the home is and how it compares to others." US DOE, "Home Energy Score Scoring Methodology," February 2017 (hereafter "US DOE, 2017"), p. 3.

[14] Green labels can also consider other property features associated with lower environmental impact.

[15] See Erica Myers, "Are Home Buyers Myopic? Evidence from Capitalization of Energy Costs," (hereafter "Myers, 2017"), E2e Working Paper 024, January 2017; Terry M. Dinan and John A. Miranowski, "Estimating the Implicit Price of Energy Efficiency Improvements in the Residential Housing Market: A Hedonic Approach," *Journal of Urban Economics* 25(1), 1989, pp. 52–67; Ruth C. Johnson and David L. Kaserman, "Housing Market Capitalization of Energy-Saving Durable Good Investments," *Economic Inquiry* 21(3), July 1983, pp. 374–386; Joseph Laquatra et al., "Housing Market Capitalization of Energy Efficiency Revisited," *ACEEE Summer Study of Energy Efficiency in Buildings, Teaming for Efficiency, Proceedings 8*, 2002; and Rick Nevin and Gregory Watson, "Evidence of Rational Market Valuations for Home Energy Efficiency," *The Appraisal Journal*, October 1998, pp. 401–409.

found that home buyers' assessments of energy costs were relatively accurate and concluded that there was "little evidence that home buyers are systematically "under-valuing" future fuel costs."[16]

While the existing research indicates that potential homeowners are able to (and do) account for differences in future expected energy costs when deciding their offers, in principle energy ratings could provide *incremental* information about a property's energy efficiency, allowing the potential buyer to make an even *more precise* assessment of the property's value. Such incremental information might also be useful to potential buyers with preferences for more (or less) energy-efficient houses for reasons other than financial consequences.

## A. Challenges to Developing Energy Ratings

Developing a single measure that accurately communicates information about a property's energy efficiency and that generates improved outcomes is not a simple task.[17] Several factors contribute to the challenge of developing information to improve on homebuyers' decisions.

- ***Ratings may not accurately capture the property's energy performance.*** Unlike other products that have energy labels (e.g., vehicles, dishwashers), an energy rating assesses a property in its entirety. But each property is a large collection of different attributes, and each property is unique. By contrast, all other products with mandatory energy efficiency labels are consumer products that allow measurement of energy efficiency under controlled laboratory conditions. Moreover, past energy use is not necessarily a reliable indicator of the property's energy efficiency. Thus, accurate information on a property's inherent energy efficiency requires an assessment that is independent of the current energy use. Such assessment is typically accomplished through engineering algorithms that rely on the property's physical specifications and energy use features. However, these engineering formulas may be misspecified as well as imprecise, particularly when the property has unique features that can only be captured through a more detailed assessment.
- ***There is no clear benchmark for rating energy performance.*** Different energy rating methods can assess and convey different information depending on emphasis, model specification, and the data used to inform or estimate the model. For example, certain energy scores provide information on a property's energy efficiency relative to "similar" properties, whereas other scoring methods focus on the absolute quantity of expected energy use. Some may try to accomplish both.
  - If measured in relative terms, an energy rating typically provides no information on what constitutes "similar" properties. The criteria for similarity might (or might not) include the region the property is located in, the style of the home, and the property's size (i.e., interior square footage).
  - If measured in absolute energy terms, the metric may need to combine different types of energy consumption, including electricity, natural gas, and home heating oil, in ways that depend on certain assumptions. This in turn may complicate comparisons between properties because appropriate assumptions may vary across regions in ways that are difficult to capture or vary over time and financial consequences to homeowners depends on energy costs, which differ across energy types.

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[16] Myers, 2017, p. 3.

[17] Stavins, Schatzki, and Borck, 2013.

- ***Ratings do not provide direct information about future energy expenditures.*** While a relative energy rating provides information on a property's performance relative to other properties along, say, a numerical scale (e.g., 1 to 10), it will not explicitly help the homebuyer develop an estimate of the future energy expenditures. Green labels similarly provide no direct information about future energy expenditures. Further, while a metric reflecting benchmarked energy use does provide incremental information to help the potential homebuyer estimate future energy expenditures, developing such estimates requires many additional steps that the potential buyer may be unable (or unwilling) to do, such as collecting information on unit energy costs and translating the energy quantity (e.g., kilowatt-hours, MMBtus) into financial expenditures. As a result, information reported in technical energy units (e.g., MMBtu) may not be easily interpreted by many homebuyers.

Given all of these challenges and concerns, it is unclear the extent to which an energy rating provides reliable incremental information about a home's energy performance. In **Section IV**, we discuss empirical research suggesting that ratings do impact property values, but not necessarily in proportion to the differences in anticipated energy expenditures. If energy metrics do not provide information that helps accurately project future energy costs, this may be a contributing factor to this problem.

An additional concern with energy ratings, including green labels, is that homebuyer responses may reflect not only the property's economic value, but also behavioral factors unrelated to the property's economic value. Homebuyers may respond differently, for instance, to different presentations of the same information. Given this possibility, it is important to consider how information is to be communicated to potential homebuyers. Energy ratings can be communicated in a variety of ways, including colorful infographics with information on air emissions such as carbon dioxide ($CO_2$). **Figure 1** illustrates different energy scorecards used to communicate energy ratings, along with other information, such as audit results and estimated GHG emissions. These scorecards communicate information in different ways, and may make certain information more prominent or salient in the homebuyer's mind relative to other information. We are unaware of empirical research evaluating the impact of different modes for communicating energy rating and scorecard information on homebuyer offers.

## B. Costs of Developing Ratings

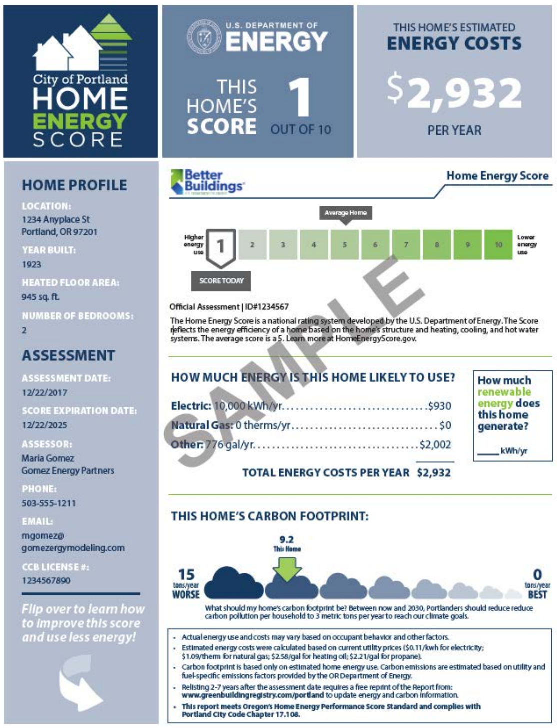
The energy certification and assessment process imposes economic costs, including the cost of hiring a qualified certifier to undertake the assessment. There are also nonfinancial costs, such as seller time (and hassle) required to identify a reliable assessor, together with potential delays in the listing process.

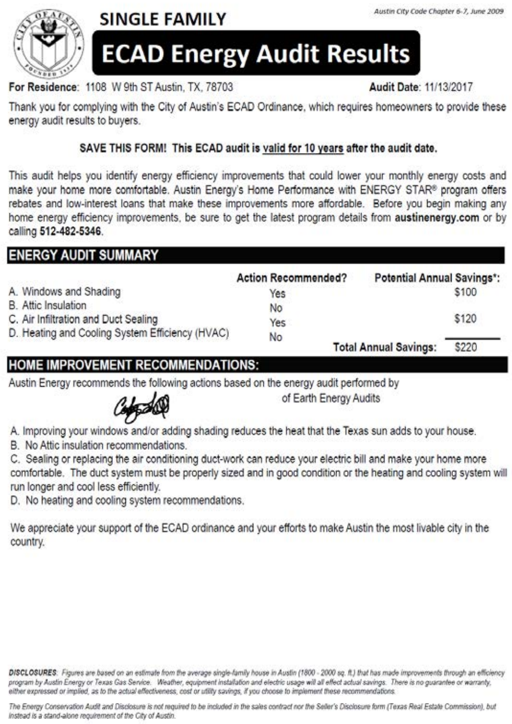
A recent survey of energy auditors found that the average fee for a basic residential home audit was about $350, while another study found average costs of $492 (with about 70% of audits costing between $300 and $700).[18] Costs to generate an energy rating may be lower than energy audit costs, as this type of assessment is less thorough than a full home energy audit. As described below, costs for energy rating assessments that are required to comply with regulations in Portland, Oregon, and Austin, Texas, range from $100 to $250, substantially below average audit costs. This suggests that audit activities accompanying these energy ratings are less thorough than the "basic" audits undertaken in the studies referenced above.

[18] Karen L. Palmer et al., "Assessing the Energy-Efficiency Gap: Results from a Survey of Home Energy Auditors," *Resources for the Future Discussion Paper No. 11-42*, October 4, 2011; and *Residential Energy Services Network, Inc.*, "National Average Cost of Home Energy Ratings," February 27, 2009.

Mandated energy ratings could also affect the functioning of the real estate market. If there is an insufficient supply of qualified assessors, for example, then mandated energy ratings could delay the transaction process. Thus, in theory, mandated energy ratings could slow the transaction process and affect the supply of properties available on the market.

**Figure 1. Portland, Austin, Massachusetts, and the United Kingdom Energy Ratings/Audits**



Austin City Code Chapter 6-7, June 2009

SINGLE FAMILY

**ECAD Energy Audit Results**

**For Residence:** 1108 W 9th ST Austin, TX, 78703 **Audit Date:** 11/13/2017

Thank you for complying with the City of Austin's ECAD Ordinance, which requires homeowners to provide these energy audit results to buyers.

**SAVE THIS FORM! This ECAD audit is valid for 10 years after the audit date.**

This audit helps you identify energy efficiency improvements that could lower your monthly energy costs and make your home more comfortable. Austin Energy's Home Performance with ENERGY STAR® program offers rebates and low-interest loans that make these improvements more affordable. Before you begin making any home energy efficiency improvements, be sure to get the latest program details from **austinenergy.com** or by calling **512-482-5346**.

**ENERGY AUDIT SUMMARY**

| | Action Recommended? | Potential Annual Savings*: |
|---|---|---|
| A. Windows and Shading | Yes | $100 |
| B. Attic Insulation | No | |
| C. Air Infiltration and Duct Sealing | Yes | $120 |
| D. Heating and Cooling System Efficiency (HVAC) | No | |
| | Total Annual Savings: | $220 |

**HOME IMPROVEMENT RECOMMENDATIONS:**

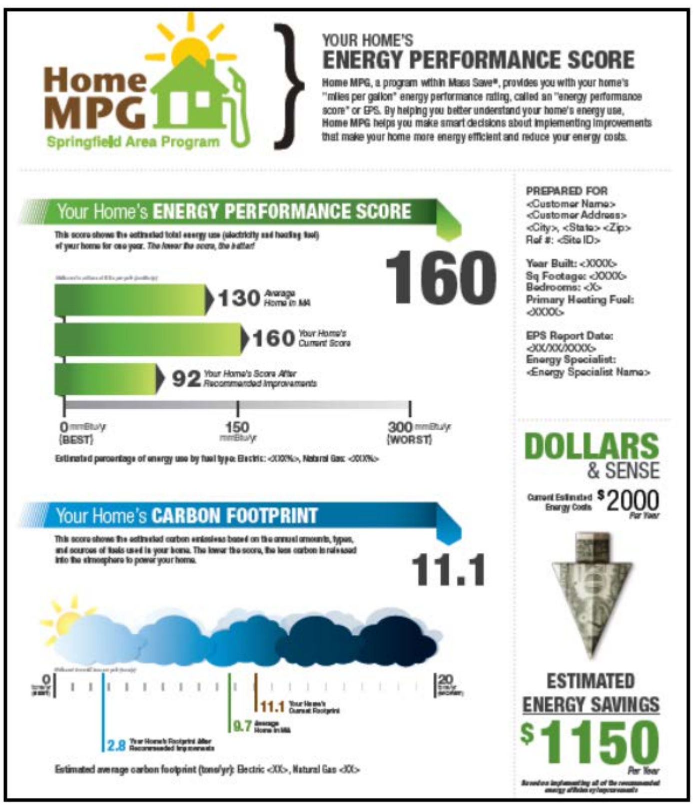
Austin Energy recommends the following actions based on the energy audit performed by of Earth Energy Audits

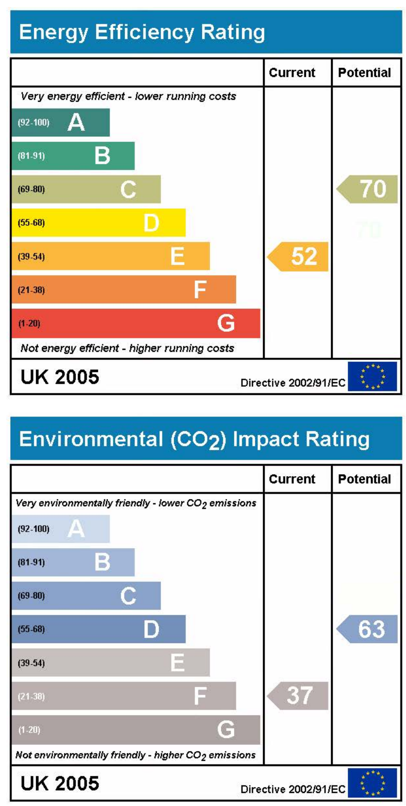
A. Improving your windows and/or adding shading reduces the heat that the Texas sun adds to your house.
B. No Attic insulation recommendations.
C. Sealing or replacing the air conditioning duct-work can reduce your electric bill and make your home more comfortable. The duct system must be properly sized and in good condition or the heating and cooling system will run longer and cool less efficiently.
D. No heating and cooling system recommendations.

We appreciate your support of the ECAD ordinance and your efforts to make Austin the most livable city in the country.

*DISCLOSURES: Figures are based on an estimate from the average single-family house in Austin (1800 - 2000 sq. ft.) that has made improvements through an efficiency program by Austin Energy or Texas Gas Service. Weather, equipment installation and electric usage will all effect actual savings. There is no guarantee or warranty, either expressed or implied, as to the actual effectiveness, cost or utility savings, if you choose to implement these recommendations.*

*The Energy Conservation Audit and Disclosure is not required to be included in the sales contract nor the Seller's Disclosure form (Texas Real Estate Commission), but instead is a stand-alone requirement of the City of Austin.*



## C. Certification of Ratings

Energy ratings are determined by third-party certifiers. These individuals typically undergo various types of training to develop the technical skills and expertise required to deliver accurate and reliable energy ratings. In addition, certifiers may require licensing by local (or state) governments to ensure that they have the requisite training, skills, and expertise.

As with any product certification or rating, there can be incentives to distort energy ratings.[19] Because an energy rating may impact a property's sale price, sellers will generally prefer a higher rating. As a result, sellers may seek out certifiers willing to provide an inflated rating, and certifiers may offer to provide inflated ratings to gain business or higher fees from sellers.

Given the existence of incentives to inflate or otherwise misrepresent energy ratings, steps should be taken to ensure accurate energy rating outcomes. Several approaches are available; however, these options may reduce program participation or raise costs. One approach is to make the rating process transparent, thereby reducing the cost of monitoring and enforcement. Use of formulaic approaches with limited opportunity for subjective judgment by the certifier can also reduce misrepresentation risk. For this reason, among others, most energy ratings rely on engineering formulas to determine a property's energy ratings. However, limiting certifier discretion may also decrease accuracy of the rating by limiting the certifier's ability to account for each property's unique characteristics. Another approach to limiting rating distortions is ongoing monitoring of certifiers to ensure that they are reporting accurately. This could be achieved by independent audit, although this could be costly.

## D. Energy (and Emission) Reductions

In order for building rating policies to generate economic benefits, they need to foster changes in occupant energy use or energy efficiency investment decisions. Evidence on the impact of rating programs on energy use is limited. The only study we are aware of that directly addresses this question is a study of the EPC program in Denmark, which found that the introduction of EPCs did not lead to any change in residential energy use.[20] Other qualitative assessments of the EPC program suggest similar conclusions about the program's effectiveness.[21] We are not aware of any assessments of the impact of energy rating programs on energy use in the US. In part, this lack of studies may reflect the relatively recent adoption of mandatory policies. One piece of evidence that is available is that in Austin, Texas, one of the first US programs, only 11% of residential households acted on any of the

[19] These incentives are not limited to energy rating. For example, the property's energy score can affect the apparent value of energy efficiency investments. If assessors are financially connected to a company performing energy efficiency investments, they may have an incentive to give homes low scores to increase business. Thus, a clear separation between companies performing audits and companies undertaking improvements may mitigate these incentives to some degree.

[20] Vibeke Hansen Kjærbye, "Does Energy Labelling on Residential Housing Cause Energy Savings?" AKF Working Paper, 2008.

[21] These assessments tend to reach the conclusion that the EPC to date has had limited impact on energy use. For example, one analysis of the EPC concluded that "the EPC currently hardly plays a role in people's decision-making." (See Casper Tigchelaar, Julia Backhaus, and Marjolein de Best-Waldhober, "Consumer Response to Energy Labels in Buildings," *Intelligent Energy Europe*, September 2011.) These analyses tend to draw these conclusions based on interviews that largely focus on the impact of EPCs on home purchase and rental decisions, however, and not on decisions related to energy use and investment. See also Julia Backhaus, Casper Tigchelaar, and Marjolein de Best-Waldhober, "Key Findings & Policy Recommendations to Improve Effectiveness of Energy Performance Certificates & the Energy Performance of Buildings Directive," *Intelligent Energy Europe*, September 2011; Liz Lainé, "Room for Improvement: The Impact of EPCs on Consumer Decision-Making," *Consumer Focus*, February 2011; and Hermann Amecke, "The Effectiveness of Energy Performance Certificates – Evidence from Germany," *Climate Policy Initiative* Report, August 26, 2011.

measures identified in required home energy audits.[22] But even this figure may overstate program performance, because many of these households would have undertaken energy audits voluntarily absent the requirement.

