Center for Real Estate
Massachusetts Institute of Technology

Working Paper Series
#08-15

Energy Efficiency and Economic Value in Affordable Housing

Andrea Chegut, MIT Center for Real Estate
Piet Eichholtz*, Maastricht University
Rogier Holtermans, Maastricht University

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We analyze the value effects of energy efficiency in the affordable housing market, by using a sample of 28,465 homes sold by Dutch affordable housing institutions in the period between 2003 and 2013. We use Energy Performance Certificates to determine the value of energy efficiency in these transactions. We document that dwellings with high energy efficiency sell for 1.9 to 7.2 percent more compared to otherwise similar dwellings with low energy efficiency. This implies a premium of some 3,000 to 11,400 euros for highly energy efficient affordable housing.

Keywords: affordable housing, energy efficiency, energy performance certificates

JEL Codes: R31, Q41, Q5

* Piet Eichholtz is corresponding author. Maastricht University, Department of Finance, PO Box 616, 6200 MD, Maastricht; phone +31 43 3883838; p.eichholtz@maastrichtuniversity.nl

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Andrea Chegut
MIT, Center for Real Estate
Cambridge, MA
achegut@mit.edu

Piet Eichholtz*
Maastricht University
The Netherlands
p.eichholtz@
maastrichtuniversity.nl

Rogier Holtermans
Maastricht University
The Netherlands
r.holtermans@
maastrichtuniversity.nl

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1. Introduction

Approximately 27 percent of aggregate energy use in the European Union's member states stems from the residential sector (Bertoldi, Hirl, and Labanca, 2012). In 2010, this resulted in an estimated 225 billion euro energy bill and 630 million tons of CO_2 emissions for the European housing sector.[1]

This signals growing economic importance of energy consumption in housing, and the European Union continues to encourage the uptake of energy efficiency measures in the built environment. The Energy Performance of Buildings Directive of 2003, its recast in 2010, the Energy Efficiency Plan of 2011 and the subsequent 80 billion euro Horizon 2020 energy efficiency stimulus package all aim to stimulate the improvement of energy efficiency and a reduction in energy demand from buildings through regulatory directives, energy efficiency measurement initiatives and financial incentives. On top of that, many member states have their own rules and incentives stimulating sustainability in the built environment.

Motivated by the energy consumption in the residential sector and the scale of its carbon emissions, this study looks at the financial outcomes of energy efficiency in an important and hitherto neglected segment of the housing market: the affordable housing sector.

There are a number of studies investigating the impact of energy performance on the economic performance of real estate, as measured by rental value, occupancy, and transaction price. For commercial real estate these studies generally find positive rental and transaction premiums for environmentally certified buildings relative to conventional buildings, as well as higher and more stable occupancy rates.[2]

In the housing market, the studies concentrating on the financial performance of energy efficiency are fewer in number. Generally, these housing studies also document positive transaction price premiums for energy efficient dwellings as measured by Energy

[1] These estimates are based on the average electricity and gas price statistics for the EU-27 as provided by Eurostat (2013) and the total electricity and gas consumption figures for the residential sector from Bertoldi et al. (2012). The average electricity and gas prices for households in the EU-27 in 2010 were respectively 17.3 and 5.7 Eurocent per KWh. In that year, the residential sector's electricity consumption was 843 billion KWh and its gas consumption 1,385 billion KWh. Multiplying these consumption figures with the average prices yields a total energy bill of approximately 225 billion euros in 2010. We convert these consumption statistics to kg of CO_2 emissions using a conversion factor of 0.445 for electricity and 0.184 for natural gas as documented by the Carbon Trust (2013).

[2] See Bonde and Song (2013), Chegut, et al. (2014), Eichholtz, et al. (2010, 2013), Fuerst and McAllister (2011), Kok and Jennen (2012).

Performance Certificates (EPC) or other environmental certificates, and find that the size of these premiums depend on the level of energy efficiency (Brounen and Kok, 2011; Cerin, et al., 2014; Feige, et al., 2013; Hyland, et al., 2012). However, almost all of these housing studies take the owner-occupied housing sector into account, which is just one component of the housing market.

Affordable or public housing, which accounts for 17 percent of housing in Europe (Whitehead and Scanlon, 2007) has hardly been investigated in the literature studying the economic effects of energy efficiency. However, its size alone makes it an important sector in the energy efficiency abatement discussion. Moreover, affordable or public housing institutions face significant financial constraints in repaying the investments in energy efficiency related building improvements. This is caused by a split-incentive problem, where building owners invest in energy efficiency for buildings and tenants benefit from the resulting lower energy bill. In many countries, affordable housing sector rents are capped or limited in their increases, which makes the repayment of energy efficiency building investments through increased rents very difficult. These split incentives are a large problem also in the Netherlands, where the affordable housing sector's 2.4 million dwellings accounts for 31 percent of the total housing stock (Autoriteit Woningcorporaties, 2012) and where rent increases are strongly regulated.

However, Dutch affordable housing institutions also regularly sell part of their stock, so an alternative method to get compensated for investments in environmental performance is through the realization of a possible increase in the value of their assets as a result of these improvements. To date, however, there is no evidence showing whether or not this is indeed the case, and given the uncertainty regarding this matter, affordable housing institutions may well underinvest in energy efficiency improvements of their dwellings. The main research question of this paper is to shed light on this issue, by investigating whether energy efficiency is priced in affordable dwellings. We do that by examining a large sample of transactions of individual dwellings by Dutch affordable housing institutions.

To identify these improved energy efficient dwellings, we collect a sample of 28,465 transactions of affordable dwellings from the Netherlands' land registry, the Kadaster, in the period from 2003 until mid-2013 and link it to a database of Energy Performance Certificates maintained by the Netherlands Enterprise Agency (NEA).

We investigate the impact of energy efficiency on the transaction price per square meter in three ways. First, we estimate the value impact of energy labels in general, by comparing the transaction prices of labeled dwellings with those of non-labeled ones. About 42 percent of the dwellings in our sample have an Energy Performance Certificate, and we use the non-certified dwellings as the control sample.