# IV. Existing Mandatory Requirements

Within the US, there is a patchwork of state and local requirements related to documenting and disclosing household energy efficiency. Requirements differ along several dimensions, including the type of action required (energy rating, audit, or both), the timing of the requirements (e.g., prior to sale), the type of properties affected (all properties, new properties only, or properties older than a specified age), and the manner in which the rating is reported. Some highlighted findings are:

- Mandatory requirements related to energy rating or audits are relatively uncommon in the US.[23] At present, Berkeley, California[24], and Portland, Oregon, are the only locations with mandatory energy rating requirements applicable to all homes.
- Austin, Texas, has requirements for energy audits for older homes, but these requirements do not include a scoring requirement.
- Several states and localities have requirements related to disclosure of utility billing data (e.g., Chicago, Illinois; Montgomery County, Maryland; Alaska; Hawaii; and New York).[25]
- Several states and localities have various requirements targeting new residential properties, some of which include energy scoring (e.g., Florida; Kansas; and Santa Fe, New Mexico).[26]

In contrast to the US, energy rating is required throughout the European Community. To provide greater context regarding programs that require energy ratings, below we summarize programs in place in Portland, Oregon, and in Europe. We also describe the program in Austin, Texas, which mandates energy audits, but not energy ratings. In **Section V**, we analyze outcomes of each of these programs.

### *1. Portland, Oregon*

As of January 2018, Portland, Oregon, requires energy ratings for all houses on the market. Under the Residential Energy Performance Rating and Disclosure (REPRD) program, property sellers are required to disclose a Home Energy Performance Report (HEP Report), which includes a US DOE Home Energy Score (HES), at the time of listing the property for sale.[27] The requirements are limited to the City of Portland.

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[22] Shonda Novak, "Impact of home energy audit rule less than expected," *The Austin American-Statesman*, July 16, 2010.

[23] Some states and local governments have undertaken voluntary energy scoring initiatives. For example, see National Association of State Energy Officials, "Residential Energy Labeling: Strategies for Scalability."

[24] Grace Kaufman, "Using Disclosure for Market Transformation: Berkeley's New Building Energy Savings Ordinance (BESO) and the U.S. DOE Home Energy Score," 2018, at http://eecoordinator.info/using-disclosure-for-market-transformation-berkeleys-new-building-energy-savings-ordinance-beso-and-the-u-s-doe-home-energy-score/.

[25] Richard Faesy, "An MPG Sticker for Houses: Home Energy Labeling" (hereafter "Faesy, 2017"), National Conference of State Legislatures, April 6, 2017; see also Florida Statutes § 553.9085 and Kansas Statutes Annotated § 66-1228.

[26] Faesy, 2017.

[27] "Administrative Rules: Residential Energy Performance Rating and Disclosure" (hereafter "Administrative Rules"), *Bureau of Planning and Sustainability*, p. 2.

An HEP Report has many required elements, including:[28]

- the HES rating, which rates properties on a scale from 1 to 10, and an explanation of the score;
- an estimate of the total annual energy used in units of energy;
- an estimate of the total annual cost of energy purchased in dollars; and
- an estimate of the home's GHG emissions.

HEP Reports are developed through a home energy audit undertaken by a home energy assessor. To be authorized by the City of Portland to develop an HEP Report, an assessor must undergo various trainings and certifications, including licensing by the state of Oregon and certification in the US DOE HES program.[29] Homeowners can find an authorized assessor through a public on-line database maintained by the city.[30] The costs of an audit are estimated by Portland to range from $150 to $250.[31] Typically, the cost of the home energy audit is paid by the seller, although the City of Portland has a program that provides free assessments if the seller's income is at or below 60% of the median income in the area.[32] Once generated, the HES rating is valid for eight years, while other components of the HEP Report remain valid for two years.[33] Thus, going forward, a seller might avoid certain costs if an HEP report was developed in the recent past.

Information is made available to potential homebuyers through several routes. First, HEP Reports are stored in an online database that can be accessed by potential buyers.[34] Second, HEP Reports must be provided to the listing real estate agent, and the HES rating must be included in the real estate listing, including the regional multiple listing service (RMLS) listing and any other third-party listing services intended for use by real estate agents or homebuyers.[35] Third, the seller must include the HEP Report as an attachment to the real estate listing (or include a link to the webpage that lists the HEP Report) and provide printed copies of the HEP Report to those who visit the premises.

#### *2. Austin, Texas*

The City of Austin's Energy Conservation Audit and Disclosure (ECAD) ordinance first took effect in June 2009. The ordinance requires that homeowners undertake a home energy audit, with affected households determined by

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[28] Administrative Rules, Part 3.2(1) (Requirements for Home Energy Performance Report).

[29] Authorization is a multistep process that also includes trainings specific to the City of Portland. See Part 3.2(2) of the Administrative Rules (Requirements for Home Energy Performance Report).

[30] Portland contracts with a single company that maintains an online list of authorized assessors, maintains the online database of HEP Reports, and provides centralized information on the assessor certification process. See Earth Advantage, "City of Portland Home Energy Assessors" at https://www.earthadvantage.org/pdxhes/assessors.html.

[31] Portland indicates that it expects the per-audit cost to decline given experience in Austin, Texas, where costs declined as the volume of home energy assessments increased. See City of Portland, "Home Energy Score" at https://www.portlandoregon.gov/bps/article/586918#Q13.

[32] Where the area is defined as the Portland-Vancouver-Hillsboro, OR-WA Metropolitan Statistical Area. See City of Portland, "Application for a Free Home Energy Assessment (Home Energy Score)" at https://www.portlandoregon.gov/bps/75139.

[33] Part 3.2(6) of the Administrative Rules (Requirements for Home Energy Performance Report).

[34] Green Building Registry at http://www.greenbuildingregistry.com.

[35] Part 3.3(2) of the Administrative Rules (General Compliance Requirements).

location and age, irrespective of whether the home is for sale.[36] Property sellers must provide prospective homebuyers with a copy of the energy audit, although the audit need not be included in public advertisements or listings.[37] However, the audit does not require that an energy rating be calculated or reported.

Audits must be performed by assessors that meet certain certifications or approvals.[38] The City of Austin maintains a directory of these certified professionals that is accessible via the Austin Energy website.[39] The cost of the energy audit is paid by the current homeowner. These costs vary across assessors, and an anecdotal review of assessors found that reported costs range from $100 to $130 for single-family homes with one air conditioning (AC) system.[40,41]

Audit results are reported in a standardized form developed by Austin Energy, although the ordinance does not specify how the energy audit is implemented. The standardized report provides multiple pages of information on the property's energy efficiency features (e.g., window pane type, solar shading, and HVAC system leakage) and recommended actions to reduce energy use, with estimates of potential savings.[42] An example of the standardized report is provided in the **Appendix**. Once an energy audit is performed, it is valid for 10 years.[43]

For multifamily properties, the report includes an estimate of monthly electric cost (in $) and use (in kWh) in comparison to the "Austin average."[44] These reports are provided to potential renters to give them an expectation of future energy expenditures.

There has been limited analysis of the impact of the audit requirement on home energy use and investment in energy-efficient technology. Because the audit requirements are closely tied to subsidies for energy efficiency investments offered by Austin Energy, the city's municipal utility, it may be difficult to distinguish the impact of the audit program from these other programs. It is worth noting that not all households have fully complied with the

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[36] Homeowners are subject to the rule if they meet three criteria: (1) the home is in the service area of the local utility (Austin Energy), (2) the home is within Austin's city limits, and (3) the home was built at least 10 years before the time of sale. See Austin, Texas – Code of Ordinances, § 6-7-11 (Residential Energy Audit) and § 6-7-12 (Disclosure Required).

[37] See Austin, Texas – Code of Ordinances, § 6-7-11 (Residential Energy Audit) and § 6-7-12 (Disclosure Required).

[38] See Austin, Texas – Code of Ordinances, § 6-7-5(A) (Energy Audit Requirements). Ordinance requirements can be met through an audit undertaken by professionals certified as either Residential Energy Services Network (RESNET) Raters or Building Performance Institute (BPI) Building Analyst Professionals. RESNET and BPI each have unique certification requirements, including prior work experience. See Austin, Texas – Code of Ordinances, § 6-7-2 (Applicability) and § 6-7-13 (Exemptions); see Austin Energy, "Become an ECAD Energy Professional" at https://austinenergy.com/ae/energy-efficiency/ecad-ordinance/energy-professionals/become-energy-professional; and Building Performance Institute, "Energy Auditor" at http://www.bpi.org/certified-professionals/energy-auditor.

[39] See Austin Energy, "Energy Conservation Audit and Disclosure (ECAD) Auditors" at https://austinenergy.com/wcm/connect/6448f917-64bc-416f-a3cf-d792ce99d18c/ECAD-Energy-Professionals.pdf?MOD=AJPERES&CVID=mgosUbt.

[40] See Conservation Specialists of Austin, "ECAD Audits $100" at http://www.conservationaustin.com/id64.html ("Our ECAD Audit cost[s] $100 for a single family home, 1,800sqft or smaller, with one air conditioning system."). See also Green Leaf, "Energy Audits at http://www.greenleaf-energy.com/pricingtable/, and Austin ECAD Specialist, "ECAD Audits," at https://www.ecadspecialist.com/service/ecad-audits.

[41] The City of Portland also notes that "[t]he cost of a home energy performance assessment in Austin is currently stable at $125." See City of Portland, "Home Energy Score," at https://www.portlandoregon.gov/bps/article/586918#Q13.

[42] See "Understanding the ECAD Audit Form." Savings associated with suggested improvements are based on an average house.

[43] See Austin, Texas – Code of Ordinances, § 6-7-5(B) (Energy Audit Requirements).

[44] See slide 7 of "Update on the Energy Conservation Audit and Disclosure (ECAD) Ordinance," November 13, 2014, available at http://www.austintexas.gov/edims/document.cfm?id=222245.

audit requirements. As of August 2014, multifamily compliance was approximately 80% and residential compliance was somewhat greater than 50%.[45]

### *3. European Union (EU)*

The EU approved the Energy Performance of Buildings Directive (EPBD) on December 16, 2002. The directive requires that energy performance certificates (EPCs) be made available when buildings are constructed, sold, or rented.[46] Member states were required to introduce an effective certification scheme by January 4, 2009.[47] After this deadline, the directive was amended in 2010 to strengthen the energy performance requirements through improved systems for quality control.[48] The amendment also requires that the EPC be included in property advertisements in commercial media[49] and shown and handed over to the prospective new tenants or buyers.[50] As of 2014, all 28 member states had implemented programs to comply with the directive, although not all had implemented independent quality control. **Figure 2** shows the implementation of the directive over time, with red bars indicating the number of countries that complied with the directive in each year and the gray area providing cumulative totals.

**Figure 2. Country-Level Development of EPC Systems Over Time**

[45] See Tyler Whitson, "Austin Energy works to increase ECAD compliance," *Austin Monitor*, November 17, 2014.

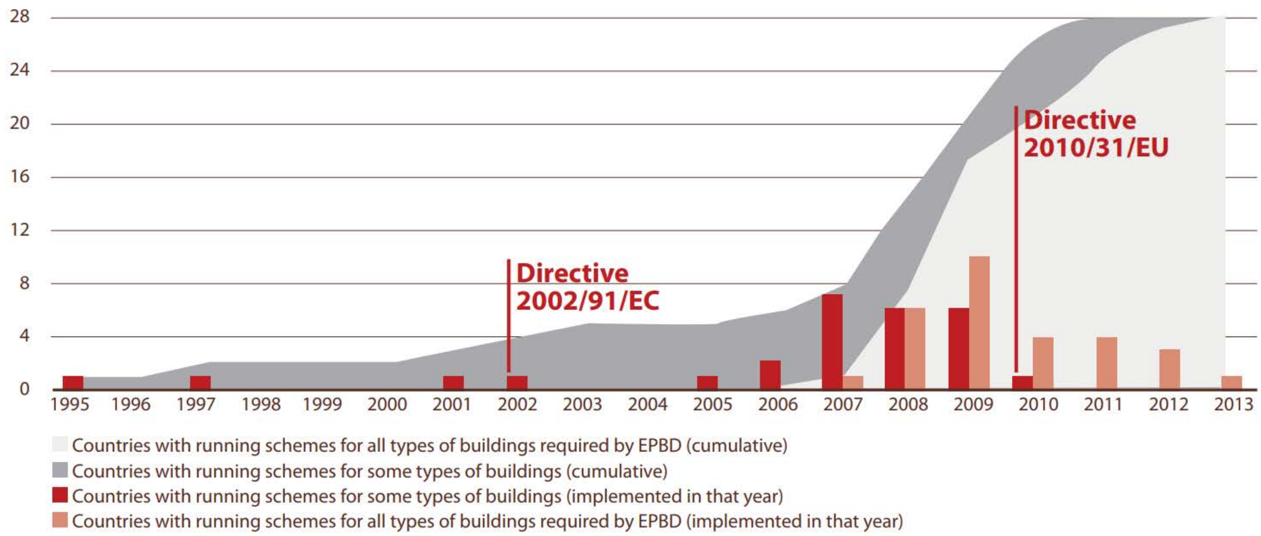
[46] See Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Al27042.

[47] "The initial date for the EPBD implementation was by 4 January 2006, but MS [Member State] could opt for an extension period up to 4 January 2009." See "Energy Performance Certificates Across the EU: A Mapping of National Approaches," Buildings Performance Institute Europe, October 2014, p. 12.

[48] "Energy Performance Certificates Across the EU: A Mapping of National Approaches," Buildings Performance Institute Europe, October 2014, p. 13.

[49] "Member States shall require that when [buildings having an energy performance certificate] are offered for sale or for rent, the energy performance indicator of the building or the building unit, as applicable, is stated in the advertisements in commercial media." See Article 12 of directive 2010/31/EU of the European Parliament and of the Counsel of 19 May 2010 on the energy performance of buildings (recast) (hereafter "Directive 2010/31/EU").

[50] "Member States shall require that, when buildings or building units are constructed, sold or rented out, the energy performance certificate or a copy thereof is shown to the prospective new tenant or buyer and handed over to the buyer or new tenant." See Directive 2010/31/EU.




**Source**: "Energy Performance Certificates Across the EU: A Mapping of National Approaches," Buildings Performance Institute Europe, October 2014, p. 13, available at http://bpie.eu/wp-content/uploads/2015/10/Energy-Performance-Certificates-EPC-across-the-EU.-A-mapping-of-national-approaches-2014.pdf

In many member states, the EPC includes a numeric rating and an associated letter rating ranging from A to G, where A is the best performance and G is the worst performance.[51] However, while the EPBD provides guidance for calculation and verification of EPCs, individual countries have discretion on the design of EPC standards and protocols. As a result, differences exist among the member states.[52] The EPC must provide an estimate of primary energy use, typically in kWh/$m^2$.[53] Some member states also provide additional metrics such as $CO_2$ emissions and suggestions for energy improvements. However, the directives do not specify exactly how each member state must account for certain aspects of a building, nor do they specify exactly how the indicator should be displayed.

Similarly, member states differ in their methods of gathering information to issue the EPC. Most member states (19 of the 28) require an on-site visit. However, other member states allow information to be submitted through the

[51] See Appendix B, which includes examples of energy labels.

[52] The Buildings Performance Institute Europe (BPIE) noted that differences in EPC implementation are "inevitably expected as many national differences exist between EU Member States regarding their culture, politics, national policy and legislation, building traditions, financial situation, energy infrastructure, climate, etc. Consequently, the approach associated with the successful implementation of the EPBD may differ from country to country." See Buildings Performance Institute Europe, "Energy Performance Certificates across Europe: From Design to Implementation" (hereafter "From Design to Implementation," 2010, p. 9.

[53] Under the 2010 Directive, energy performance must be determined on the basis of the calculated or actual annual energy consumed and energy performance must be "expressed in a transparent manner and shall include an … indicator of primary energy use." See Annex I of Directive 2010/31/EU. The annex also lists particular aspects of a building that should be considered when calculating energy performance. These include thermal capacity, insulation, natural ventilation, passive solar systems, and others.

mail or some other method.[54] Professionals, inspectors, and engineers are certified by their respective member states, although only half (14 of 28) of member states include mandatory training of EPC certifiers.[55]

The EPC must be handed over and posted on advertisements at the time of construction, sale, or rental of the home.[56] Otherwise, a home energy assessment is not compulsory. In many cases, an EPC is valid for up to 10 years.[57] When a home is in violation of the EPBD, most member states issue a formal warning or a monetary fine.

Across the EU, the costs of issuing an EPC vary widely. In 2010, the costs for a residential EPC were found to vary from about €45 to €800.[58] In some countries, EPC costs are subject to various regulatory limits while in other countries they are market-based. For example, in Spain, the cost of an EPC assessment is regulated and varies by the area of the home assessed.[59] In Greece, the cost of the assessment is market-based, with costs typically ranging from €80 to €150.[60]

# V. Impact of Energy Rating on Residential Property Values

By providing supplemental energy efficiency information to homebuyers prior to sale, energy ratings may affect property values and transaction prices. In this section, we summarize the existing empirical economic literature on the topic. This literature confirms that, all else equal, homes with higher ratings sell at a premium, while homes with lower ratings sell at a discount. We also analyze whether these changes in property values accurately reflect underlying differences in future energy costs. Interestingly, prior literature finds that high energy ratings appear to lead to overvaluation, or inflation, of capitalized energy savings. Thus, the property value impacts from mandatory energy ratings may be disproportionately large relative to a homeowner's future energy costs, leading to windfall gains to those with properties with high scores and windfall losses for those with low energy ratings.

## A. The Impact of Energy Ratings on Residential Property Values

When an energy rating is provided to potential buyers, this supplements existing information about a property's energy efficiency. In principle, with this information, potential buyers can develop more accurate estimates of a dwelling's future energy costs, which in turn can lead to more precise estimates of the property's value. Energy rating information may also impact property valuations because the buyer values energy efficiency on a per se basis, perhaps out of concern for environmental impacts.

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[54] See Buildings Performance Institute Europe, "Energy Performance Certificates Across the EU: A Mapping of National Approaches" (hereafter "A Mapping of National Approaches"), October 2014, pp. 7, 24.

[55] See "A Mapping of National Approaches," p. 6.

[56] Construction includes substantial renovations, though this is a subjective determination that differs between member states.

[57] As examples, this is the case in both France and Estonia. See Ministère de la Transition écologique et solidaire, https://www.ecologique-solidaire.gouv.fr/diagnostic-performance-energetique-dpe and https://www.energia.ee/en/tark-tarbimine/kokkuhoid.