Second, we study the energy labeled sample separately. This way, we can compare transactions of homes with high energy efficiency – those having an A or B label – with homes that are less energy efficient – having a label C through G, and it allows us to directly study the relationship between the energy performance index – on which the labels are based – and the prices of affordable homes.

Third, we analyze to which extent the characteristics of the household buying the dwelling influences the value premium. We focus on household income and financial wealth, and also involve demographic characteristics of the household in the analysis, such as the number of household members, the number of children and the number of elderly people.

In each of these settings, we analyze the relationship between energy efficiency and the transaction prices of affordable housing by employing a standard hedonic pricing model. This way, we control for building quality, location and general housing market conditions, as well as for thermal characteristics such as insulation quality.

We document that affordable dwellings with high-quality energy labels – Energy Performance Certificates of A or B – have higher transaction values than their otherwise comparable peers. Dwellings with an energy label of B or higher transact for 2.6 percent more compared to housing with label C or lower. Specifically, an A-labeled dwelling sells for 7.1 percent more, while a B-labeled dwelling commands a 1.9 percent premium compared to otherwise similar housing with a C label. This implies that the average affordable home with a C label in our sample would sell for almost 11,000 euros more were it to transact as an A-labelled dwelling and for some 3,000 euros more in case of a B label. These results suggest that although it may be difficult for affordable housing institutions to recoup their investments in energy efficiency improvements directly through increased rents or reduced energy costs, they might be able to recover the investment, at least in part, at the time of sale.

The results regarding the effects of household characteristics and energy efficiency value premiums show that the higher income households in the sample – keeping in mind that these incomes are relatively low compared to the national average – pay approximately 1 to 3 percent more for an affordable dwelling as compared to low-income households, and an additional 1 percent more if that dwelling has an EPC label. Within the labeled subsample, we see a premium of 4.6 percent for A and B labeled dwellings compared to C or less for low- and high-income households and 1.6 percent for middle-income households. Higher financial wealth is associated with a somewhat lower willingness to pay for high energy efficiency. Household composition does affect the general willingness to pay for affordable housing, but not for energy efficiency.

In the remainder of this paper, we first briefly discuss related studies focusing on the impact of energy-efficiency in the residential real estate sector. Thereafter, we describe the Dutch affordable housing market. Subsequently, we discuss the data and data sources we use for the analysis, and provide some sample statistics. The following sections present the method and the empirical results. The paper ends with a conclusion and a discussion of the policy implications of this study.

2. The Housing Market and the Value of Energy Efficiency

There is a nascent literature regarding the value of energy efficiency in housing markets in Europe and Asia, as well as the U.S. These studies generally find that homes and apartments that are certified as having low primary energy demand have higher transaction prices and/or rents. However, there are variations across the studies in the type of certification studied, the extent of environmental performance measures linked to the certification and the magnitude of the premium for energy efficiency.

The first study to analyze the impact of energy efficiency on house prices is Brounen and Kok (2011). Their work analyzes the impact of Energy Performance Certificates on the transaction prices of Dutch housing, and employs a sample of homes sold in 2008 and 2009. Of these, 31,993 had an EPC label at the time of transaction and the other 145,325 non-labeled homes were used as a comparison group. Based on the thermal quality of the homes, they are rated from A++ to G, where an A++ label indicates the highest energy efficiency. Dutch homes with an A label sell for 10.2 percent more than otherwise similar homes with a D label. The premium for B labeled homes is 5.5 percent and houses with a C label sell for 2.1 percent more. Dwellings having a label inferior to D trade at a discount.

Cerin et al. (2014) investigate whether the energy efficiency of homes in Sweden contributes to the transaction price, subsequent to the implementation of the European Union's Energy Performance of Buildings Directive. The authors study transactions from 2009 and 2010, and analyze the impact of the actual electricity consumption in kWh per square meter on the transaction price for Swedish homes. In contrast to what is documented by Brounen and Kok (2011), only the most energy efficient homes command a small price premium and there is no observable discount for inefficient homes. An additional decrease in energy consumption of 1 percent for the most energy efficient homes yields a transaction price increase of 0.03 percent.

Hyland et al. (2012) perform a similar study for the Irish housing market, but also include housing rents in their analysis. The authors study the relationship between Ireland's Building Energy Rating (BER) and transaction prices and rental rates of residential housing in Ireland for the period from 2008 to 2012. In line with the results for the Dutch housing market the authors document a price premium of 11 percent for an A labeled home compared to a D label. Dwellings with a B label command a price premium of 5.8 percent. Dwellings with labels F and G trade at a 5.6 percent discount relative to homes with a D label. For rents, the authors document a higher rental value of 1.9 percent for an A labeled dwelling compared to a D label. Surprisingly, the rental premium for a B labeled dwelling is 4.2 percent. Rental units with an E label experience a discount of 1.6 percent relative to a D label, and F and G labeled units have 2.7 percent lower rents. Moreover, the authors find that energy efficiency matters more when selling conditions are worse and dwellings are smaller.

Feige et al. (2013) study the effect of different sustainability attributes on the rental value of Swiss residential units in 2009. They employ a broad range of sustainability criteria, and find that the environmental performance of dwellings is positively related to rent levels. Especially attributes that improve water efficiency, the health and comfort level, and the safety and security of a building contribute positively to the rent level. Interestingly, the energy efficiency of a dwelling is negatively related to the rent level. The authors argue that this might be caused by the common Swiss practice of incorporating the energy costs in the rent.

Recently, Copiello (2015) has performed a case study of one refurbished affordable apartment building in Turin, Italy. The refurbishment has increased the building's environmental performance, improving its envelope insulation, heating systems and other installations. The author finds that apartment rents in the building have gone up substantially, leading to a satisfactory financial return on the investment, so providing a market-based incentive towards improvements in environmental performance in affordable housing.