[58] See Buildings Performance Institute Europe, "From Design to Implementation," p. 35. See also, Tab 5-1 and Tab 5-2 on p. 46.

[59] See EPS Spain, "Energy Performance Certificate," http://www.elcertificadodeeficienciaenergetica.es/get-energy-performance-certificate.htm.

[60] See My Constructor, http://energeiako-pistopoiitiko-myconstructor.gr/energeiako-pistopoiitiko/kostos-energeiako-pistopoiitiko/.

**Table 1** summarizes existing estimates of the impact of energy ratings and green labels on property values,[61] with further description provided in **Box 1** (for energy ratings) and **Box 2** (for green labels).[62] These studies have analyzed energy ratings in multiple countries, including the US, Australia, Great Britain, Japan, and the Netherlands. Across these studies, energy ratings and green labels are associated with differences in property values, which supports the conclusion that energy ratings and green labels affect property values. All else being equal, on average properties with higher energy ratings (or green labels) had higher property values (that is, they sold at a premium), and those with low ratings had lower property values (that is, they sold at a discount). Magnitudes vary across studies, but the impacts are material. Estimated premiums from high energy ratings or green labels range from approximately 1.2% to 27% relative to comparable properties of average energy efficiency. In contrast, estimated discounts for properties with low energy ratings range from approximately 3.6% to 10.6% relative to properties with average energy efficiency. [63]

Energy ratings may affect other aspects of the real estate market, such as the period of time a home is on the market prior to sale (the "listing period"). However, limited research has been directed at these aspects, to date.

[61] Sources not identified in other footnotes include: Eichholtz, Piet, Nils Kok, and John M. Quigley, "Doing Well by Doing Good? Green Office Buildings," *American Economic Review* 100, December 2010, pp. 2492-2509 (Eichholtz, Kok, and Quigley (2010a)). Eichholtz, Piet, Nils Kok, and John M. Quigley, "Sustainability and the Dynamics of Green Building," April 2010 (Eichholtz, Kok, and Quigley (2010b)). Wiley, Jonathan, Justin Benefield, Ken Johnson, "Green Design and the Market for Commercial Office Space," Journal of Real Estate Finance Economics 41: 228-243 (July 2008). Pivo, Gary and Jeffrey D. Fisher, "Income, Value, and Returns in Socially Responsible Office Properties," The Journal of Real Estate Research 32(3): 243-270 (2010); Fuerst, Franz and Patrick McAllister, "Green Noise and Green Value? Measuring the Effects of Environmental Certification on Office Values," Real Estate Economics 39(1): 45-69 (2011); Bloom, Bryan, MaryEllen Nobe and Michael Nobe, "Valuing Green Home Designs: A Study of ENERGY STAR Homes," The Journal of Sustainable Real Estate 3(1): 109-126 (2011); Fuerst, Franz and Chichiro Shimizu, "Green Luxury Goods? The Economics of Eco-Labels in the Japanese Housing Market," Institute of Economic Research, Hitotsubashi University, September 2014; Cerin, Pontus, Lars Hassel and Natalia Semenova, :Energy Performance and Housing Prices," Sustainable Development 22: 404-401 (2014); Jensen, Ole Michael, Anders Hansen and Jesper Kragh, "Market response to the public display of energy performance rating at property sale," Energy Policy 93: 229-235 (2016).

[62] Existing empirical research generally estimates the relative difference in transaction prices for homes with different energy ratings, holding all else equal. However, this empirical approach does not capture the price impact of mandatory energy ratings as compared to the absence of mandatory ratings. While it might be reasonable to assume that homebuyers implicitly assume an average rating when forming offers in the absence of an energy rating, this empirical question requires testing.

[63] See for instance Marie Hyland, Ronan C. Lyons, and Sean Lyons, "The value of domestic building energy efficiency – evidence from Ireland," University of Oxford Department of Economics Discussion Paper Series, 2013; and Franz Fuerst, Pat McAllister, Anupam Nanda, and Pete Wyatt, "Energy performance ratings and house prices in Wales: an empirical study," *Energy Policy*, 92, pp. 20-33, 2016 at https://doi.org/10.1016/j.enpol.2016.01.024.

## Table 1. Estimates of the Impact of Energy Ratings and "Green" Labels on Property Values

| Year | Author(s) | Building Type | Program Type | Country | Program Name | Home Value Responses to Energy Efficiency Rating | Over- or Under-Capitalization of Energy Savings |
|---|---|---|---|---|---|---|---|
| 2008 | Australian Department of Environment (2008)<br><br>Aroul and Hansz (nd) | Residential | Mandatory<br><br>Mandatory & Voluntary | Australia | EER<br><br>Green building | Half-star ratings on an Energy Efficiency Rating are associated with higher home prices:<br>▪ 2005: 1.23%<br>▪ 2006: 1.91%<br><br>Homes built to a mandatory "green" standard are associated with a 2% higher sale price. | Gain or loss of 1 Star in energy rating (EER) for a median Australian home:<br>▪ Market value of the label: ±12,822 to 19,808 AUD<br>▪ Capitalized difference in energy: ±4,193 AUD<br>▪ % of market Impact due to cachet/stigma: 67 to 79% |
| 2010 | Eichholtz, Kok and Quigley (2010a) | Commercial | Voluntary | USA | Energy Star & LEED | Energy Star rating is associated with:<br>▪ 10% higher rent<br>▪ 16% to 19% higher sale price. | |
| 2010 | Eichholtz, Kok and Quigley (2010b) | Commercial | Voluntary | USA | Energy Star & LEED | Energy Star rating is associated with:<br>▪ 2 % higher rent (or 7% based on occupancy-adjusted rent)<br>▪ 13% higher sale price. | Energy Star office building in U.S. compared w/non-certified and less efficient but otherwise comparable office building:<br>▪ Market value of the label : 8 to 26% higher value for Energy Star bldg (14% premium in value, roughly $37.50/sq ft)<br>▪ Capitalized difference in energy: +$5.90 to $9.10/sq ft<br>▪ % of market impact due to cachet/stigma: 76 to 84% |
| 2010 | Wiley, Benefield and Johnson (2010) | Commercial | Voluntary | USA | Energy Star & LEED | Energy Star rating is associated with 7% to 9% higher rent. | |
| 2010 | Pivo and Fisher (2010) | Commercial | Voluntary | USA | Energy Star | Energy Star rating is associated with:<br>▪ 3% higher rent (based on operating income as measure of rent)<br>▪ 9% higher sale price (based on assessed market value as measure of price). | |
| 2011 | Brounen and Kok (2011) | Residential | Mandatory (with partial compliance) | Denmark | EPC | Green EPC labels are associated with sales prices 3.7% higher. "Green" is defined as scoring A, B or C on A to G scale. | A-labeled home relative to G-labeled home:<br>▪ Market value of the label : €34,378<br>▪ Capitalized difference in energy: €14,190<br>▪ % of market impact due to cachet/stigma: 59%<br><br>E-labeled home relative to G-labeled home: |
| 2011 | Fuerst and McAllister (2011) | Commercial | Voluntary | USA | Energy Star & LEED | Energy Star rating is associated with:<br>▪ 4% higher rent<br>▪ 26% to 27% higher sale price. | |
| 2011 | Kok and Jennen (2011) | Commercial | Mandatory | Netherlands | EPC | Higher Energy Index ratings (A to G scale) are associated with higher rents:<br>▪ Each point corresponds to 4.7% higher rents<br>▪ 6.5-7.5% higher rents for ratings of A, B, or C<br>▪ Only 1 of the 7 EPC letter scores has a statistically significant relationship with rent. | |
| 2011 | Bloom, Nobe, and Nobe (2011) | Residential | Voluntary | Colorado, USA | Energy Star Rating | ENERGY STAR homes are sold for $8.66 more per square foot than non-ENERGY STAR homes. | |

## Table 1. Estimates of the Impact of Energy Ratings and "Green" Labels on Property Values (continued)

| Year | Author(s) | Building Type | Program Type | Country | Program Name | Home Value Responses to Energy Efficiency Rating | Over- or Under-Capitalization of Energy Savings |
|---|---|---|---|---|---|---|---|
| 2013 | Hyland, Lyons, and Lyons (2013) | Residential | Mandatory | Ireland | BER - A Building Energy Rating (Ireland) | Property prices are associated with energy ratings (relative to D-rated properties):<br>▪ 9.3% price premiums for A ratings<br>▪ 5.3% price premiums for B ratings<br>▪ 10.6% price discounts for F or G ratings | |
| 2014 | Kahn and Kok (2014) | Residential | Voluntary | California, USA | Geen label (Energy Star label, a LEED certification, and a GreenPoint Rated label) | Homes with a "green" label transact at a premium (>2.1%) relative to comparable, non-labeled homes. | Green-labeled (LEED, Energy Star, Green Point) homes in California:<br>▪ Market value of the label : +8.7%, or $34,800 relative to average home price of $400,000<br>▪ Capitalized difference in energy: ≤ $14,400 ($720/yr, assume cap rate of at least 5%)<br>▪ % of market impact due to cachet/stigma: ≥ 58% |
| 2014 | Fuerst and Shimizu (2014) | Residential | Voluntary | Japan | Green buildings (eco-labelled condominiums) | There is a 1.7% price premium for green-labelled condominiums. Wealthier buyers are willing to pay higher premia for green-labelled properties. | |
| 2014 | Cerin, Hassel, and Semenova (2014) | Residential | Mandatory | Sweden | EPC | The energy performance is associated with the transaction price when the performance is conditional on a reference benchmark.<br>▪ Coefficient on log PRICE: 0.006*** | |
| 2016 | Fuerst, McAllister, Nanda, and Wyatt (2016) | Residential | Mandatory | Wales | EPC | Dwelling prices are associated with energy ratings (relative to D-rated properties):<br>▪ 12.8% price premiums for A or B ratings<br>▪ 3.5% price premiums for C ratings<br>▪ 3.6% price discounts for E ratings<br>▪ 6.5% price discounts for F ratings | |
| 2016 | Jensen, Hansen, and Kragh (2016) | Residential | Mandatory | Denmark | ECP | There are larger impacts of ratings on property sales prices after June 2010 when ratings are required for property sales. | |
| 2017 | Walls, Palmer, Gerarden, and Bak (2017) | Residential | Voluntary | USA (NC, TX, OR) | Energy Star Certification | ▪ Energy Star certification increases the sales prices of homes built between 1995 and 2006 but has no statistically significant effect on sales prices for newer homes.<br>Effects of<br>▪ AEGB certification in Austin, TX: 7% to 8% price premium vs. noncertified home<br>▪ Earth Advantage certification in Portland, OR: 3% premium vs. non certified home. | Energy Star and 2 local certifications for single-family homes in Austin (TX), Portland (OR) and Research Triangle (NC)<br>▪ Market value of the label : Energy Star in Austin for older homes was worth +5.8% ($14,504) or $2,387/yr<br>▪ Capitalized difference in energy: $323 to $697/yr<br>▪ % of market impact due to cachet/stigma: 66 - 97% (Austin example: 71 to 86%) |

**Box 1: Impact of Energy Ratings on Property Values**

Several studies have analyzed the impact of mandatory energy rating in individual European countries and Australia. In Europe, energy ratings range from A for properties with high energy efficiency to G for energy inefficient homes. In the Netherlands, Brounen and Kok (2011) found that homes with an A rating had a 10.1% price premium over comparable D-rated homes,[64] while in England and Wales, Fuerst et al. (2013) found that a home with A or B ratings had values 13.8% larger than homes with the lowest energy rating (G), all else being equal.[65]

In contrast, empirical evidence suggests that the market discounts properties with low energy ratings:

- In the Netherlands, Brounen and Kok (2011) found that properties with the lowest energy rating (category G) had a value 4.8% less than properties with the middle energy rating (category D). The associated reduction in market value for these properties was $14,000 to $17,300.
- In England and Wales, Fuerst et al. (2013) found that G- and F-rated properties were valued 7.6% and 1.6% lower than comparable D-rated homes, respectively. The associated difference in market value for these properties is roughly $20,000 to $28,000.
- In Australia, the Australian government found that homes with the lowest energy rating (zero stars) sold for an average of 6.36% less than otherwise comparable homes with median energy efficiency (a two-star rating). The associated discount loss for these homes was $24,000 to $32,000.[66]

Studies have also found that energy ratings can impact property rental prices. Kok and Jennen (2011)[67] found that less-efficient buildings (categories D, E, F, and G) rented at a discount of 6.5% per square meter compared to offices with higher efficiency ratings (categories A, B, and C). The average rent for the less-efficient offices was $1.40 per square foot less than that for otherwise comparable offices with high (A, B, and C) energy ratings.

[64] Brounen and Kok (2011) analyzed data from sales of residential properties in the Netherlands from January 2008, when the energy performance certificate (EPC) program went into effect, through October 2009. The Netherlands requires owners of any dwelling constructed before 2000 that is not a registered historic structure to obtain an EPC before selling or leasing the building. The owner must contract with a licensed professional to conduct an energy performance audit and then must provide a certificate indicating the audit results to any prospective buyer or tenant. Brounen, Dirk and Nils Kok, “On the Economics of Energy Labels in the Housing Market,” *Journal of Environmental Economics and Management* 62(2), September 2011, pp. 166-179.

[65] Fuerst et al. (2013) analyze England and Wales from 1995 through 2011. The British EPC assigns one of seven letter grades, ranging from A, most energy-efficient, to G, least energy-efficient. The authors analyzed more than 320,000 homes that had been sold at least twice during this period, representing approximately 10% of such homes in England and Wales. Analysis of homes that had sold at least twice during this period is a unique feature of this study, allowing investigation of the impact of the label on price appreciation over time, as well as the impact of the label on price.

[66] The Australian government (DEWHA, 2008) studied the impact of mandatory energy labeling on the value of more than 5,000 homes sold in the Australian Capital Territory (Canberra and suburbs) during 2005 and 2006. Australian Government, Department of the Environment, Water, Heritage and the Arts, “Energy Efficiency Rating and House Price in the Act,” 2008.

[67] Kok and Jennen (2011) studied more than 1,000 leasing transactions in EPC-labeled office buildings in the Netherlands between 2006 and 2010. Kok, Nils and Marteen Jennen, "The Value of Energy Labels in the European Office Market," May 2011.

**Box 2: Impact of Green Labels on Property Values**

Green labels include certifications from private associations (e.g., LEED, Green Point) and certifications from government agencies (e.g., Energy Star operated by the US DOE). Consistent with the evidence on energy rating, analysis of green labels finds that properties with these labels have higher market valuations than otherwise comparable properties. For example, Kahn and Kok (2014) found an average market premium of 9% for green-labeled single-family homes relative to otherwise similar homes without a green label in California.[68] Specifically, they document an average premium of $34,800 for green-labeled homes relative to an average market price for an unlabeled home of about $400,000.

By contrast, Walls et al. (2016) report mixed results, with a green label having a statistically significant relationship with higher valuations in some cases, and no relationship in other cases.[69] Their analysis examines green energy labels and sales prices for single-family homes in Austin, Texas; Portland, Oregon; and the Research Triangle area of North Carolina. The study finds that an Energy Star rating was associated with a 5% premium in Austin and, in the Research Triangle, an 18% premium area prior to 2006, but no statistically significant impact for homes built after 2006, and no statistically significant impact at all in Portland. By contrast, green labels from local entities are associated with a statistically significant premium in Austin of 10–26% (for homes with an AEGB rating) and in Portland of 4–10% (for homes with an Earth Advantage certification).

## B. The Impact of Energy Ratings Relative to Capitalized Future Energy Costs

In principle, energy ratings are intended to provide supplemental information to potential homebuyers about future energy expenditures. Given this objective, an important question is whether differences in property values of otherwise similar houses with different ratings in fact reflect differences in capitalized future energy expenditures. For example, if a home with a higher-than-average energy rating sells at a 10% premium relative to the average, is this premium less than, equal to, or greater than the present value of future energy costs because of the house's greater energy efficiency?

If house value premiums are less than the expected energy savings, this suggests that buyers may have insufficient information to accurately estimate energy savings, such that the insufficient information biases the cost estimate downward. If house value premiums are greater than the expected energy savings, this suggests that other factors unrelated to energy savings are likely to be affecting property values. For example, buyers may place a higher value on more energy-efficient homes due to their private concern about environmental impacts from energy use (or to communicate their concern to others). In this case, a property with a higher energy rating may have cachet value relative to other properties with lower energy ratings. Conversely, properties with an unfavorable energy rating may suffer from stigma effects, thus reducing market value. Behavioral responses to energy scorecards and to the way that information is communicated could also affect transaction prices. For

[68] See also Aroul and Hansz (2012), and Earth Advantage (2011). Aroul, Ramya and J. Andrew Hansz, "The Value of "Green": Evidence from the First Mandatory Residential Green Building Program," Journal of Real Estate Research, 34(1): 27-49, 2012. Kahn, Matthew and Nils Kok, "The capitalization of green labels in the California housing market," Regional Science and Urban Economics 47:25-24 (2014).

[69] Walls, Margaret, et al., "Is Energy Efficiency Capitalized into Home Prices? Evidence from Three US Cities," Journal of Environmental Economics and Management 82: 104-124 (2017).

example, the weight put on energy rating information by buyers could be greater when communicated via infographics, which may increase the salience of such information. In general, behavioral responses could affect property values positively or negatively.

Existing empirical studies allow comparison of market premiums/discounts to differences in the capitalized value of future energy expenditures.[70] Uniformly across studies, the impact of energy rating on property value exceeds the capitalized value of future energy cost savings. Estimates vary across studies, but the estimated differences are generally large, with premiums exceeding capitalized energy costs by approximately 37% to 97%.[71] For example, Alberini et al. (2011) find that the market premium for the Energy Star certification in Austin, Texas, is 71% to 85% of the change in transaction price due to the energy rating.[72]

These results suggest that the impact of energy ratings reflects energy savings as well as other factors, with higher-rated properties earning an incremental premium and lower-rated properties realizing an incremental discount. These studies do not provide insight into the source of these premiums or discounts, however.