In Asia, Yoshida and Sugiura (2015) assess the impact of certification under the Tokyo Green Building Program on the transaction value of residential real estate.[3] The authors employ a sample of condominiums sold in the period from 2002 to 2009, and document that new certified units sell at a substantial discount of approximately 11 to 12 percent compared to non-certified apartment units. However, certified dwellings do sell at a premium in the secondary market.

Deng, et al. (2012) investigate the effect of Green Mark certification on the transaction price of residential housing in Singapore.[4] The authors find that certified dwellings sell at a 4 to 6 percent premium. The observed premium varies significantly across the certification categories, with Platinum rated buildings commanding the highest premium – 14 percent. The transaction price for buildings with the lowest type of certification does not differ significantly from non-certified buildings.

In China, rating systems for the environmental performance of buildings are not formally adopted. Therefore, a study by Zheng, et al. (2012) evaluates the impact of "marketing greenness" on the transaction price of housing in Beijing. The authors construct a Google Green Index based on the search rank of housing complexes with respect to their green features for the period from 2003 to 2008 to test the relationship between the initial asking price and the "greenness" of these properties. The authors document that the greenest building in the sample sells at a 17.7 percent premium compared to the least green building.

Dastrup, et al. (2012) focus on the impact of solar panels on the transaction prices of owner-occupied homes in California, and find that these are capitalized in the transaction value at a 3.6 to 4.0 percent premium, corresponding to a predicted increase in transaction value of about 22,500 dollars. The premium is higher in streets with fewer solar-powered homes.

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[3] The Tokyo Green Building Program scores various environmental factors of different types of real estate. The score takes into account the energy efficiency, resource efficiency, use of energy efficient equipment, life span, planting and the mitigation of the heat island phenomenon of a building.

[4] Singapore's Green Mark program assesses the environmental attributes of buildings. The program evaluates the energy and water efficiency, the quality of the indoor environment and the overall environmental impact of real estate.

Kahn and Kok (2013) assess the impact of green home certification on transaction values in California. The authors employ a dataset of homes sold between 2007 and 2012. Homes with a green certification transact for 2 to 4 percent more compared to otherwise similar homes, and energy efficiency is more important for dwellings located in a hotter climate or in districts with higher electricity prices. Green ideology of consumers has a further positive impact on the transaction value of green homes.

The existing findings in Europe, Asia and America suggest that energy efficiency commands a premium in residential sales and rents. However, with the exception of Copiello (2015), none of these studies involves affordable housing. This implies a void in understanding the role of energy efficiency in the housing stock, especially for Europe, where affordable housing institutions play such a prominent role in the residential sector. Moreover, Schaffrin and Reibling (2015) show that low-income households spend a relatively large share of their income on utility costs, which could imply that possible value effects of investments in the environmental performance in housing are large in affordable housing.

To help fill this gap in the literature, we focus on energy efficient affordable housing. We measure the financial performance of dwelling energy efficiency in the European country with the highest number of affordable dwellings per capita: the Netherlands.

3. The Dutch Affordable Housing Market

In relative terms, the Netherlands has by far the largest affordable housing sector of all the countries in Europe: almost one out of three households live in a dwelling owned by a affordable housing institution (Aedes, 2013a). Another yardstick of prominence is that the 381 Dutch affordable housing institutions together own approximately 2.4 million dwellings (Autoriteit Woningcorporaties, 2013). Together, they dwarf Dutch institutional investors in housing, who own a combined portfolio of only 136,000 dwellings (Finance Ideas, 2014).

Hence, to scale up investments in the environmental performance of homes in the Netherlands, affordable housing institutions are a logical starting point. That holds for other European Union countries as well. The affordable housing sector in other European countries is substantially smaller, but is still approximately 17 percent of the total housing stock (Whitehead and Scanlon, 2007).[5]

With an affordable housing sector this large, it is inevitable that these institutions also cater to middle- and lower-middle income groups besides their core client base, i.e. families with the lowest incomes. The Dutch affordable housing stock reflects this. With an average value of 149,000 euros in 2012 (Aedes, 2013b), the dwellings they own are only 36 percent less valuable than an average owner-occupied home. The average quality of these dwellings is also underlined by the fact that some 42 percent are single-family homes (Aedes, 2013b), where affordable housing in most other countries is associated with projects, i.e. high rise apartment buildings, often located in the less attractive parts of cities. Only 11 percent of the Dutch affordable housing would fit that description, whereas the remainder of the portfolio consists of multi-family housing with 4 floors at most (Aedes, 2013b), as well as some senior housing.

In 2012, Dutch affordable housing institutions charged an average rent of 434 euros per month excluding utility costs (Aedes, 2013b). This is lower than the market rent in most Dutch regions, so households that live in a dwelling owned by an affordable housing landlord tend to stay there, and many affordable housing institutions have waiting lists for their product, especially in the big cities and in the Randstad region in the western part of the country.[6]

Almost all households living in dwellings owned by affordable housing institutions are eligible for rent protection. This implies that the rent of an existing contract can only be increased by a percentage set by the government, usually inflation plus a mark-up. Even when an owner does a major renovation, improving the quality of a dwelling, or when an owner invests in energy efficiency, thereby lowering the utility costs for the tenant, the rent on existing contracts cannot be increased to compensate the owner for the investment expense.[7] This makes it difficult to recoup an investment in the environmental performance

[5] This number is based on a survey of affordable housing institutions in Austria, Denmark, England, France, Germany, Hungary, Ireland, the Netherlands, and Sweden performed by Scanlon and Whitehead (2007).
[6] The Randstad is a region in the Netherlands consisting of the nation's four largest cities, Amsterdam, Rotterdam, the Hague and Utrecht, as well as the smaller cities lying between them. In total, some 41 percent of the total Dutch population lives in this area. Retrieved from: http://www.cbs.nl/en-GB/menu/methoden/toelichtingen/alfabet/r/randstad-region.htm.
[7] Only if at least 70 percent of households living in a housing complex agree with a rent increase associated with a refurbishment can the rent be increased for all of the existing tenants in that complex under Dutch law. This

through improved rental cash flows, and it creates a disincentive for the diffusion of energy efficient affordable housing.

However, affordable housing institutions may be able to partly recoup these investments if they sell part of their housing stock in the market. Most European countries' affordable housing institutions are not allowed to do that, so the sale of affordable dwellings is quite rare. But in the Netherlands, affordable housing institutions are allowed and even stimulated to gradually sell dwellings from their stock (Binnenlandse Zaken en Koninkrijksrelaties, 1992). This policy allows affordable housing institutions to sustain a steady cash inflow, which they can reinvest in new construction and in the renovation of their remaining housing stock, thereby realizing their ambitions regarding its quality and environmental performance. The policy also aims to foster private home ownership among low- and middle-income households. This unique regulatory environment in the Netherlands creates a natural experiment that allows us to analyze whether consumers in affordable housing value energy efficiency investments.

4. Data and Descriptive Statistics

4.1 Data

In order to investigate the impact of energy efficiency on the transaction value of affordable housing empirically we combine various data sources. For every year between 2003 and 2013 we retrieve the universe of affordable housing institutions active in the Netherlands from the Autoriteit Woningcorporaties.[8] Using the affordable housing institutions' original listed name as obtained from the Autoriteit Woningcorporaties, we gather information regarding the housing transactions by each institution in the database of the Dutch land registry, the Kadaster. This database provides the exact location of each transacted dwelling, as well as its transaction price, and a set of dwelling characteristics. This matching exercise leads to the identification of 77,069 transactions by Dutch affordable housing institutions in the period from 2003 up to mid-2013.

number is hard to accomplish in practice, and even if successful, this negotiation process usually does not provide additional rental cash flows that suffice to recoup the investment costs borne by the owner.

[8] The Autoriteit Woningcorporaties is the supervisory body to which all Dutch affordable housing institutions report. We use the overview of institutions they maintain to ensure complete coverage in the earlier years of our sample period since many Dutch affordable housing institutions merged over the last decade: the affordable housing market consolidated from about 510 institutions in 2004 to 381 institutions in 2012.

The dwelling quality information provided by the Kadaster is rather limited in scope, and in order to get a more comprehensive set of dwelling characteristics we match the Autoriteit Woningcorporaties and Kadaster data with data from the Dutch Realtors Association (NVM). The NVM documents detailed information for every home that is sold by an associated realtor. This enables us to extensively control for the impact of quality differences throughout our analyses. Based on the location of each home – by employing the unique combination of the building's postcode, house number, and house number addition – we combine the information from the NVM database with the set of transactions supplied by the Kadaster. This leads to a total of 43,871 matched transactions.

Further information on the Energy Performance Certificate (EPC) and energy performance index of each home is obtained from the NEA, which is part of the Dutch Ministry of Economic Affairs. This agency facilitates the energy performance certification of existing and new buildings in the Netherlands.

Incomplete information on quality characteristics across transactions limits the sample, and our final sample includes a total of 28,465 transactions.[9] Of these dwellings, 11,994 have an energy label, and the other 16,471 observations serve as the control sample.

4.2 Descriptive Statistics

This section compares the average characteristics of the labeled dwelling sample with the non-labeled dwellings. The first column in Table 1 describes the total sample, and the second and third columns describe the non-labeled and labeled samples, respectively.

The average home in the sample sells for more than 1,700 euros per square meter, with an average size of approximately 91 square meters divided over four rooms. Most of the homes are either apartments or duplexes, and these two types account for about 78 percent of the total sample. Most of the homes in the full sample have been constructed between 1961 and 1990. The quality of exterior (interior) maintenance is rated as medium or better for 95.7 (95.6) percent of the observations.

Concerning the thermal quality characteristics, almost 90 percent of the homes use a central heating system. The insulation quality is on average quite poor with 74 percent of the

[9] Due to non-consistent information on the transaction price between the Kadaster and NVM databases the sample reduces to 32,840 observations. Finally, missing dwelling quality characteristics and ensuring that every postcode area has at least one labeled building further reduces the sample to 28,465 observations.

observations displaying a low insulation quality, less than two types of insulation. Less than 10 percent of the homes have four or more types of insulation.

Comparing the labeled homes in our sample to the non-labeled homes displays that both samples deviate only mildly from each other. Labeled and non-labeled affordable housing commands approximately the same transaction price per square meter. Non-labeled affordable dwellings tend to be slightly larger than labeled ones, and they are more often apartments instead of semi-duplexes and semi-detached homes. Non-labeled homes also tend to be a bit younger and are more often constructed after the year 2000.

However, the thermal and quality characteristics of labeled homes are on average of somewhat lower quality than their non-labeled counterparts. For example, the insulation quality of non-labeled homes is a bit higher on average. While 8.8 percent of the EPC labeled dwellings have insulation of high quality, this is the case for 10.0 percent of the non-labeled dwellings. Therefore, it seems that affordable housing institutions did not opt for labeling only the best and most energy efficient portion of their housing stock during the sample period.

The distribution of the energy label reveals that label C, D, and E are the largest label categories, cumulatively representing some 75 percent of the sample. Furthermore, less than one percent of the affordable homes sold have an A label compared to a national average of more than three percent.[10] In general, comparing the overall label distribution for our affordable housing sample to the national average shows that our sample has a slightly worse average label compared to the national figures.

– Table 1 –

Table 2 examines the differences across label categories within the labeled sample of affordable homes. Based on the transaction price per square meter the largest difference occurs between label categories A to C and D to G. The average home with energy label C or higher transacts for some 360 euros per square meter more than the average home with label D or lower. The distribution of dwelling types shows that apartments tend to have a higher energy label. Duplexes and semi-duplexes are more strongly represented in the lower quality

[10] The national figures and distribution for all Dutch homes are available from the NEA, www.senternovem.databank.nl.

label categories. Comparing the dwelling construction period across label categories displays that homes with a higher quality energy label tend to be constructed more recently.

The thermal and quality characteristics are substantially different across the label categories as well. Comparing the average dwelling size between homes with a lower and higher quality label indicates that homes with an energy label of C or higher are significantly smaller than homes with a D label or lower. The same result holds for the number of rooms. This difference might be driven by the fact that homes constructed in earlier periods tend to be larger than contemporary ones.