These premiums and discounts appear to be an unintended policy consequence. While energy ratings are intended to lead to more accurate and precise property valuation by providing better information about energy costs, the impact of these ratings appears to reflect unobservable factors that cause buyers to overshoot the intended effect. This will result in both winners and losers in the housing market, where, based on energy-rating effects only, owners of highly rated properties receive a disproportionate gain and owners of low-rated properties realize a disproportionate discount.

# VI. Aggregate and Distributional Changes in Property Values

Given the large effects that energy ratings seem to have on property values, one should be on the lookout for potentially broader effects. For example, mandatory energy rating may impact the aggregate value of the housing stock, with the distribution of these impacts varying across socioeconomic groups. In turn, the aggregate value of the housing stock could change buyers' perceptions about energy efficiency of the housing stock, suggesting that joint causality is possible.

Energy ratings may have distributional consequences, including impacts to particular socioeconomic groups (e.g., low-income households) or geographic areas. In general, such impacts are often an inadvertent consequence of new policies, particularly those targeting improved economic efficiency. Thus, if mandatory energy ratings improve buyer estimates of future energy expenditures, leading to a more accurate capitalization of these costs into their

[70] These analyses consider energy ratings intended to capture only energy efficiency. Other ratings might consider additional factors beyond energy efficiency. For these other ratings, capitalized expected energy savings would not provide an apples-to-apples comparison, because property values reflect the additional factors. For example, the LEED Green Star and the EPS certificates attest to a property's environmental performance across a wide range of sustainability metrics in addition to energy efficiency. These rating systems are multidimensional and somewhat complex. Thus, individuals may interpret these certifications as reflecting the property's ecological superiority as opposed to indicating only energy efficiency.

[71] Estimated differences are calculated as the ratio of (1) the difference between value of the label, as established in the market, and the capitalized value of the difference in the energy costs, and (2) the value of the label, as established in the market. See Sessions (2015).

[72] In Austin in 2007, the average annual energy bill for the owner of a noncertified home was estimated at $2,322. Based on energy savings of 15–30%, an Energy Star-certified home would generate annual savings of $348 to $697. By contrast, the estimated premium for an Energy Star home was $14,504, implying annual savings of at least $2,387.

offers, efficiency may be improved. However, the fact that energy ratings appear to a have a disproportionately large impact on property values suggests that energy ratings may have meaningful financial consequences that are unrelated to the policy's objectives.

We undertake several analyses to better understand the economic impacts of mandated energy labeling. These analyses consider the relationship of energy ratings and the underlying determinants of energy ratings to measures associated with economic well-being. These analyses consider four data sets: (i) Residential Energy Consumption Survey (RECS) data; (ii) the Energy Conservation Audit and Disclosure (ECAD) data from Austin, Texas, (iii) RMLS data from Portland, Oregon, and (iv) the energy performance certificate data for England and Wales.

We reach several conclusions based on these analyses:

- Across income/wealth categories, there is no discernable pattern of energy ratings. That is, energy ratings do not appear to increase or decrease as income/wealth increases, on average.
- The lack of a discernable trend masks two important offsetting effects that vary across income/wealth groups. Holding constant observed property features, such as size and number of bedrooms, properties associated with higher income/wealth communities have higher ratings, on average. We observe this in our statistical analysis of both Portland and England/Wales. One factor driving this relationship is that higher income/wealth properties are more likely to have energy efficiency "features," such as wall and roof insulation, double-paned windows, and programmable thermostats, each of which tend to increase energy ratings via the ratings' formulas. We observe this in Austin and in the RECS data. On the other hand, higher income/wealth households tend to own larger homes, which tend to consume more energy, thus potentially reducing energy ratings. These effects can depend on the benchmarks used when rating properties.
- Across neighborhoods within a metro area, average energy ratings may differ. For example, in Portland, Oregon, average energy ratings vary from 2.43 to 5.16 across zip codes. Differences across zip codes may reflect socioeconomic factors, vintage of the housing stock (older homes have lower ratings, all else equal), property size or other architectural features. But geographic variation in ratings could lead to diversity in neighborhood impacts of mandatory energy rating.
- In aggregate, ratings across all properties at the metro level could be above or below the "average" chosen for comparison. In theory, this could lead to aggregate changes in housing stock value in the area subject to the rating requirement. For example, in Portland, Oregon, the average property energy rating was 4.42 out of 10 over the program's first six months. Assuming that buyers would otherwise have (naively) assumed a property was a 5 of 10, this lowers property values $2,266 per transaction, on average. However, assuming that buyers accurately estimate expected energy costs, property values may be impacted if buyers' response to the rating inflates the true differences in energy costs. Assuming 33% premiums/discounts (at the lower end of the range empirically observed), the impact is approximately $755 per transaction, on average.

Below, we provide further detail on these analyses.

## A. Analysis of Residential Energy Consumption Survey Data

The 2015 RECS includes housing characteristics for a sample of dwellings in the US collected between August 2015 and April 2016. The survey includes information about energy efficiency features of residential properties such as programmable thermostats, AC heat pumps, ceiling fans, Energy STAR appliances, and insulated windows. Our sample includes 4,231 single-family attached and detached dwellings.

**Table 2** shows the proportion of residential properties that have individual energy efficiency features for eight neighborhood income categories, where neighborhood income is the zip code's average income.[73] The share of dwellings with energy efficiency features is seen to increase with household income for all energy efficiency characteristics. For instance, the percentage of properties that have a programmable heat thermostat increases from 41.9%when annual income is below $20,000 to 80.1% when annual income exceeds $140,000.

**Table 2. Percentage of Housing Units with Energy Efficiency Features by Household Income**

| | Less than $20,000 | $20,000 to $39,999 | $40,000 to $59,999 | $60,000 to $79,999 | $80,000 to $99,999 | $100,000 to $119,999 | $120,000 to $139,999 | $140,000 or More |
|---|---|---|---|---|---|---|---|---|
| Number of Households | 463 | 870 | 703 | 608 | 428 | 370 | 257 | 532 |
| Percent of Households by Income Range | 10.9% | 20.6% | 16.6% | 14.4% | 10.1% | 8.7% | 6.1% | 12.6% |
| **HVAC System** | | | | | | | | |
| Prog. Heat Thermostat | 41.9% | 47.6% | 54.6% | 58.7% | 61.9% | 68.6% | 70.4% | 80.1% |
| Prog. AC Thermostat | 30.7% | 37.7% | 46.8% | 49.0% | 56.1% | 61.4% | 63.4% | 72.7% |
| 2000+ Vintage Central AC | 39.7% | 50.6% | 56.5% | 56.1% | 65.4% | 63.2% | 62.6% | 69.4% |
| AC by Heat Pump | 13.2% | 17.6% | 23.5% | 19.6% | 25.0% | 21.9% | 25.7% | 28.8% |
| 2000+ Vintage Heat Equipment | 67.4% | 66.2% | 65.1% | 66.1% | 70.6% | 67.3% | 71.2% | 73.5% |
| Space Heated by Heat Pump | 96.1% | 97.4% | 96.9% | 96.7% | 97.7% | 98.9% | 97.7% | 97.7% |
| Ceiling Fans | 71.9% | 79.5% | 83.8% | 83.7% | 82.5% | 84.6% | 82.9% | 83.6% |
| Natural Gas Used for Space Heating | 42.3% | 48.6% | 48.2% | 50.5% | 55.6% | 56.8% | 56.4% | 63.3% |
| **Appliances** | | | | | | | | |
| 2000+ Vintage Clothes Washer | 77.1% | 86.1% | 88.5% | 91.0% | 90.4% | 91.1% | 91.8% | 93.6% |
| Energy Star Qualified Clothes Washer | 27.2% | 39.1% | 45.1% | 53.9% | 54.2% | 59.5% | 62.6% | 65.4% |
| 2000+ Vintage Clothes Dryer | 77.1% | 86.1% | 88.5% | 91.0% | 90.4% | 91.1% | 91.8% | 93.6% |
| Natural Gas Clothes Dryer | 13.2% | 15.3% | 17.6% | 18.3% | 22.4% | 20.8% | 25.7% | 26.3% |
| 2000+ Vintage Dishwasher | 34.1% | 54.6% | 62.9% | 74.3% | 77.6% | 81.9% | 87.9% | 88.3% |
| Energy Star Qualified Dishwasher | 12.5% | 23.9% | 29.4% | 39.1% | 43.0% | 50.0% | 54.9% | 58.5% |
| 2000+ Vintage Refrigerator | 84.4% | 84.7% | 87.8% | 89.6% | 90.9% | 92.4% | 90.7% | 91.2% |
| Energy Star Qualified Refrigerator | 31.3% | 40.9% | 50.2% | 55.4% | 62.4% | 61.9% | 66.5% | 68.6% |
| **Features** | | | | | | | | |
| 2000+ Vintage Water Heater | 82.7% | 84.5% | 85.5% | 85.2% | 86.7% | 85.7% | 85.6% | 88.7% |
| Natural Gas Cook Top | 0.6% | 0.3% | 0.7% | 0.7% | 0.5% | 0.3% | 1.9% | 1.9% |
| Natural Gas Water Heater | 41.9% | 46.4% | 46.7% | 48.5% | 51.9% | 52.7% | 53.7% | 62.4% |
| **Building Envelope** | | | | | | | | |
| Double Pane Glass or Better | 46.9% | 62.5% | 63.9% | 69.7% | 69.9% | 75.4% | 76.7% | 78.6% |
| Adequate Insulation | 75.6% | 82.0% | 81.7% | 90.5% | 89.3% | 86.5% | 88.3% | 92.1% |

**Note**: Analysis includes single-family detached and attached houses
**Source**: 2015 Residential Energy Consumption Survey (RECS)

These results indicate that properties in higher-income neighborhoods are more likely to have energy efficiency features than properties in lower-income neighborhoods. Because energy ratings are lower for properties with fewer efficiency features, properties located in lower-income neighborhoods are inferred to have lower energy ratings, all else being equal. Consequently, given that lower-income households can less afford to invest in

[73] The RECS data does not include any socioeconomic data, so we merge it with zip-code level data on average household income for 2006–2010 from the University of Michigan Institute for Social Research.

energy-efficient technologies, mandatory energy ratings could incrementally lower property values in lower-income neighborhoods.

## B. Analysis of Energy Conservation Audit and Disclosure Data

Energy Conservation Audit and Disclosure (ECAD) data contains information on energy efficiency audits of residential dwellings in Austin, Texas. These data include properties served by Austin Energy and located within Austin city limits. We analyze data on energy efficiency features from 9,889 energy audits performed 2015–2017. The types of identified features include weather-stripped attic hatches, low duct leakage, central air cooling systems, sealed plumbing penetrations, and others.

We analyze the relationship between household energy efficiency features and neighborhood average income. **Table 3** shows, for each energy efficiency feature, the share of housing units with that feature by neighborhood income categories.[74] Across energy efficiency features, we find that the share of properties with the energy efficiency feature increases with household income. For instance, the share of properties with weather-stripped attic hatches is 20.3% for households that have annual incomes between $10,000 and $39,999. This share increases to 23.5%, 33.4%, and 36.0% as higher household income increases to $40,000–$59,999, $60,000–$79,999, and above $80,000, respectively.

**Table 3. Percentage of Housing Units with Energy Efficiency Features by Household Income, Austin, Texas, 2015–2017**

| | $10,000 to $39,999 | $40,000 to $59,999 | $60,000 to $79,999 | More Than $80,000 |
|---|---|---|---|---|
| Number of Households | 1,656 | 4,183 | 2,488 | 1,562 |
| Percent of Households by Income Range | 16.7% | 42.3% | 25.2% | 15.8% |
| **Energy Efficiency Features** | | | | |
| Weather-Stripped Attic Hatches | 20.3% | 23.5% | 33.4% | 36.0% |
| Low Duct Leakage (Below 10%) | 10.5% | 13.2% | 14.3% | 16.2% |
| Cooling System is Central Air | 79.0% | 87.4% | 86.5% | 87.4% |
| Sealed Plumbing Penetrations | 22.9% | 27.4% | 30.7% | 33.2% |
| Efficient Attic Insulation (R-Values Above 30) | 10.4% | 14.2% | 18.1% | 17.7% |
| Average R-Value | 17.6 | 20.0 | 22.3 | 22.6 |

**Note:** While Austin, Texas, accounts for 99.68% of observations, the data include information for other cities in Texas such as Burnet, Cedar Park, Del Valle, Leander, Manchaca, Marble Falls, Pflugerville, and Round Rock.
**Source**: Energy Conservation Audit and Disclosure (2015–2017 ECAD) for Residential Homes–Austin Energy; Michigan Population Studies Center, Institute for Social Research, University of Michigan

As with the RECS survey data, we find that properties in higher-income neighborhoods are more likely to have energy efficiency features than properties in lower-income neighborhoods. Thus, these data indicate that property values in lower income neighborhoods may on average be adversely affected if energy rating is mandated.

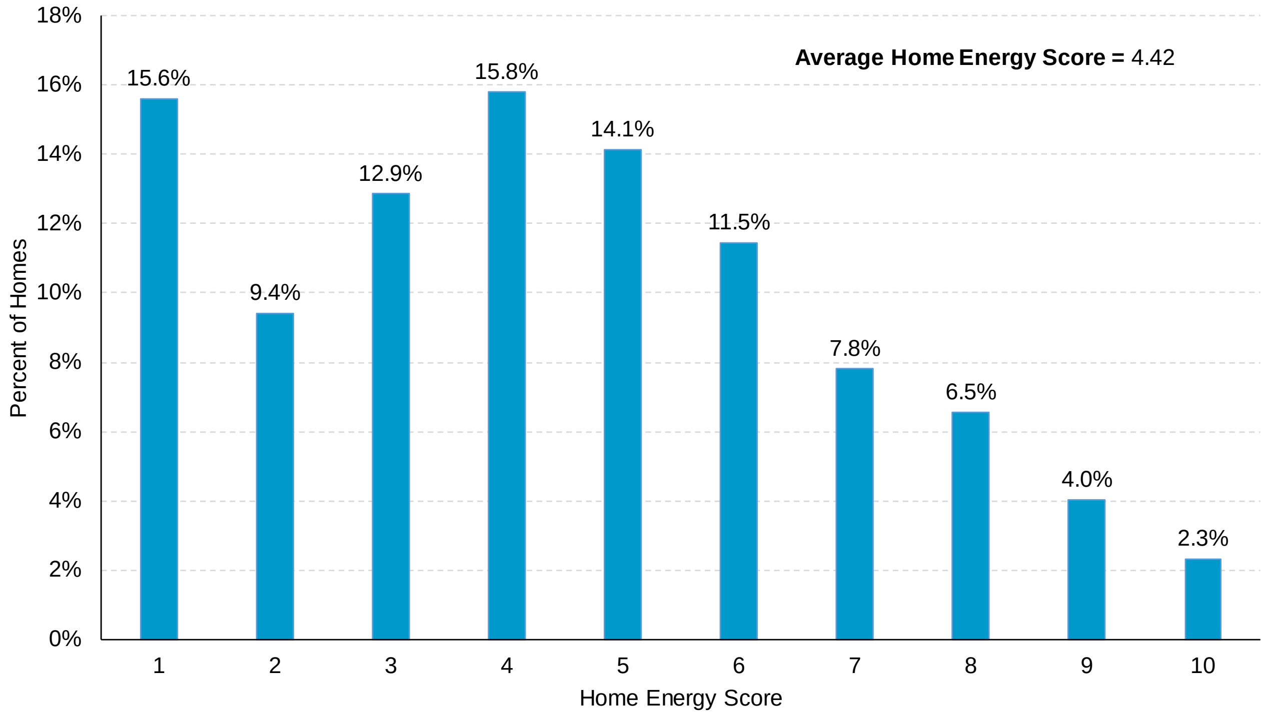
[74] As with the RECS data, we rely on zip code-level average household income (from the University of Michigan) to characterize the income of different neighborhoods in Austin.

## C. Analysis of Regional Multiple Listing Service Data from Oregon

We analyze data from the Portland, Oregon metropolitan area since the adoption of energy rating requirements at the beginning of 2018. In particular, we examine data from the RMLS, which provides data on energy rating, transaction price, square footage, number of bedrooms and bathrooms, lot size, and construction year. Our sample includes 64,547 detached residential property sales transactions occurring from January 1, 2018 to June 21, 2018.[75]

**Figure 3** shows the distribution of HES ratings. The average energy score is 4.42 out of 10, below an average value of 5.[76] The median value is 4 out of 10, and the rating that occurs most frequently (the modal value), accounting for 15.8% of observations, is 4 out of 10. **Figure 4** shows the distribution of average HES ratings across zip codes in the Portland area. Across zip codes, average energy score ranges from 2.60 to 5.80.

**Figure 3. Distribution of Home Energy Scores, Portland Oregon, 1/1/2018 to 12/31/2018**

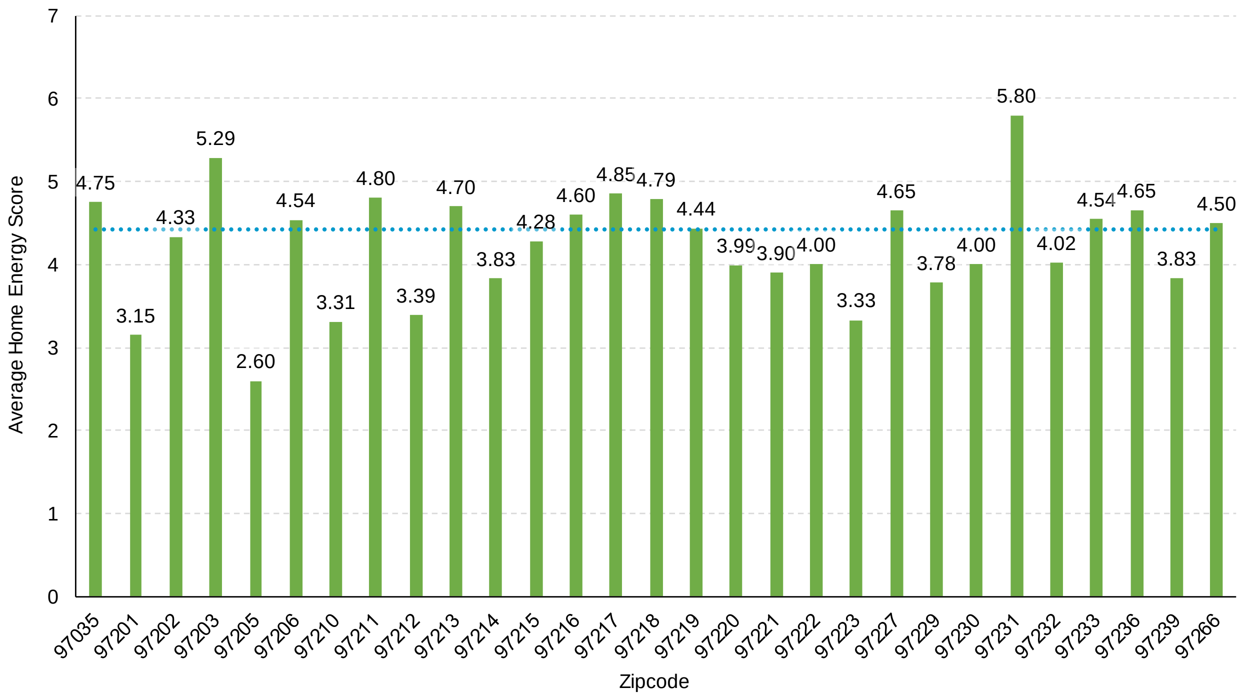



**Source**: Portland Regional Multiple Listing Service

[75] Properties are from Multnomah, Hood River, Clackamas, Yamhill, Washington, Columbia, Clark, and Skamania Counties in Oregon and Washington.