As one might expect, homes with a higher energy label more often use a central heating system, and have higher insulation quality. On average, more than 55 percent of the homes with an A label have a high insulation quality while this is the case for less than one percent of the homes with a G label. The quality of the interior and exterior maintenance further confirms this. Given that more than two thirds of the labeled sample consists of lower quality homes with energy label D or lower there is still a lot to gain from investments in energy efficient retrofits.

– Table 2 –

5. Method

To investigate how energy efficiency influences the transaction price of affordable housing, we employ the standard real estate valuation framework (Rosen, 1974). We estimate a semi-log hedonic equation, relating the log of the transaction price per dwelling to energy efficiency, building characteristics and location, and time:

$$\log P_i = \alpha + \delta G_i + \beta X_i + \gamma T + \varepsilon_i. \qquad (1)$$

In our base model in Equation (1), the dependent variable is the logarithm of the transaction price P per square meter of home i. The variable of interest of the model is G, which is a dummy variable with a value of one if building i has an energy label and zero otherwise. δ is thus the average premium (in percent) estimated for a labeled dwelling relative to non-labeled dwellings. In alternative specifications of the model, G denotes the quality of the energy label or the level of the energy performance index on which the EPC labels are based. X is a vector of hedonic characteristics (e.g. size, age, thermal and quality characteristics) and location (the four-digit postcode area the home is located in) of home i.[11] In subsequent specifications of the model, X also includes characteristics of the households buying the affordable homes from the affordable housing institution. We control for macro-economic factors using year-quarter fixed effects T. Last, α, β and γ are estimated coefficients for the control variables, and ε is an error term.

6. Results

We first assess the value of energy labels in general, distinguishing low-quality from high-quality labels. After measuring the relative value of energy labels in the full sample we further investigate the effect of dwelling energy efficiency by inspecting a subset of labeled houses only, and finally, we analyze the importance of household characteristics for the market price of energy efficiency in affordable homes.

6.1 The Value of Energy Performance Certificates in Affordable Housing

Table 3 displays the results of our regression analysis of the full sample using the base model presented in Equation (1). All specifications presented in Table 3 use the natural logarithm of the transaction price per square meter as the dependent variable. This dependent variable is related to an extensive set of hedonic and location characteristics, as well as macro-economic factors that serve as control variables in the specification.[12] The models in Table 3 explain about 90 percent of the variation in the transaction value of the homes in the sample, which compares favorably to what is typically found in the literature employing hedonic valuation models for housing.

– Table 3 –

The first column in Table 3 relates the transaction value of the buildings in the sample to the most important building characteristics, location, and macro-economic factors. The location controls are based on the four-digit zip code level; macro-economic trends are controlled for using year-quarter fixed effects.

[11] We also tested different location fixed effects, controlling for location at the municipality level or the six-digit postcode level. The results are consistent and robust. Similar location fixed effects have been employed in previous research by Kok and Jennen (2012).

[12] The strong similarity of the treatment and control samples of labeled and non-labeled homes allows us to compare these samples directly. Nevertheless, we also applied propensity score weighting in all the specifications, and the results are robust.

Results for the control variables are mostly in line with the literature. Our main interest in Column (1) lies in the coefficient for the presence of an EPC label. Interestingly and somewhat surprisingly, an EPC label in general has a negative impact of 0.8 percent on the transaction price per square meter. This effect may stem from the fact that most of our EPC labeled sample consists of homes with a relatively high primary energy demand, having an EPC label of C or less.

The second column of Table 3 controls more extensively for the quality characteristics of the homes in our sample and takes the thermal characteristics of the dwelling into account as well. The coefficients of the other control variables, both in terms of sign, magnitude and statistical significance, are in line with the previous specification. The negative labeling effect decreases in this more elaborate specification to -0.6 percent.

The results show that maintenance and thermal characteristics are priced, although the inclusion of these new variables does not push the explanatory power of the model beyond the 0.90 attained in the first specification. Both interior and exterior maintenance are significant drivers of the transaction price, but the former has a much larger effect. Dwellings with the best interior maintenance sell for 12.7 percent more than the worst, while the effect for best external maintenance is only 3.2 percent.

The insulation quality of a home also contributes statistically significantly to transaction values. Compared to homes with no insulation at all, homes with two or more types of insulation experience a gradually increasing premium. Relative to homes having low insulation quality, fully insulated homes sell at a premium of 1.6 percent. When it comes to heating systems, homes with a central heating system transact for approximately 5.5 percent more as compared to homes with a gas or coal heating system in place.

The third and fourth columns of Table 3 use similar specifications as discussed before, but cluster housing with high energy efficiency, those having labels A or B, versus housing with low energy efficiency, labels C to G, to verify our previous findings. The transaction price for housing with an A or B label is 2.1 percent higher as compared to non-labeled housing. Conversely, homes with a relatively high primary energy demand, label categories C to G, sell at a discount of 0.9 percent. Therefore, the negative effect of EPC labels in general as observed in the first and second column of Table 3 stems from dwellings with a label of C or worse.

The fourth column analyzes the value of an EPC label for each label category separately. An affordable dwelling with a low primary energy demand, having an A label, sells for 7.2 percent more compared to an otherwise similar non-labeled affordable dwelling. This implies that an average dwelling with a low primary energy demand sells for approximately 11,400 euros more than a non-labeled dwelling. Transaction premiums for homes with an EPC label of B amount to 1.9 percent. On average, this implies a premium of some 3,000 euros as compared to similar non-labeled dwellings. On the other hand, homes with a high primary energy demand, those with EPC labels in categories C to G, sell at a discount in the order of 1.5 percent compared to homes without a label. For example, an F labeled dwelling on average sells for 2,500 euros less than a comparable non-labeled dwelling.

6.2 The Value of High Energy Efficiency in Affordable Housing

Having established the baseline results in the previous analysis, we now turn to the EPC labeled set of homes in our sample to further disentangle the observed premium. The analyses presented in this section employ the same specifications as presented in Table 3, and the results for the control variables are as before, so we omit these from Table 4.

– Table 4 –

The first column of the table displays the performance of buildings with a low primary energy demand, A and B labeled buildings, relative to buildings with a high primary energy demand, buildings with an EPC label of C or lower. These dwellings command a premium of 2.6 percent compared to dwellings with a high primary energy demand. This corresponds to an increase of about 3,900 euros in transaction value. Although the categorization employed here is slightly different from the one used by Brounen and Kok (2011), the observed premium is in line with the 3.7 percent increase they document.

The actual categorization of the energy labels is based on the energy performance index. This index is constituted of a rating that directly relates to the thermal quality of the home and takes the insulation quality, heating installation, (natural) ventilation and indoor air climate, solar systems and built-in-lighting into account. The lowest rating indicates the most energy efficient home. The second column of Table 4 analyzes the direct impact of the level of a home’s energy performance index on the transaction value per square meter. We document a non-linear relationship between the energy performance index and transaction values of the dwellings in our sample.

Figure 1 displays the implicit function of the energy performance index based on the coefficients for the energy performance index in the second column of Table 4. The figure shows a clear non-linear relationship between the energy performance index and the value increment associated with energy efficiency. The value increment is highest for dwellings with a low primary energy demand and decreases quickly for dwellings with a higher primary energy demand.

The absence of A++ labeled dwellings in our sample prevents us from observing their economic performance directly, but the graph allows us to predict it. The implied premium for a dwelling with an A++ label relative to an otherwise comparable home with a G label is 12.8 percent. Interestingly, the graph suggests that a major part of that premium can be realized when an A-labeled dwelling is further upgraded to A++: 6 percent, which corresponds to an increase in transaction value of approximately 8,600 euros. Dwellings with an A label command a 6.9 percent transaction premium over dwellings with a G label. On average, this implies an increase in transaction value of some 10,000 euros. The difference in the value increment between homes with an E label or lower relative to one with a G label is negligible.

– Figure 1 –

The third column of Table 4 further differentiates across EPC label categories to assess the value of high energy efficiency in affordable housing using the most elaborate set of building and quality controls. With respect to the impact of energy efficiency we investigate the impact of the different EPC labels relative to a dwelling with an EPC label of level C. Dwellings with the lowest primary energy demand, those having an A label, sell for 7 percent more compared to those with a C label, which translates into an increase in transaction value of about 10,800 euros. A dwelling with an EPC label of B sells for 1.9 percent more compared to a similar home with a C label. Homes with labels between D and G sell at small discounts, varying between 1 and 2 percent.

6.3 The Role of Household Characteristics

The households buying the homes from the affordable housing institutions pay the premiums we report in the previous analyses. It is likely that different household types have different preferences regarding energy efficiency, and the premium may be affected by household characteristics. Specifically, Brounen et al. (2012) report that households with children consume more electricity, while elderly households consume more natural gas. Furthermore, electric appliances and thermal comfort are goods for which the demand is likely increasing with income, so households with a higher income may have a stronger preference for energy efficient homes. These factors may affect the prices paid for such homes.

The Dutch Central Bureau of Statistics maintains a comprehensive database of the characteristics of all Dutch households. Using the address of the dwellings in our sample, we match the households to the dwellings we analyze. The matching procedure leads to a sample of 24,378 dwellings with a complete set of household characteristics. Table 5 provides statistics for the total sample, as well as for households living in labeled dwellings and in non-labeled dwellings, and for households living in dwellings with high (label A and B) and low (label C to G) energy efficiency.

–Table 5 –

The table suggests that the presence of an energy label does not lead to strong household selection, since the two sub-samples are strikingly similar. Households living in labeled dwellings have slightly higher incomes of almost 300 euros per year, which is less than 1 percent of average income, and which is not statistically significant. The difference in financial wealth – excluding funded pension benefits and the value of the home – is even smaller at approximately 160 euros, less than 0.7 percent of average wealth. The difference between households living in dwellings with low primary energy demand and households living in dwellings with a higher primary energy demand is somewhat larger. The difference in income is almost 1,250 euros, about 3 percent of average income, and the difference in financial wealth some 4,500 euros, which is almost 20 percent of average financial wealth.

Regarding household composition, the differences are very small as well. Households buying labeled affordable homes are somewhat smaller than those living in non-labeled homes, and have slightly less children. Elderly households do not play a very important role as buyers of affordable housing at all. The differences are somewhat more pronounced when comparing households living in A and B labeled dwellings with households living in a home with label C to G. Households living in dwellings with an A and B label seem to be smaller and have less children than those living in homes with an energy label of C or lower.

We do the same regression as the one we reported in Table 3, comparing labeled homes to non-labeled ones, and additionally controlling for household characteristics. Results are reported in Table 6. The results for the presence and quality of the energy label are in line with those reported previously, and independent of the presence of a label, the willingness to pay for a home is higher for households with relatively high incomes and more wealth – keeping in mind that high income and wealth in our sample are still low relative to the national average. The number of children, females and elderly in a household are also associated with higher prices. Household size, on the other hand, is inversely related to the purchase price for affordable homes.

–Table 6 –

However, we are most interested in the question whether household characteristics have price effects for affordable homes in combination with these homes' energy efficiency. In order to investigate this question, we interact the household characteristics with the presence and quality of an energy label. Column (1) provides results for the presence of an EPC label, and shows that only household income matters in this setting, with higher income households willing to pay a premium of almost 1 percent for the presence of an energy label. Interestingly, the results in Column (2) indicate that when separating the energy labels in a high- and low-quality category the willingness to pay more for a home with a high-quality label ceases to be statistically significant, while low-quality energy labels are associated with a 1.6 percent discount, which is reduced for households with middle and high incomes. The last column of Table 6 displays the results for the labeled portion of the sample. The results indicate that the premium for an A or B labeled home diminishes to zero in case a household has a middle income and high financial wealth. Household composition characteristics do not show statistically significant interactions with labels on house prices, so for reasons of brevity, we do not report these results in Table 6.