[76] US DOE, 2017, p. 6.

**Figure 4. Average Home Energy Score by Zip Code, Portland, Oregon, 1/1/2018 to 12/31/2018**




**Note**: Excludes zip codes with 20 or fewer sales.
**Source**: Portland Regional Multiple Listing Service

Given the relationship between energy ratings and property values, mandatory energy ratings may have affected the aggregate value of the housing stock. For example, if homebuyers assumed naïvely that every property had a rating of 5 out of 10 in the absence of an HES rating, then the requirement might lower aggregate property values because actual ratings, on average, were below the average.[77] Making this assumption, we calculate the impact of the HES requirement on the average home sale as $2,292 per transaction. (See **Table 4**.[78]) Further empirical analysis could inform whether this assumption captures actual impacts.

As we discussed above, homebuyers may be able to form their own estimates of energy efficiency in the absence of an energy rating. If homebuyers' assessment of energy efficiency is the same as that provided by the energy rating (i.e., the rating provides no incremental information), then the HES rating requirement may not impact property values by improving expectations regarding energy costs. But because the incremental effect of energy ratings on property values tends to exceed underlying differences in energy costs, the HES rating requirement may generate knock-on effects beyond the capitalization of future energy costs. We assume that the impact of energy ratings is 33% in excess of the capitalized value of future energy savings, which is at the lower end of the 37% to 97% range found in prior work. Making this assumption, the HES rating requirement has reduced transaction

[77] This estimate assumes, among other things, that there is no substitution by homebuyers between houses affected by the requirement and those outside this region, and that buyers do not adjust their "naïve" expectations about the average property's energy efficiency rating.

[78] This calculation is based on a linear regression estimate of the marginal change in transaction price due to a change in HES score.

prices by $764 per sale, on average. (See **Table 4**.) Note that this impact reflects a portion (one-third) of the $2,292 per transaction average impact, which reflected both energy savings and the premium/discount (on the energy savings).

**Table 4. Estimate of Total Change in Property Values Due to Home Energy Scores, Portland, Oregon, 1/1/2018–12/31/2018**

| | | |
|---|---|---|
| Average Portland Home Energy Score (HES) | 4.42 | [A] |
| Assumed But-For HES [1] | 5.00 | [B] |
| Difference between But-For and Average HES | -0.58 | [C] = [A]-[B] |
| Number of Home Sales | 4,215 | [D] |
| Effect Per HES Point on Property Values in Portland ($1,000 per point)[3] | 3.969 | [E] |
| **Estimated Total Change in Property Values due to Mandatory HES ($1000s)** | **$9,660** | **[F] = [C]x[D]x[E]** |
| Average Change Per Home Sale ($) | $2,292 | [F] / [D] |
| Average Change per Home Sale Assuming 50% Premium ($) | $764 | (0.5/ 1.5) * [F] / [D] |

**Notes**: [1] The but-for Home Energy Score is assumed to be a 5 on a 1-to-10 scale. [2] The Total Value of Properties with Home Energy Scores is the sum of prices of properties with Home Energy Scores in our sample of transactions from 1/1/2018 to 12/31/2018. [3] The Effect of Home Energy Score on Property Values in Portland is measured by the coefficient on the Home Energy Score control in a hedonic property value regression, reported in Appendix A.
**Sources**: Portland Regional Multiple Listing Service; Michigan Population Studies Center, Institute for Social Research, University of Michigan

Analysis of data from the RECS survey and Austin suggests that properties in higher-income neighborhoods are more likely to have energy efficiency features. However, energy ratings may reflect multiple factors beyond a property's energy efficiency features. Thus, to understand economic impacts, it is important to analyze the relationship between energy ratings and socioeconomic factors.

**Table 5** shows the mean energy rating and dwellings characteristics for strata of property transaction prices. We evaluate the Portland data along property value strata because the data include property-specific transaction prices, but not property-specific income. The transaction price is likely to be correlated with the buyer's income and wealth, making it one indicator of household financial well-being. At the neighborhood level, there is a positive relationship between income and property values.

**Table 5. Average Characteristics of Residential Properties by Property Transaction Prices, Portland, Oregon, January 1, 2018–December 31, 2018**

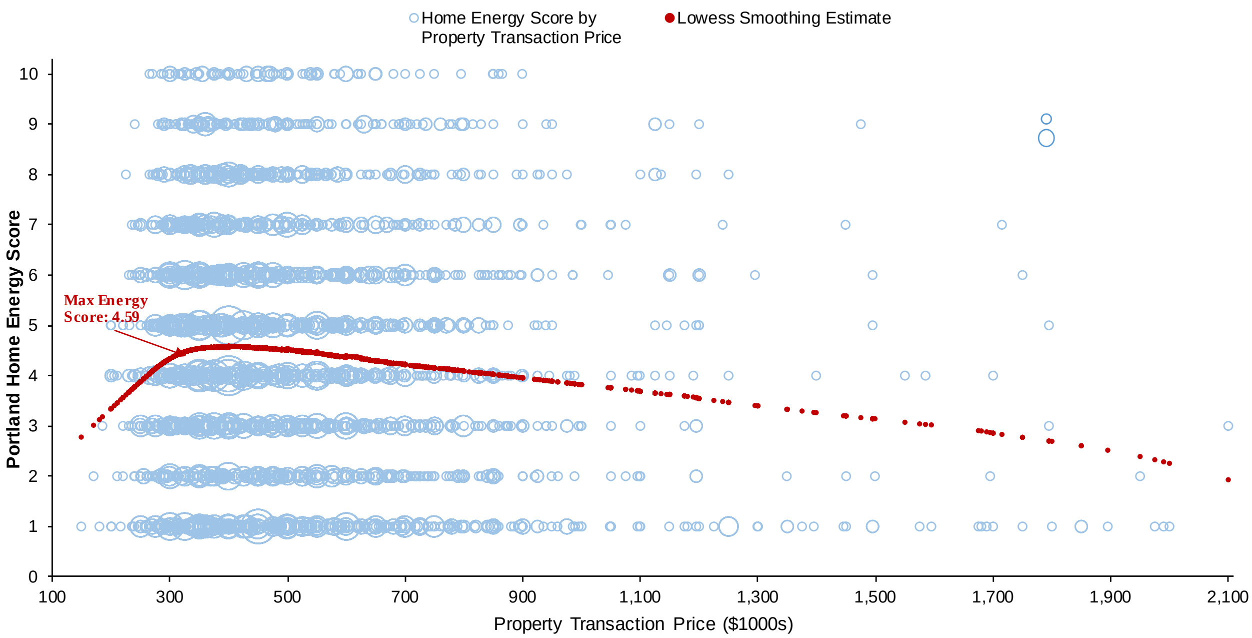
| | $149,000 to $324,999 | $325,000 to $474,999 | $475,000 to $624,999 | $625,000 to $999,999 | More Than $1,000,000 |
|---|---|---|---|---|---|
| Number of Households | 626 | 1,831 | 964 | 677 | 117 |
| Percent of Households by Income Range | 14.9% | 43.4% | 22.9% | 16.1% | 2.8% |
| Energy Score | | | | | |
| Mean | 4.25 | 4.66 | 4.36 | 4.22 | 3.32 |
| Median | 4.00 | 5.00 | 4.00 | 4.00 | 2.00 |
| Standard Deviation | 2.30 | 2.39 | 2.44 | 2.54 | 2.58 |
| Max | 10.0 | 10.0 | 10.0 | 10.0 | 9.0 |
| Min | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Mean Household Income (by zip code) | $54,165 | $62,450 | $73,482 | $82,899 | $90,016 |
| Transaction Price | $289,536 | $393,020 | $540,155 | $748,805 | $1,418,416 |
| Square Footage | 1,212.4 | 1,714.1 | 2,320.6 | 2,970.1 | 4,549.3 |
| Lot Size | 225.4 | 280.7 | 335.6 | 262.1 | 198.8 |
| Year Built | 1951 | 1951 | 1942 | 1949 | 1949 |
| Number of Bedrooms | 2.6 | 2.9 | 3.3 | 3.8 | 4.3 |
| Number of Bathrooms (Full) | 1.2 | 1.6 | 1.9 | 2.4 | 3.2 |
| Number of Bathrooms (Part) | 0.2 | 0.2 | 0.3 | 0.5 | 0.8 |

**Note:** The data are limited to the following transactions: (a) detached houses purchased 1/1/2018 or later, (b) non-zero energy score and property construction year, (c) non-null energy score and transaction price, and (d) transactions with a Home Energy Score. 99.94% of transactions are recorded in the city of Portland; others are recorded in Milwaukie, Oregon.
**Sources:** Portland RMLS; Michigan Population Studies Center, Institute for Social Research, University of Michigan.

**Table 5** shows no clear relationship between energy rating and transaction price. Properties in the second-lowest stratum have the highest average rating, although differences in averages across strata are not statistically significant. Surprisingly, properties with the highest transaction prices have the lowest average energy ratings. **Figure 5** plots the energy ratings and transaction price for all home sales (the size of each circle represents the number of transactions at each transaction price and HES rating combination). The figure shows that the highest-priced properties tend to have low energy ratings, as there are nearly 20 properties with transaction prices above $2 million, none of which have a rating above 3. The red, non-parametric trend line shows that energy ratings start at a low level, less than 3.5, and then rise to an average value above 4.5 for properties transacting at prices of approximately $320,000.[79] Average energy rating then declines as transaction price increases, with the average rating of transactions larger than $850,000 falling below 4.

[79] The nonparametric trend line is fitted using locally weighted scatterplot smoothing (i.e., Lowess smoothing).

**Figure 5. Home Energy Scores and Property Transaction Prices with Lowess Smoothing Prediction, Portland, Oregon, 1/1/2018–12/31/2018**




**Notes:** The data are limited to the following transactions: (a) detached houses purchased 1/1/2018 or later, (b) non-zero energy score and property construction year, (c) non-null energy score and transaction price, and (d) transactions with a Home Energy Score. 99.94% of transactions are recorded in the city of Portland; others are recorded in Milwaukie, Oregon. Only properties with transaction prices below $2 million are displayed.
**Source:** Portland Regional Multiple Listing Service

These summary statistics do not identify a clear linear relationship between transaction price and energy rating. To further analyze these relationships, we perform a regression analysis of energy rating as a function of transaction price, neighborhood income,[80] and property characteristics, such as house size, age, number of bedrooms, number of bathrooms, and lot size.

[80] As with prior analyses, we measure neighborhoods using data from the University of Michigan.

**Table 6** reports the results of our regressions using several specifications. In all models where the property transaction price is included as an independent variable, the coefficient is positive and statistically significant. This suggests that an increase of $100,000 in the transaction price is associated with an increase of 0.14 to 0.25 units in the predicted HES rating (holding all other control variables constant). By contrast, the coefficients on household income (measured at the neighborhood level) are negative for all models; however, the estimates are insignificant or weakly significant when neighborhood (zip code) fixed effects are included. This suggests that energy scores reflect unique neighborhood factors, but that these factors are (at most) weakly related to household income.

**Table 6. Regression Analysis of Energy Efficiency Scores, Portland, Oregon, 1/1/2018–12/31/2018**

| Dependent Variable: Energy Efficiency Scores | | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| Property Transaction Price ($ millions) | Coefficient | 1.363 | 1.534 | | 1.534 | 2.466 |
| | Standard Error | 0.274 | 0.316 | | 0.316 | 0.635 |
| | P-Value | 0.0% | 0.0% | | 0.0% | 0.0% |
| Household Income (in $1000) | Coefficient | | | 0.012 | 0.012 | -0.012 |
| | Standard Error | | | 0.029 | 0.028 | 0.002 |
| | P-Value | | | 67.8% | 67.6% | 0.0% |
| Square Footage (1000 $sq^2$) | Coefficient | -0.916 | -0.864 | -0.638 | -0.864 | -1.029 |
| | Standard Error | 0.080 | 0.080 | 0.064 | 0.080 | 0.127 |
| | P-Value | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Year Built | Coefficient | 0.020 | 0.025 | 0.025 | 0.025 | 0.021 |
| | Standard Error | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | P-Value | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Number of Bedrooms | Coefficient | -0.392 | -0.403 | -0.416 | -0.403 | -0.402 |
| | Standard Error | 0.056 | 0.056 | 0.056 | 0.056 | 0.058 |
| | P-Value | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Number of Bathrooms (Full) | Coefficient | 0.532 | 0.576 | 0.654 | 0.576 | 0.509 |
| | Standard Error | 0.070 | 0.070 | 0.068 | 0.070 | 0.077 |
| | P-Value | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Number of Bathrooms (Part) | Coefficient | 0.458 | 0.448 | 0.498 | 0.448 | 0.438 |
| | Standard Error | 0.082 | 0.081 | 0.080 | 0.081 | 0.085 |
| | P-Value | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Lot Size | Coefficient | 0.0006 | 0.0003 | 0.0003 | 0.0003 | 0.0006 |
| | Standard Error | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | P-Value | 0.0% | 0.6% | 0.6% | 0.6% | 0.0% |
| Number of Observations | | 4,215 | 4,215 | 4,215 | 4,215 | 4,215 |
| R squared | | 0.172 | 0.206 | 0.201 | 0.206 | 0.176 |
| Zip Code Fixed Effects | | No | Yes | Yes | Yes | No |
| 2SLS (Fitted Property Transaction Price) | | No | No | No | No | Yes |

**Notes:** The data are limited to transactions of detached houses. 99.94% of transactions are recorded in the City of Portland; others are recorded in Milwaukie, Oregon. All regression specifications adjust for robust standard errors.
**Sources:** Portland Regional Multiple Listing Service; Michigan Population Studies Center, Institute for Social Research, University of Michigan

The analysis also shows that the energy rating is related to other property characteristics. Larger size and more bedrooms are associated with lower ratings, while older houses and more bathrooms are associated with higher ratings. These results indicate that the energy rating depends on certain physical housing features and amenities, and not simply on energy efficiency factors (e.g., insulation, energy-efficient windows), per se*.* For example, the HES metric used in Portland is constructed to depend on house size because larger homes use more energy, all else being equal.[81] However, as noted previously, it is unclear whether potential buyers are aware of this, particularly because the HES rating has a value on a 1 to 10 scale, suggesting that it is a relative ranking.

## D. Analysis of Energy Performance Certificate Data for England and Wales

EPC data for England and Wales (the "UK data") contains information from certificates issued to residential dwellings in England and Wales. The UK requires and records energy performance certificates and ratings in accordance with the EPBD, which was discussed previously in **Section IV.3**. The UK data include 15,616,549 dwelling-level energy performance ratings from January 2006 to December 2016, as well as other energy efficiency details of the dwelling, such as the share of energy-efficient lighting, the window glazing, and the $CO_2$ emissions for each record.[82] Energy performance certificates include current energy ratings, based on a numerical score that ranges from 0 to 623 points in the UK data. The numeric energy rating is translated into a letter rating between A – the most energy-efficient – and G – the least energy-efficient. We analyze only houses and bungalows that are detached or semidetached. For each EPC, we measure neighborhood (gross) household income in 2015–16, by MSOA, using data from the UK Office for National Statistics.[83] After implementing the data restrictions described above, our sample includes 3,239,019 certificates issued to dwellings in England and Wales, which have energy ratings ranging from 1 to 255.

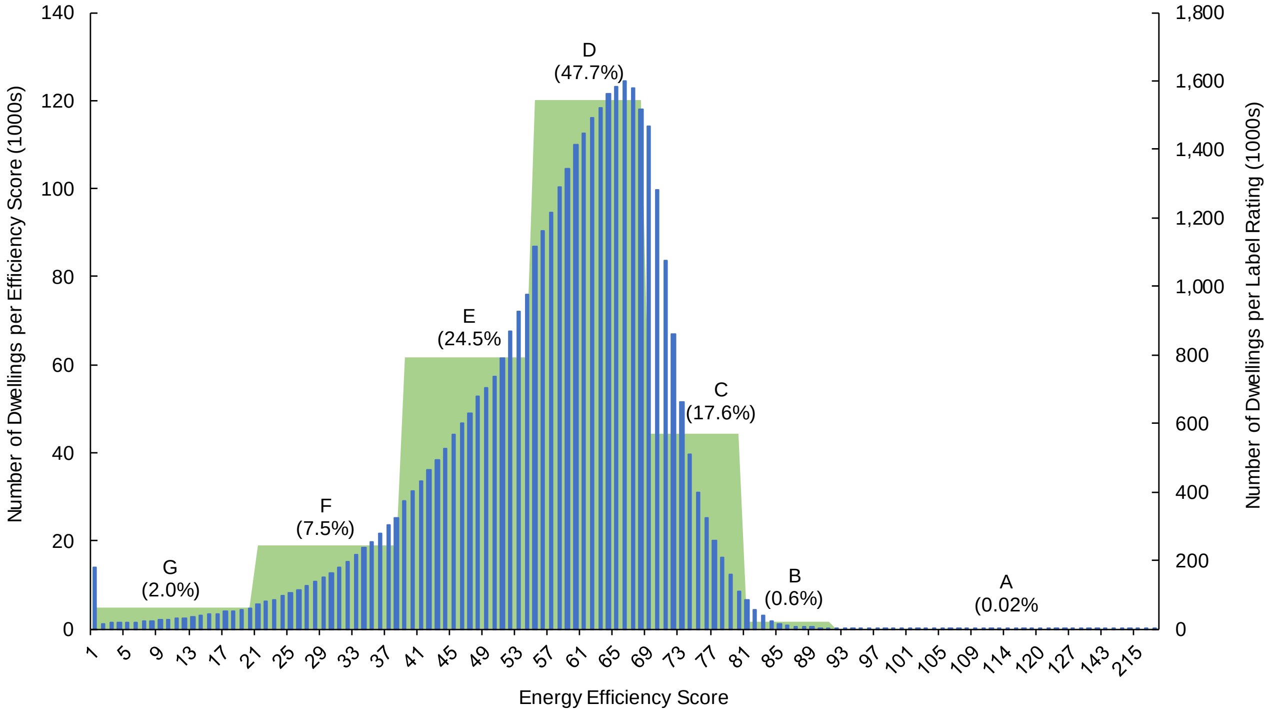
[81] US DOE, 2017.