7. Conclusions and Policy Implications

The Dutch housing sector spent approximately 11.3 billion euros on energy in 2010, emitting approximately 29,500 tons of CO_2. And the cost of energy is rising. Year over year, Dutch consumers face a 3 to 5 percent increase in electricity and natural gas costs, which outstrips the average growth in wages. Thus, for society to apportion less disposable income to household energy expenses in the present and the future, regulators are pushing building owners to abate energy costs through retrofit investments and more stringent and energy-efficient building codes. For the Netherlands, as for other European countries, an important sector in decreasing household energy consumption is the affordable housing sector.

One of the key differences between the owner-occupied residential market and the affordable housing rental market is that affordable housing institutions cannot directly benefit from investments in energy efficiency through lower energy expenses. The tenant pays the reduced energy bill and the building owner undertakes the energy efficiency investment, resulting in a split incentive. Recouping that lower energy bill through higher rents is difficult due to an extensive program of rent protection.

One solution for affordable housing owners would be to sell energy efficient affordable dwellings in the housing market. In principle, this solution is open to affordable housing institutions everywhere, but in many countries, there are legal impediments to doing so. Dutch affordable housing institutions are allowed to sell from their stock, and we use this natural experiment in housing policy for our analysis of the value of energy efficiency in affordable housing.

We employ a hedonic pricing model to analyze the impact of energy efficiency on the transaction price per square meter and we separate the sample into EPC labeled and non-labeled dwellings. The results of our EPC labeled sample show that the most energy efficient homes, homes with an energy label of A or B, command a higher transaction price per square meter. We document that a dwelling with an A label commands a 7.0 percent premium compared to an otherwise similar dwelling with a C label, and this premium is 1.9 percent for homes having a B label. This suggests that the average C labeled home in our sample would sell for some 10,800 euros more were it to trade as an A label. The increase in transaction value for a B label is just over 2,900 euros.

We are also able to analyze whether household characteristics affect the value premiums for dwelling energy efficiency. It turns out that they do, but in a very limited way. Dwellings bought by households with higher incomes are valued at an additional premium of almost 1 percent. Within the labeled subsample, households with a relatively high income pay a 4.6 percent premium for the most energy efficient homes, while that premium is only 1.6 percent for middle-income families and even lower if they have higher wealth. Demographic household characteristics are not significantly associated with value premiums for energy efficient dwellings.

To get a sense of the economic importance of these average transaction premiums we compare it to estimates regarding the costs that affordable housing institutions face when making sustainability retrofits. For example, estimates carried out for the demonstration sites of the Building Energy Efficiency for Massive Market Uptake project as part of the European Union's 7th framework program provide some anecdotal evidence on the costs of energy efficiency retrofitting in the construction market (Chegut and Holtermans, 2014). The estimated costs of energy efficient retrofits for the demonstration sites are approximately 190 euros per square meter for a typical site. The results documented in Table 4 indicate that renovating a C labeled dwelling to achieve an A label would increase the transaction price per square meter by 123 euros. These rough estimates suggest that the investment in energy efficient retrofits may be partly compensated by an increase in transaction price. However, more research on the costs of a larger sample of energy efficiency retrofits should be conducted in order to draw firm conclusions regarding the cost-benefit trade-off of such retrofits in affordable housing.

Still, given the economic and statistical significance of the results documented in this study, we find that the affordable housing market values energy efficiency and is willing to pay for it. The Dutch affordable housing sector offers a policy example of how to potentially amortize energy efficiency investments through transaction premiums for energy efficient dwellings. Other countries with affordable housing institutions and split incentive issues may consider the Dutch model as one approach to resolve this disincentive for energy efficiency investments in the affordable housing market. This could foster the proliferation of energy efficiency in the housing market.

Acknowledgements

Financial support for this research was provided by the European Union's Building Energy Efficiency for Massive Market Uptake project – part of the European 7th framework program, the Dutch Association for Affordable Housing Institutions (AEDES), and by the Netherlands Enterprise Agency, which is part of the Dutch Ministry of Economic Affairs. We thank Erdal Aydin, Dirk Brounen, Avis Devine, Marc Francke, Nils Kok, Ramona van Marwijk and Dennis Schoenmaker as well as participants at the AREUEA National Conference 2013 and ARES Annual Meeting 2015 for their useful comments and Lars Brugman from the Dutch Land Registry (Kadaster) for his research assistance.

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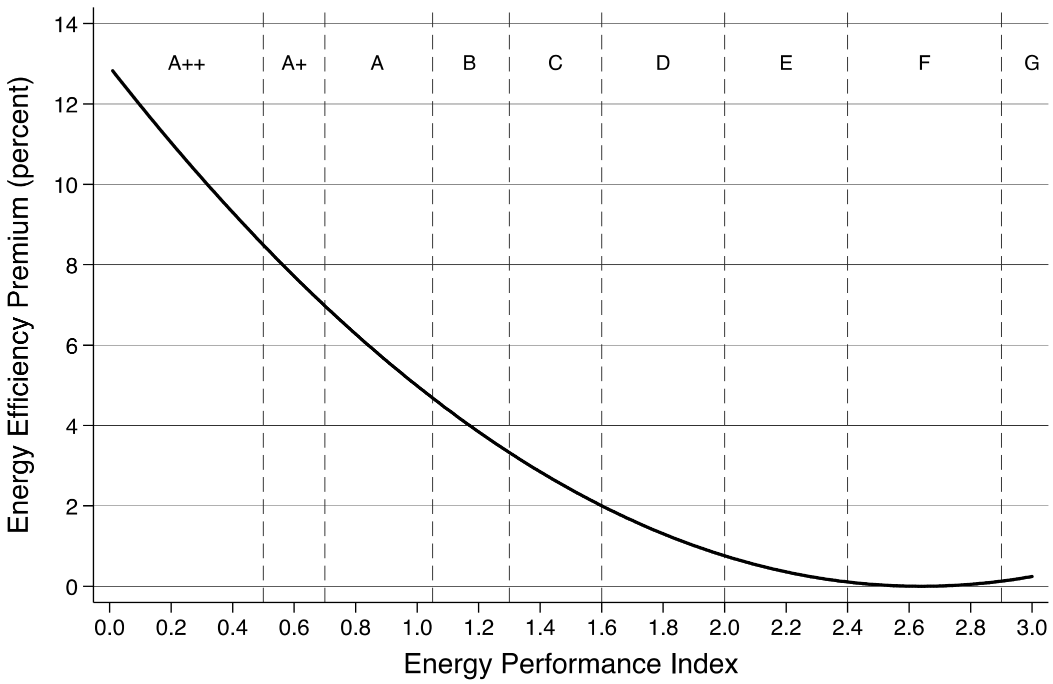
Figure 1
Transaction Value and Energy Performance Index