[82] The UK data may also include multiple certificates for a single dwelling since certificates may be reissued over time and expire 10 years after issue.

[83] An MSOA is a "middle layer super output area," which is a geography used by the UK Census. There are 7,201 MSOAs in England and Wales combined.

**Figure 6** shows the distribution of EPC values for the UK, including both the letter rating and the underlying point rating. The distribution of ratings is highly concentrated to intermediate values, with 89.8% of homes having a letter rating of C, D, or E, and only 2.7% having values of A, B, or G. These results suggest that the EPC may provide relatively little information to market participants, as there is only modest differentiation between the rating values, with most values in the middle.

**Figure 6. Number of Dwellings by Efficiency Score and Label Rating; Houses and Bungalows, Detached or Semidetached, England and Wales**




**Note:** Energy label ratings are the “current energy rating” of the dwelling and the energy efficiency score is the “current energy efficiency” recorded by the UK Ministry of Housing. The data are restricted to “Houses” or “Bungalows” that are either “Semi-Detached” or “Detached.” Transaction type is restricted to “Marketed Sale.”
**Source:** Energy Performance Certificates from the UK Ministry of Housing, Communities & Local Government

We analyze the relationship between EPC rating and (gross) household income (measured at the neighborhood level). **Table 7** shows the results of a regression analysis of EPC ratings on (i) neighborhood (gross) household income (in £ millions), (ii) square footage of the dwelling, (iii) the number of habitable rooms in the dwelling, and (iv) the number of open fireplaces. The regression model includes county fixed effects in model (1) and does not include fixed effects in model (2).

**Table 7. Regression Analysis of Energy Efficiency Scores, England and Wales**

| **Dependent Variable: Energy Rating (0 to 255)** | | **(1)** | **(2)** |
|---|---|---|---|
| Gross Household Income (£ millions) | Coefficient | 45.93347 | 15.10619 |
| | Standard Error | 1.07221 | 1.07462 |
| | P-Value | 0.00000 | 0.00000 |
| Square Footage (1000 $m^2$) | Coefficient | -0.191 | -0.207 |
| | Standard Error | 0.173 | 0.188 |
| | P-Value | 0.269 | 0.270 |
| Number of Habitable Rooms | Coefficient | 0.216 | 0.230 |
| | Standard Error | 0.013 | 0.013 |
| | P-Value | 0.000 | 0.000 |
| Number of Open Fireplaces | Coefficient | -6.107 | -6.164 |
| | Standard Error | 0.134 | 0.133 |
| | P-Value | 0.000 | 0.000 |
| Number of Observations | | 3,161,077 | 3,218,485 |
| R squared | | 0.098 | 0.091 |
| County Fixed-Effects | | Y | N |

**Note:** All regressions adjust for robust standard errors. The data are restricted to “Houses” or “Bungalows” that are either “Semi-Detached” or “Detached.” Transaction type is restricted to “Marketed Sale.” “Gross Household Income” is the average total annual household income for the MSOA in which the home is located.
**Sources:** Energy performance certificates from the UK Ministry of Housing, Communities & Local Government; mall-area income estimates for middle layer super output areas in England and Wales,” 2015–16, are from the UK Office of National Statistics; “UK Countries and Territories by Postcode Area” is available at http://www.roblocher.com/technotes/uk-postareas.html.

In both models, gross household income has a positive and statistically significant coefficient – 45.9 for model (1) and 15.1 for model (2). This suggests that an increase of £1,000 in household income is associated with an increase of 0.045 points in the energy rating. However, the relatively small number of control variables available limits the conclusions that can be drawn from this specification. Note that, in contrast to the analysis for Portland using the HES energy rating, area has no statistically significant relationship with EPC rating. However, other household features associated with larger houses, such as the number of bedrooms, have statistically significant negative effects on energy rating.

## Appendix A: Hedonic Property Value Regression, Portland, Oregon, 1/1/2018 to 12/31/2018

| Dependent Variable:<br>Property Transaction Price ($1000s) | | |
|---|---|---|
| Energy Efficiency Score | Coefficient | 3.969 |
| | Standard Error | 0.766 |
| | P-Value | 0.000 |
| Household Income (in $1000) | Coefficient | 0.0004 |
| | Standard Error | 0.001 |
| | P-Value | 0.653 |
| Square Footage (1000 sq$^2$) | Coefficient | 149.068 |
| | Standard Error | 9.543 |
| | P-Value | 0.000 |
| Year Built | Coefficient | 0.238 |
| | Standard Error | 0.088 |
| | P-Value | 0.007 |
| Number of Bedrooms | Coefficient | -7.174 |
| | Standard Error | 4.424 |
| | P-Value | 0.105 |
| Number of Bathrooms (Full) | Coefficient | 48.910 |
| | Standard Error | 5.409 |
| | P-Value | 0.000 |
| Number of Bathrooms (Part) | Coefficient | 31.052 |
| | Standard Error | 5.131 |
| | P-Value | 0.000 |
| Lot Size | Coefficient | 0.0005 |
| | Standard Error | 0.005 |
| | P-Value | 0.926 |
| Number of Observations | | 4,215 |
| R squared | | 0.777 |
| Zip Code Fixed Effects | | Yes |
| Month Code Fixed Effects | | Yes |

**Notes:** Sample is limited to transactions of detached houses starting from 1/1/2018. Robust standard errors are reported.

**Sources:** Portland RMLS; Michigan Population Studies Center, Institute for Social Research, University of Michigan.

## Appendix B: Examples of Home Energy Ratings and Audits

City of Portland HOME ENERGY SCORE

U.S. DEPARTMENT OF ENERGY

THIS HOME'S SCORE **1** OUT OF 10

THIS HOME'S ESTIMATED **ENERGY COSTS**

**$2,932** PER YEAR

### HOME PROFILE

**LOCATION:**
1234 Anyplace St
Portland, OR 97201

**YEAR BUILT:**
1923

**HEATED FLOOR AREA:**
945 sq. ft.

**NUMBER OF BEDROOMS:**
2

### ASSESSMENT

**ASSESSMENT DATE:**
12/22/2017

**SCORE EXPIRATION DATE:**
12/22/2025

**ASSESSOR:**
Maria Gomez
Gomez Energy Partners

**PHONE:**
503-555-1211

**EMAIL:**
mgomez@
gomezergymodeling.com

**CCB LICENSE #:**
1234567890

*Flip over to learn how to improve this score and use less energy!*

Better Buildings — **Home Energy Score**


SAMPLE

Official Assessment | ID#1234567

The Home Energy Score is a national rating system developed by the U.S. Department of Energy. The Score reflects the energy efficiency of a home based on the home's structure and heating, cooling, and hot water systems. The average score is a 5. Learn more at HomeEnergyScore.gov.

### HOW MUCH ENERGY IS THIS HOME LIKELY TO USE?

| | | |
|---|---|---|
| **Electric:** | 10,000 kWh/yr. | $930 |
| **Natural Gas:** | 0 therms/yr. | $0 |
| **Other:** | 776 gal/yr. | $2,002 |
| **TOTAL ENERGY COSTS PER YEAR** | | **$2,932** |

**How much renewable energy does this home generate?**

____ kWh/yr

### THIS HOME'S CARBON FOOTPRINT:


What should my home's carbon footprint be? Between now and 2030, Portlanders should reduce reduce carbon pollution per household to 3 metric tons per year to reach our climate goals.

- Actual energy use and costs may vary based on occupant behavior and other factors.
- Estimated energy costs were calculated based on current utility prices ($0.11/kwh for electricity; $1.09/therm for natural gas; $2.58/gal for heating oil; $2.21/gal for propane).
- Carbon footprint is based only on estimated home energy use. Carbon emissions are estimated based on utility and fuel-specific emissions factors provided by the OR Department of Energy.
- Relisting 2-7 years after the assessment date requires a free reprint of the Report from: **www.greenbuildingregistry.com/portland** to update energy and carbon information.
- **This report meets Oregon's Home Energy Performance Score Standard and complies with Portland City Code Chapter 17.108.**

| Score today: | Score with improvements:* | Estimated energy savings with improvements: | Estimated carbon reduction with improvements: |
|---|---|---|---|
| 1 | 9 | $1,672 PER YEAR | 57% PER YEAR |

## TACKLE ENERGY WASTE TODAY!

**Enjoy the rewards of a comfortable, energy efficient home that saves you money.**

- [x] Get your home energy assessment. Done!
- [ ] Choose energy improvements from the list of recommendations below.

  Need help deciding what to do first? Non-profit Enhabit offers free 15-minute phone consults with expert home advisors. Call 855-870-0049.
- [ ] Select a contractor (or two, for comparison) and obtain bids.

  Checkout **www.energytrust.org/findacontractor** or call toll free **1-866-368-7878**.
- [ ] Explore financing options at **www.enhabit.org** or **www.energytrust.org**.

## * PRACTICAL ENERGY IMPROVEMENTS | COMPLETE NOW OR LATER

**To achieve the "score with improvements," all recommended improvements listed below must be completed. Improvements all have a simple payback of ten years or less and may be eligible for mortgage financing. For a more detailed explanation of costs and payback, please get a bid from a contractor.**

| FEATURE | TODAY'S CONDITION | RECOMMENDED IMPROVEMENTS |
|---|---|---|
| Attic insulation | Ceiling insulated to R-0 | Insulate to R-38 or R-49 if code requires it |
| Attic insulation | Ceiling insulated to R-19 | Insulate to R-38 or R-49 if code requires it |
| Duct insulation | Un-insulated | Insulate to R-8 |
| Duct sealing | Un-sealed | Reduce leakage to a maximum of 10% of total airflow |
| Envelope/Air Sealing | Not professionally air sealed | Professionally air seal |
| Heating Equipment | Oil furnace 60% AFUE | Upgrade to ENERGY STAR |
| Heating Equipment | Natural Gas/Propane Furnace | Upgrade to ENERGY STAR |
| Wall insulation | Insulated to R-0 | Fully insulate wall cavities |
| Water Heater | Standard electric tank | Upgrade to ENERGY STAR, minimum 2.76 EF (Energy Factor) |
| Windows | Multiple types | Upgrade to ENERGY STAR |
| Air Conditioner | None | |
| Basement wall insulation | None | |
| Floor insulation | Insulated to R-0 | |
| Foundation wall insulation | None | |
| Skylights | None | |
| Cathedral ceiling | None | |
| Solar PV | None | Visit www.energytrust.org/solar to learn more |



## YOU CAN DO IT YOURSELF!

Looking for low-cost ways to cut energy waste, boost your comfort and lower your energy bills? Visit the resources below to learn about easy changes you can make today:

**www.energytrust.org/tips** and **www.communityenergyproject.org/services**

City of Portland HOME ENERGY SCORE

U.S. DEPARTMENT OF ENERGY

THIS HOME'S SCORE 1 OUT OF 10

THIS HOME'S ESTIMATED ENERGY COSTS

$2,932 PER YEAR

## HOME PROFILE

**LOCATION:**
1234 Anyplace St
Portland, OR 97201

**YEAR BUILT:**
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**HEATED FLOOR AREA:**
945 sq. ft.

**NUMBER OF BEDROOMS:**
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## ASSESSMENT

**ASSESSMENT DATE:**
12/22/2017

**SCORE EXPIRATION DATE:**
12/22/2025

**ASSESSOR:**
Maria Gomez
Gomez Energy Partners

**PHONE:**
503-555-1211

**EMAIL:**
mgomez@gomezergymodeling.com

**CCB LICENSE #:**
1234567890

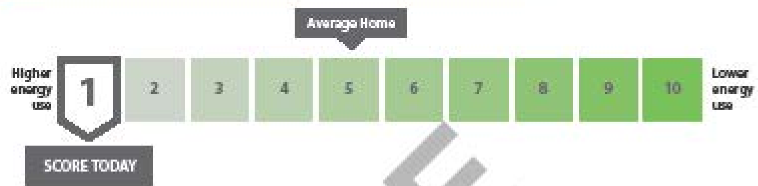
## MAKE THE MOST OUT OF YOUR NEW HOME!

To learn more about ways to cut energy waste, boost your comfort and keep your energy bills low visit:

www.energytrust.org/tips

Better Buildings

**Home Energy Score**




SAMPLE

Official Assessment | ID#1234567

The Home Energy Score is a national rating system developed by the U.S. Department of Energy. The Score reflects the energy efficiency of a home based on the home's structure and heating, cooling, and hot water systems. The average score is a 5. Learn more at HomeEnergyScore.gov.

### HOW MUCH ENERGY IS THIS HOME LIKELY TO USE?

**Electric:** 10,000 kWh/yr. .............................. $930
**Natural Gas:** 0 therms/yr. .............................. $0
**Other:** 776 gal/yr. .............................. $2,002

**TOTAL ENERGY COSTS PER YEAR $2,932**

**How much renewable energy does this home generate?**
____ kWh/yr

### THIS HOME'S CARBON FOOTPRINT:


What should my home's carbon footprint be? Between now and 2030, Portlanders should reduce reduce carbon pollution per household to 3 metric tons per year to reach our climate goals.

- Actual energy use and costs may vary based on occupant behavior and other factors.
- Estimated energy costs were calculated based on current utility prices ($0.11/kwh for electricity; $1.09/therm for natural gas; $2.58/gal for heating oil; $2.21/gal for propane).
- Carbon footprint is based only on estimated home energy use. Carbon emissions are estimated based on utility and fuel-specific emissions factors provided by the OR Department of Energy.
- Relisting 2-7 years after the assessment date requires a free reprint of the Report from: www.greenbuildingregistry.com/portland to update energy and carbon information.
- This report meets Oregon's Home Energy Performance Score Standard and complies with Portland City Code Chapter 17.108.

Austin City Code Chapter 6-7, June 2009

## SINGLE FAMILY

# ECAD Energy Audit Results

**For Residence**: 1108 W 9th ST Austin, TX, 78703 **Audit Date**: 11/13/2017

Thank you for complying with the City of Austin's ECAD Ordinance, which requires homeowners to provide these energy audit results to buyers.

**SAVE THIS FORM! This ECAD audit is valid for 10 years after the audit date.**

This audit helps you identify energy efficiency improvements that could lower your monthly energy costs and make your home more comfortable. Austin Energy's Home Performance with ENERGY STAR® program offers rebates and low-interest loans that make these improvements more affordable. Before you begin making any home energy efficiency improvements, be sure to get the latest program details from **austinenergy.com** or by calling **512-482-5346**.

## ENERGY AUDIT SUMMARY

| | Action Recommended? | Potential Annual Savings*: |
|---|---|---|
| A. Windows and Shading | Yes | $100 |
| B. Attic Insulation | No | |
| C. Air Infiltration and Duct Sealing | Yes | $120 |
| D. Heating and Cooling System Efficiency (HVAC) | No | |
| | **Total Annual Savings:** | $220 |

## HOME IMPROVEMENT RECOMMENDATIONS:

Austin Energy recommends the following actions based on the energy audit performed by [signature] of Earth Energy Audits

A. Improving your windows and/or adding shading reduces the heat that the Texas sun adds to your house.

B. No Attic insulation recommendations.

C. Sealing or replacing the air conditioning duct-work can reduce your electric bill and make your home more comfortable. The duct system must be properly sized and in good condition or the heating and cooling system will run longer and cool less efficiently.

D. No heating and cooling system recommendations.

We appreciate your support of the ECAD ordinance and your efforts to make Austin the most livable city in the country.

***DISCLOSURES**: Figures are based on an estimate from the average single-family house in Austin (1800 - 2000 sq. ft.) that has made improvements through an efficiency program by Austin Energy or Texas Gas Service. Weather, equipment installation and electric usage will all effect actual savings. There is no guarantee or warranty, either expressed or implied, as to the actual effectiveness, cost or utility savings, if you choose to implement these recommendations.*

*The Energy Conservation Audit and Disclosure is not required to be included in the sales contract nor the Seller's Disclosure form (Texas Real Estate Commission), but instead is a stand-alone requirement of the City of Austin.*

*In support of the City of Austin's*
*Energy Conservation Audit and Disclosure Ordinance*
*Austin City Code Chapter 6-7, June 2009*

## SINGLE FAMILY
# Energy Audit Data

**DATA SUMMARY** Submission Date: 11/13/2017

### PROPERTY

Austin Energy Electric Meter Number: 3275031
Owner Name: HOLMES BETTY
Street Address: 1108 W 9th ST
City, State, Zip Code: Austin, TX, 78703
Tax Assessor's Property ID: 106991
Year Built: 1900
Estimated Square Footage: 5,533

### AUDITOR

Auditor: Coby Sackett
Company Name: Earth Energy Audits
Phone Number: (512) 466-7679
Property Audit Date: 11/13/2017

### WINDOWS & SHADING

Type(s) of Window(s): Single Pane, Double Pane, Low E Windows Installed
Type(s) of Existing Solar Shading: Awnings, Tree Cover providing shading.

### ATTIC INSULATION

Attic Insulation Type: No Access
Average R-Value: 11
Open Chases(s): No uninsulated or unsealed chases in residence.

### HEATING & COOLING AIR DUCT SYSTEM

HVAC SYSTEM:
Condenser: Manufacturing Date: 2012 Estimated EER: 11.5
Furnace/AH: Manufacturing Date: post-06 Estimated AFUE: 80
HVAC Duct Air Leakage: 143 CFM % Leakage: 14.3 %
Duct System Type(s) Mylar Flex
Enrolled in the Austin Energy Power Partner Thermostat Program: No

ADDITIONAL SYSTEM:
Condenser: Manufacturing Date: 2013 Estimated EER: 11.5
Furnace/AH: Manufacturing Date: post-06 Estimated AFUE: 80
HVAC Duct Air Leakage: 66 CFM % Leakage: 11.0 %
Duct System Type(s): Mylar Flex
Enrolled in the Austin Energy Power Partner Thermostat Program: No

### AIR INFILTRATION/WEATHERIZATION

Exterior doors: weather-stripped? Yes
Attic access: weather-stripped? Not checked
Plumbing penetrations: sealed? Plumbing penetrations are sealed

### ADDITIONAL AUDIT INFORMATION

Domestic Water Heater Type(s): Tankless Fuel Type: NaturalGas
Type(s) of Toilet(s): 4 High efficiency toilet(s)

## PROPERTY IDENTIFICATION

Outdoor Temperature F 78.0

County Travis | Property ID 106991 | Property Type Single Family | Building Count 2

Meter Number 3275031 | Second Meter | Gas Type AUST I/S Res

Street # 1108 | Direction W | Street Name 9th | Suffix Street | Unit

City Austin | State TX | Zip 78703 | Occupied By Owner | Count of Occupants

Year Built 1900 | Foundation Combination | Estimated Sq Footage 5,533 | Average Duct Leakage 0.0%

Levels 3.0 | Bedrms 3 | Baths 3.5 | Fireplaces 7 | Average Wall Height 10 ft | Average Attic R-Value 11

## WINDOWS & SHADING

Types of Windows ☑ Single Pane ☑ Double Pane ☑ Low-e ☐ Skylights ☐ Other

Types of Shading ☐ Solar Screens ☐ Solar Film ☑ Awnings ☐ Skylights Cover ☑ Other Tree Cover

| Windows | S | SW | W | NW | N | NE | E | SE | Skylight |
|---|---|---|---|---|---|---|---|---|---|
| Needs Shade (sq ft) | 145 | 0 | 63 | 0 | 0 | 0 | 0 | 0 | 0 |

Choose House Shape ◉ Other

Bldg Front Orientation: ○ NW ○ N ○ NE ○ W ○ E ○ SW ◉ S ○ SE

## APPLIANCES & WATER HEATER

| APPLIANCES (Remaining in Home) | | '92 or older | '93 or newer |
|---|---|---|---|
| Refrigerators | | 0 | 2 |
| Freezers | | 0 | 0 |
| Clothes Washers | | 0 | 2 |
| Clothes Dryers | Electric | 0 | 2 |
| Dish Washers | | 1 | |
| Range/Stove/Ovens | Gas | 1 | |
| Inefficient Toilets (> 1.6 gal) | | 0 | |
| Efficient Toilets (<= 1.6 gal) | | 4 | |

Pool Pumps 2 | Speed Two

Pool Pump Timers 2

Water Heaters 1

WH1 Tankless | Fuel 1 Natural Gas

WH2 | Fuel 2

Water Heater Timers 1

MISC Lighting Combination | Solar PV N | Electric Vehicle Charger N | Natural Gas Generator N

Sprinklers ☑ Year Installed | Rainwater Collector N | Water Saving Devices Some Installed

## ATTIC INSULATION & AIR INFILTRATION

Roof Type Pitched | Roof Materials Metal | Roof Color Medium | Total Attic R-Value 11

Attic Insulation | Insulation Type No Access | Secondary Insulation Type

Square Feet 3,065 | Inches Deep | R-Value 11

Vaulted Ceiling Insulation | Insulation Type No Vaulted Ceiling | Secondary Insulation Type

Square Feet | Inches Deep | R-Value

Cathedral Ceiling Insulation | Insulation Type No Cathedral Ceiling

Square Feet | Inches Deep | R-Value

Attic/Knee Wall Insulation Status No Attic or Knee Walls

N Radiant Barrier | Chases Insulated or Sealed

Plumbing Penetrations Sealed Y | Furnace & WH Closet Appropriately Sealed Y

# Exterior Doors 7 | # Doors Weather-stripped 7 | Whole House Fan None

# Conditioned Stair Boxes/Hatches 0 | # Insulated 0 | # Weather-stripped 0

12/19/2014

SINGLE FAMILY ECAD DATA COLLECTION FORM PAGE 1 OF 3

**HEATING & COOLING (1)** **Zone Description** First Floor (Living, Kitchen, Main) **Est. Sq. Ft. (Zone)** 1,314

COOLING Type Central Air Thermostat Other Programmable

Condenser Mfg Date 2012 Est. EER 11.5 Est. Condenser BTUs None

Tonnage ◉ From Mfg Spec 2.5 OR ○ Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Central Fuel Type Gas Location Outside (Attic) Air Handler Up Flow

Furnace Mfg Date '06+ Est. BTUs [3.0] 60K - 65K Est. BTUs (other) AFUE [Electric Start] 80%

DUCT SYSTEM *(Check all that apply)* ☐ NONE ☑ Mylar Flex ☐ Grey Flex ☐ Duct Board ☐ Sheet Metal

Duct Locations ☐ Conditioned Space ☐ Crawl Spaces ☑ Furrdowns ☑ Attic

Duct Condition Good R-Value R-6

Return Air Sq. In. 688 Grille Type Stamped Return Plenum Seal Mastic

LEAKAGE Target CFM 1000 Current Est. CFM 1,376

○ Did Not Reach Pressure ◉ Measured Pressure Test Leakage CFM 143 % Leakage 14%

Supply Air Reading F 60.0 Return Air Reading F 70.0 Delta T 10.0

**HEATING & COOLING (2)** **Zone Description** Guest House **Est. Sq. Ft. (Zone)** 699

COOLING Type Central Air Thermostat Other Programmable

Condenser Mfg Date 2013 Est. EER 11.5 Est. Condenser BTUs None

☐ Tonnage ◉ From Mfg Spec 1.5 OR ○ Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Central Fuel Type Gas Location Outside (Attic) Air Handler Up Flow

Furnace Mfg Date '06+ Est. BTUs [1.5] 40K - 45K Est. BTUs (other) AFUE [Electric Start] 80%

DUCT SYSTEM *(Check all that apply)* ☐ NONE ☑ Mylar Flex ☐ Grey Flex ☐ Duct Board ☐ Sheet Metal

Duct Locations Conditioned Space ☐ Crawl Spaces ☐ Furrdowns ☑ Attic

Duct Condition Good R-Value R-6

Return Air Sq. In. 400 Grille Type Stamped Return Plenum Seal Mastic

LEAKAGE Target CFM 600 Current Est. CFM 800

○ Did Not Reach Pressure ◉ Measured Pressure Test Leakage CFM 66 % Leakage 11%

Supply Air Reading F 53.0 Return Air Reading F 71.0 Delta T 18.0

**HEATING & COOLING (3)** **Zone Description** Second Floor (Master Suite) **Est. Sq. Ft. (Zone)** 1,398

COOLING Type Central Air Thermostat Other Programmable

Condenser Mfg Date 2012 Est. EER 11.5 Est. Condenser BTUs None

Tonnage ◉ From Mfg Spec 3.0 OR ○ Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Heat Pump Fuel Type Electric Location Inside House (Closet) Air Handler Up Flow

Furnace Mfg Date '90-'05 Est. BTUs [3.0] 60K - 65K Est. BTUs (other) AFUE

DUCT SYSTEM *(Check all that apply)* ☐ NONE ☑ Mylar Flex ☐ Grey Flex ☐ Duct Board ☐ Sheet Metal

Duct Locations ☐ Conditioned Space ☐ Crawl Spaces ☑ Furrdowns ☐ Attic

Duct Condition Good R-Value R-6

Return Air Sq. In. 400 Grille Type Stamped Return Plenum Seal Mastic

LEAKAGE Target CFM 1200 Current Est. CFM 800

○ Did Not Reach Pressure ◉ Measured Pressure Test Leakage CFM 212 % Leakage 18%

Supply Air Reading F 47.0 Return Air Reading F 65.0 Delta T 18.0

SINGLE FAMILY ECAD DATA COLLECTION FORM PAGE 2 OF 3 106991

**HEATING & COOLING (4)** **Zone Description** First Floor Formals **Est. Sq. Ft. (Zone)** 1,052

COOLING Type Mini-split Heat Pump Thermostat Other Programmable

Condenser Mfg Date 2011 Est. EER 11.5 Est. Condenser BTUs

Tonnage From Mfg Spec OR Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Mini-split Heat Pump Fuel Type Location Air Handler

Furnace Mfg Date Est. BTUs Est. BTUs (other) AFUE

DUCT SYSTEM *(Check all that apply)* ☐ **NONE** ☑ Mylar Flex ☐ Grey Flex ☐ Duct Board ☐ Sheet Metal

Duct Locations ☐ Conditioned Space ☑ Crawl Spaces ☐ Furrdowns ☐ Attic

Duct Condition Good R-Value R-6

Return Air Sq. In. 392 Grille Type Stamped Return Plenum Seal Mastic

LEAKAGE Target CFM Current Est. CFM 784

○ Did Not Reach Pressure ◉ Measured Pressure Test Leakage CFM 192 % Leakage 0%

Supply Air Reading F 53.0 Return Air Reading F 70.0 Delta T 17.0

**HEATING & COOLING (5)** **Zone Description** Third Floor **Est. Sq. Ft. (Zone)** 1,070

COOLING Type Central Air Thermostat Other Programmable

Condenser Mfg Date 2011 Est. EER 11.5 Est. Condenser BTUs None

Tonnage ◉ From Mfg Spec 2.0 OR ○ Est. from Sq. Ft. Sq. Ft. per Ton

HEATING Type Mini-split Heat Pump Fuel Type Location Inside House (Sealed Atti Air Handler Other

Furnace Mfg Date Est. BTUs Est. BTUs (other) AFUE

DUCT SYSTEM *(Check all that apply)* ☐ **NONE** ☑ Mylar Flex ☐ Grey Flex ☐ Duct Board ☐ Sheet Metal

Duct Locations ☐ Conditioned Space ☐ Crawl Spaces ☑ Furrdowns ☑ Attic

Duct Condition Good R-Value R-6

Return Air Sq. In. 488 Grille Type Stamped Return Plenum Seal Mastic

LEAKAGE Target CFM 800 Current Est. CFM 976

○ Did Not Reach Pressure ◉ Measured Pressure Test Leakage CFM 127 % Leakage 16%

Supply Air Reading F 55.0 Return Air Reading F 72.0 Delta T 17.0

**NOTES & INSTRUCTIONS**

No access to the attic but the home is insulated with open-cell spray foam.

HVAC Unit 4 shows zero duct leakage. That is a flaw in the form. The duct leakage for this unit is 24%. Ductwork looks good, but crawlspace units tend to Test slightly higher.

Roof is a combination of metal & slate.

SINGLE FAMILY ECAD DATA COLLECTION FORM PAGE 3 OF 3 106991

**Germany** provides a five-page report on expected and actual energy consumption.[84]

ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom ¹ 18.11.2013

Gültig bis: 03.07.2024

Registriernummer ² BY-2014-000092188 (oder: "Registriernummer wurde beantragt am ...")

1

**Gebäude**

| | |
|---|---|
| Gebäudetyp | Mehrfamilienhaus |
| Adresse | Musterstraße 1, 81245 München |
| Gebäudeteil | ganzes Gebäude |
| Baujahr Gebäude ³ | 2007 |
| Baujahr Wärmeerzeuger ³ ⁴ | 2007 |
| Anzahl Wohnungen | 5 |
| Gebäudenutzfläche ($A_N$) | 624 m² ☑ nach § 19 EnEV aus der Wohnfläche ermittelt |
| Wesentliche Energieträger für Heizung und Warmwasser ³ | Erdgas_H |
| Erneuerbare Energien | Art: keine Verwendung: keine |
| Art der Lüftung/Kühlung | ☐ Fensterlüftung ☑ Lüftungsanlage mit Wärmerückgewinnung ☐ Anlage zur Kühlung ☐ Schachtlüftung ☐ Lüftungsanlage ohne Wärmerückgewinnung |
| Anlass der Ausstellung des Energieausweises | ☐ Neubau ☐ Modernisierung (Änderung/Erweiterung) ☑ Sonstiges (freiwillig) ☐ Vermietung/Verkauf |

**Hinweise zu den Angaben über die energetische Qualität des Gebäudes**

Die energetische Qualität eines Gebäudes kann durch die Berechnung des **Energiebedarfs** unter Annahme von standardisierten Randbedingungen oder durch die Auswertung des **Energieverbrauchs** ermittelt werden. Als Bezugsfläche dient die energetische Gebäudenutzfläche nach der EnEV, die sich in der Regel von den allgemeinen Wohnflächenangaben unterscheidet. Die angegebenen Vergleichswerte sollen überschlägige Vergleiche ermöglichen (**Erläuterungen - siehe Seite 5**). Teil des Energieausweises sind die Modernisierungsempfehlungen (Seite 4).

☐ Der Energieausweis wurde auf der Grundlage von Berechnungen des **Energiebedarfs** erstellt (Energiebedarfsausweis). Die Ergebnisse werden auf **Seite 2** dargestellt. Zusätzliche Informationen zum Verbrauch sind freiwillig. (**Erläuterungen - siehe Seite 5**)

☑ Der Energieausweis wurde auf der Grundlage von Auswertungen des **Energieverbrauchs** erstellt (Energieverbrauchsausweis). Die Ergebnisse sind auf **Seite 3** dargestellt.

Datenerhebung Bedarf/Verbrauch durch ☑ Eigentümer ☐ Aussteller

☐ Dem Energieausweis sind zusätzliche Informationen zur energetischen Qualität beigefügt (freiwillige Angabe).

**Hinweise zur Verwendung des Energieausweises**

Der Energieausweis dient lediglich der Information. Die Angaben im Energieausweis beziehen sich auf das gesamte Gebäude oder den oben bezeichneten Gebäudeteil. Der Energieausweis ist lediglich dafür gedacht, einen überschlägigen Vergleich von Gebäuden zu ermöglichen.

Aussteller
Energieberater BAFA158454
Walter Götzfried
Anemonenweg 13
87656 Germaringen

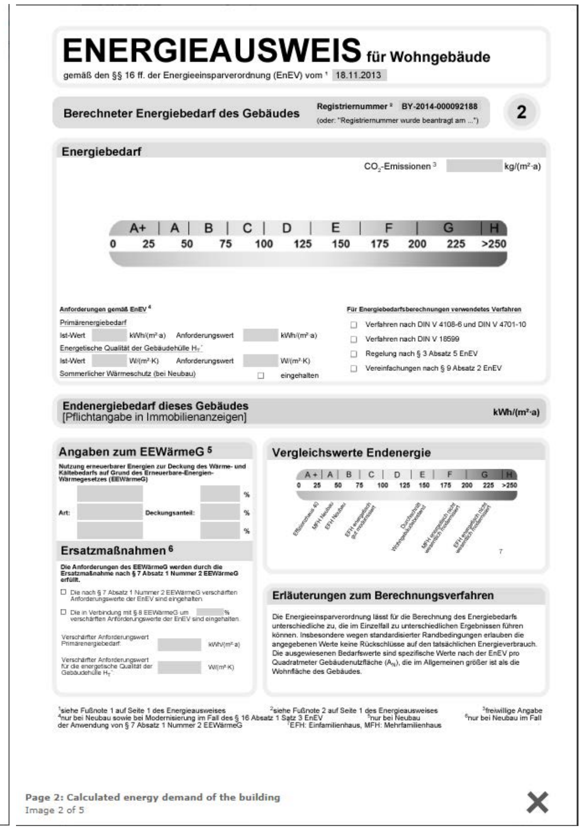
04.07.2014
Ausstellungsdatum

EnerSan GbR

Unterschrift des Ausstellers

Page 1 Energy consumption certificate Residential building
Image 1 of 5

Page 1. Energy Consumption



ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom ¹ 18.11.2013

Berechneter Energiebedarf des Gebäudes

Registriernummer ² BY-2014-000092188 (oder: "Registriernummer wurde beantragt am ...")

2

**Energiebedarf**

$CO_2$-Emissionen ³ kg/(m²·a)

A+ | A | B | C | D | E | F | G | H

0 25 50 75 100 125 150 175 200 225 >250

Anforderungen gemäß EnEV ⁴
Primärenergiebedarf
Ist-Wert kWh/(m²·a) Anforderungswert kWh/(m²·a)
Energetische Qualität der Gebäudehülle $H_T'$
Ist-Wert W/(m²·K) Anforderungswert W/(m²·K)
Sommerlicher Wärmeschutz (bei Neubau) ☐ eingehalten

Für Energiebedarfsberechnungen verwendetes Verfahren
☐ Verfahren nach DIN V 4108-6 und DIN V 4701-10
☐ Verfahren nach DIN V 18599
☐ Regelung nach § 3 Absatz 5 EnEV
☐ Vereinfachungen nach § 9 Absatz 2 EnEV

**Endenergiebedarf dieses Gebäudes** [Pflichtangabe in Immobilienanzeigen] kWh/(m²·a)

**Angaben zum EEWärmeG ⁵**

**Vergleichswerte Endenergie**

**Ersatzmaßnahmen ⁶**

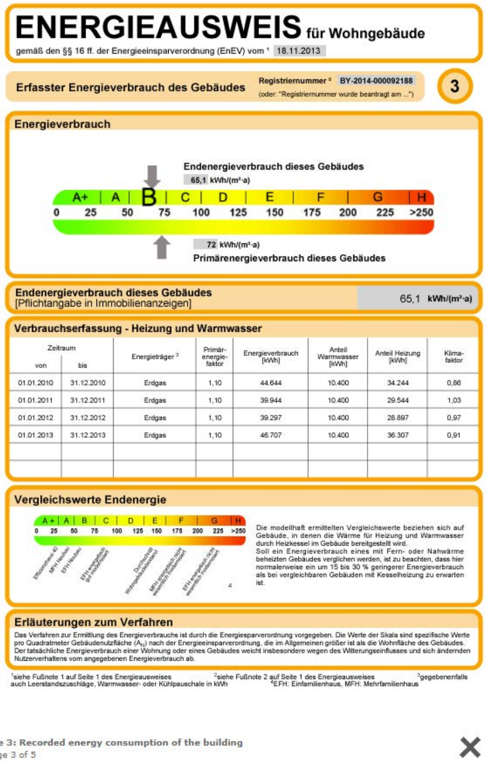
**Erläuterungen zum Berechnungsverfahren**

Die Energieeinsparverordnung lässt für die Berechnung des Energiebedarfs unterschiedliche zu, die im Einzelfall zu unterschiedlichen Ergebnissen führen können. Insbesondere wegen standardisierter Randbedingungen erlauben die angegebenen Werte keine Rückschlüsse auf den tatsächlichen Energieverbrauch. Die ausgewiesenen Bedarfswerte sind spezifische Werte nach der EnEV pro Quadratmeter Gebäudenutzfläche ($A_N$), die im Allgemeinen größer ist als die Wohnfläche des Gebäudes.

Page 2: Calculated energy demand of the building
Image 2 of 5

Page 2. Calculated Energy Demand

[84] See Deutsche Energie-Agentur, "Transparent energy use" at https://www.dena.de/en/topics-projects/energy-efficiency/buildings/consulting-and-planning/energy-performance-certificate/.


ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1] 18.11.2013

Erfasster Energieverbrauch des Gebäudes — Registriernummer [2] BY-2014-000092188 — 3

Energieverbrauch

Endenergieverbrauch dieses Gebäudes 65,1 kWh/(m²·a)

72 kWh/(m²·a) Primärenergieverbrauch dieses Gebäudes

Endenergieverbrauch dieses Gebäudes [Pflichtangabe in Immobilienanzeigen] 65,1 kWh/(m²·a)

Verbrauchserfassung - Heizung und Warmwasser

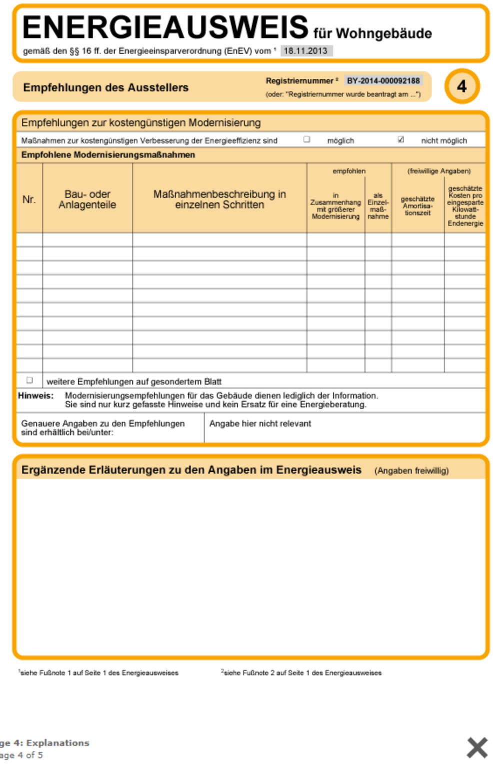
| Zeitraum von | Zeitraum bis | Energieträger [3] | Primärenergiefaktor | Energieverbrauch [kWh] | Anteil Warmwasser [kWh] | Anteil Heizung [kWh] | Klimafaktor |
|---|---|---|---|---|---|---|---|
| 01.01.2010 | 31.12.2010 | Erdgas | 1,10 | 44.644 | 10.400 | 34.244 | 0,86 |
| 01.01.2011 | 31.12.2011 | Erdgas | 1,10 | 39.944 | 10.400 | 29.544 | 1,03 |
| 01.01.2012 | 31.12.2012 | Erdgas | 1,10 | 39.297 | 10.400 | 28.897 | 0,97 |
| 01.01.2013 | 31.12.2013 | Erdgas | 1,10 | 46.707 | 10.400 | 36.307 | 0,91 |

Vergleichswerte Endenergie

Erläuterungen zum Verfahren

Page 3: Recorded energy consumption of the building
Image 3 of 5

Page 3. Actual Energy Demand


ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1] 18.11.2013

Empfehlungen des Ausstellers — Registriernummer [2] BY-2014-000092188 — 4

Empfehlungen zur kostengünstigen Modernisierung

Empfohlene Modernisierungsmaßnahmen

Hinweis: Modernisierungsempfehlungen für das Gebäude dienen lediglich der Information. Sie sind nur kurz gefasste Hinweise und kein Ersatz für eine Energieberatung.

Genauere Angaben zu den Empfehlungen sind erhältlich bei/unter: Angabe hier nicht relevant

Ergänzende Erläuterungen zu den Angaben im Energieausweis (Angaben freiwillig)

Page 4: Explanations
Image 4 of 5

Page 4. Explanations


ENERGIEAUSWEIS für Wohngebäude

gemäß den §§ 16 ff. der Energieeinsparverordnung (EnEV) vom [1] 18.11.2013

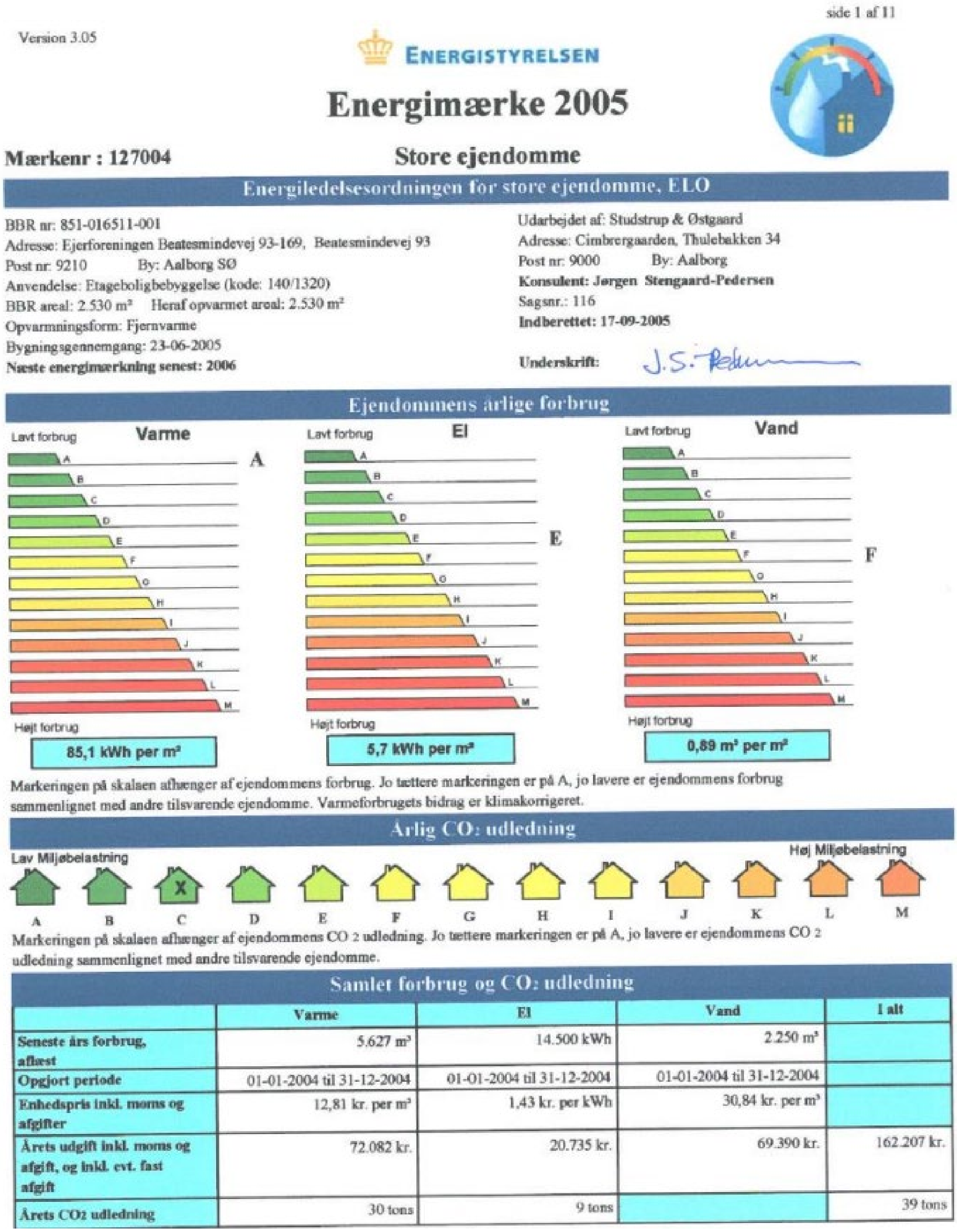
Erläuterungen — 5

Angabe Gebäudeteil - Seite 1; Erneuerbare Energien - Seite 1; Energiebedarf - Seite 2; Primärenergiebedarf - Seite 2; Energetische Qualität der Gebäudehülle - Seite 2; Endenergiebedarf - Seite 2; Angaben zum EEWärmeG - Seite 2; Endenergieverbrauch - Seite 3; Primärenergieverbrauch - Seite 3; Pflichtangaben für Immobilienanzeigen - Seite 2 und 3; Vergleichswerte - Seite 2 und 3

Page 5: Modernization recommendations for the energy certificate
Bild 5 von 5

Page 5. Explanations (continued)

## Denmark (2005)[85]



side 1 af 11

Version 3.05

ENERGISTYRELSEN

# Energimærke 2005

**Mærkenr : 127004**

**Store ejendomme**

Energiledelsesordningen for store ejendomme, ELO

BBR nr: 851-016511-001
Adresse: Ejerforeningen Beatesmindevej 93-169, Beatesmindevej 93
Post nr: 9210 By: Aalborg SØ
Anvendelse: Etageboligbebyggelse (kode: 140/1320)
BBR areal: 2.530 m² Heraf opvarmet areal: 2.530 m²
Opvarmningsform: Fjernvarme
Bygningsgennemgang: 23-06-2005
**Næste energimærkning senest: 2006**

Udarbejdet af: Studstrup & Østgaard
Adresse: Cimbrergaarden, Thulebakken 34
Post nr: 9000 By: Aalborg
**Konsulent: Jørgen Stengaard-Pedersen**
Sagsnr.: 116
**Indberettet: 17-09-2005**

**Underskrift:** J.S. Pedersen

Ejendommens årlige forbrug



Markeringen på skalaen afhænger af ejendommens forbrug. Jo tættere markeringen er på A, jo lavere er ejendommens forbrug sammenlignet med andre tilsvarende ejendomme. Varmeforbrugets bidrag er klimakorrigeret.

Årlig $CO_2$ udledning



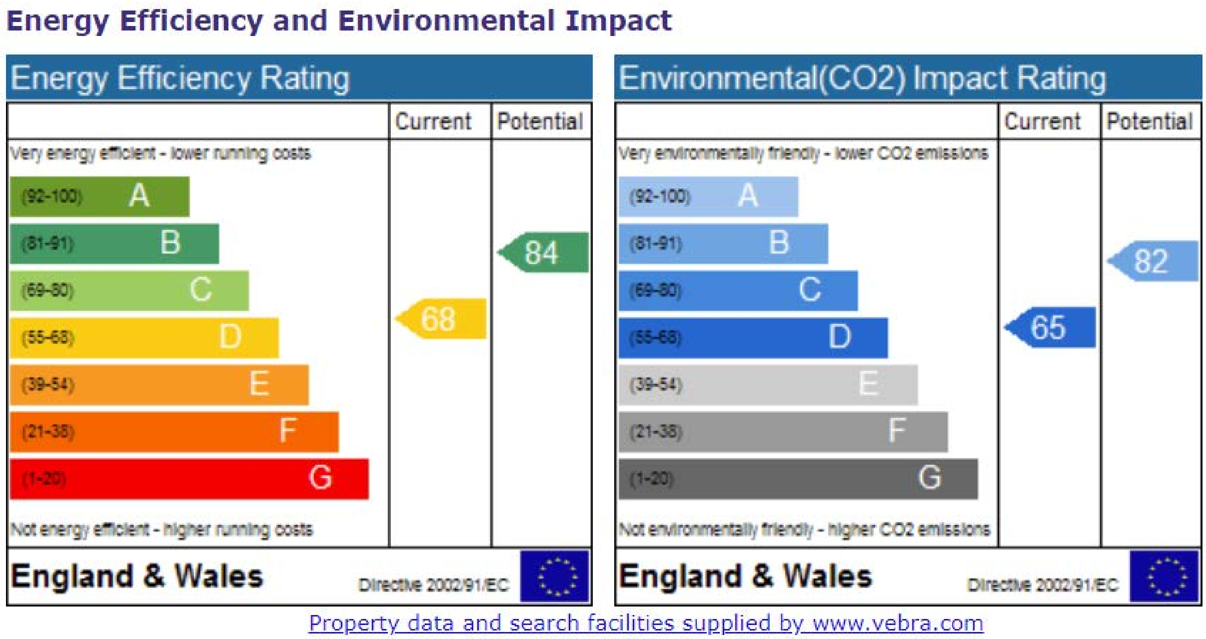
Markeringen på skalaen afhænger af ejendommens $CO_2$ udledning. Jo tættere markeringen er på A, jo lavere er ejendommens $CO_2$ udledning sammenlignet med andre tilsvarende ejendomme.

Samlet forbrug og $CO_2$ udledning

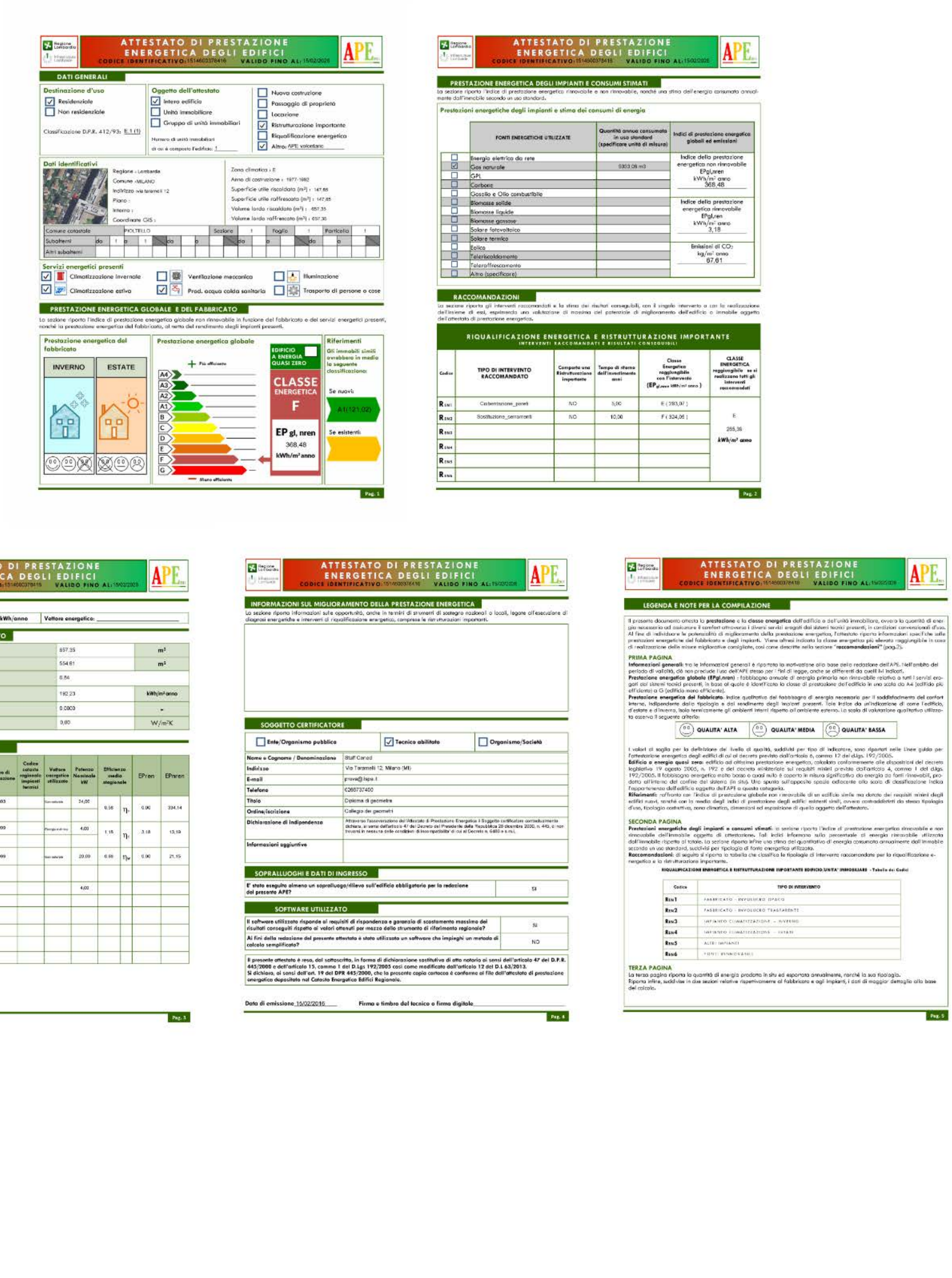
| | Varme | El | Vand | I alt |
|---|---|---|---|---|
| **Seneste års forbrug, aflæst** | 5.627 m³ | 14.500 kWh | 2.250 m³ | |
| **Opgjort periode** | 01-01-2004 til 31-12-2004 | 01-01-2004 til 31-12-2004 | 01-01-2004 til 31-12-2004 | |
| **Enhedspris inkl. moms og afgifter** | 12,81 kr. per m³ | 1,43 kr. per kWh | 30,84 kr. per m³ | |
| **Årets udgift inkl. moms og afgift, og inkl. evt. fast afgift** | 72.082 kr. | 20.735 kr. | 69.390 kr. | 162.207 kr. |
| **Årets $CO_2$ udledning** | 30 tons | 9 tons | | 39 tons |

[85] See Casper Villumsen, "Energy Performance Certificates: Organizational setup for EPCs in Denmark," Danish Energy Agency, December 17, 2015, at http://www.inogate.org/documents/CRV_energy_labelling_DK.pdf.

**England and Wales**



## Italy (2017)[86]



[86] See Certificazione Energetica degli Edifici (CENED), "Infrastrutture Lombarde," at http://www.cened.it/cose.