Notes: The above figure displays the non-linear relationship between the energy performance index and the incremental transaction value per square meter. The graph has been rebased to zero for ease of interpretation. The vertical dashed lines display the different cut-off values for the energy labels. This categorization has been revised in January 2015; the cut-off values used are the ones applicable at the time of transaction.

Table 1
Descriptive Statistics

	Total Sample	Non-Labeled Buildings	Labeled Buildings
Transaction price (euro per square meter)	1,719.00	1,733.58	1,700.03
	[575.70]	[576.90]	[573.49]
Dwelling type			
Apartment	39.89	42.94	35.69
Duplex	37.95	37.11	39.10
Semi-duplex	16.59	15.05	18.70
Semi-detached	5.57	4.89	6.50
Period of construction			
Pre 1930	7.64	7.77	7.48
1930-1944	2.82	2.5	3.28
1945-1960	15.04	14.83	15.32
1961-1970	21.59	20	23.79
1971-1980	26.33	26.83	25.65
1981-1990	21.67	22.18	20.98
1991-2000	3.02	3.22	2.74
> 2000	1.89	2.68	0.77
Building characteristics			
Dwelling size (square meter)	90.63	91.34	89.65
	[24.08]	[24.79]	[23.03]
Number of stories	2.09	2.06	2.13
	[0.88]	[0.89]	[0.87]
Number of rooms	3.91	3.87	3.97
	[1.11]	[1.11]	[1.10]
Basement	3.38	3.51	3.20
Attic	25.98	23.57	29.30
Garden	60.46	57.46	64.58
Parking	7.86	8.04	7.60
Monument	0.32	0.36	0.25
Ground lease	18.49	20.59	15.62
Partial lot	17.59	19.72	14.67
Quality characteristics			
Interior maintenance low[a]	4.37	4.41	4.31
Interior maintenance medium[b]	94.02	93.41	94.86
Interior maintenance high[c]	1.61	2.18	0.83
Exterior maintenance low[a]	1.03	1.06	0.99
Exterior maintenance medium[b]	96.11	95.24	97.32
Exterior maintenance high[c]	2.86	3.7	1.69
Thermal characteristics			
Insulation quality low[d]	74.04	73.41	74.90
Insulation quality medium[e]	16.44	16.55	16.28
Insulation quality high[f]	9.52	10.04	8.81

Notes: Standard deviations in brackets. All variables in percentages, unless indicated otherwise.

Table 1 (continued)
Descriptive Statistics

	Total Sample	Non-Labeled Buildings	Labeled Buildings
Thermal characteristics			
Heating information missing	7.03	6.44	7.85
Gas or coal heater	3.17	3.51	2.70
Central heating	89.80	90.05	89.45
Transaction characteristics			
Cost payable by vendor	8.20	5.25	12.26
Time on the market (days)	86.84	77.72	99.37
	[109.25]	[99.58]	[120.16]
Energy label (percent)			
A			0.53
B			6.46
C			25.89
D			29.93
E			19.27
F			12.05
G			5.88
# of Observations	28,465	16,471	11,994

Notes: Standard deviations in brackets. All variables in percentages, unless indicated otherwise.

[a] Rated 1 to 4 on a scale of 1 to 9

[b] Rated 5 to 7 on a scale of 1 to 9

[c] Rated 8 or 9 on a scale of 1 to 9

[d] 0 or 1 type of insulation out of 5

[e] 2 or 3 types of insulation out of 5

[f] 4 or 5 types of insulation out of 5

Table 2
Descriptive Statistics by Energy Performance Certificate

	A	B	C	D	E	F	G
Transaction price (euro per square meter)	2,095.17	2,126.00	1,754.00	1,644.30	1,627.91	1,615.80	1,651.66
	[998.54]	[806.57]	[553.06]	[536.60]	[524.67]	[513.01]	[514.17]
Dwelling type							
Apartment	61.90	64.00	43.90	30.47	32.24	27.54	20.71
Duplex	14.29	23.61	36.68	46.30	43.01	33.91	30.21
Semi-duplex	15.87	9.94	16.94	19.00	17.96	23.81	26.81
Semi-detached	7.94	2.45	2.48	4.23	6.79	14.74	22.27
Period of construction							
Pre 1930	28.57	12.52	3.64	4.87	8.96	9.90	20.43
1930-1944	0.00	0.52	1.13	2.56	5.11	6.78	6.52
1945-1960	1.59	3.10	6.60	11.59	20.38	30.73	39.29
1961-1970	11.11	11.35	12.69	26.04	35.14	32.11	21.70
1971-1980	12.70	10.71	24.96	34.07	27.17	19.38	11.21
1981-1990	0.00	40.90	44.90	19.78	3.20	1.11	0.71
1991-2000	1.59	14.06	5.80	1.06	0.04	0.00	0.00
> 2000	44.44	6.84	0.29	0.03	0.00	0.00	0.14
Building characteristics							
Dwelling size (square meter)	87.73	79.35	87.73	92.13	91.22	91.27	88.49
	[26.90]	[25.78]	[22.84]	[23.30]	[22.18]	[21.10]	[21.66]
Number of stories	1.73	1.69	2.03	2.23	2.19	2.24	2.25
	[0.87]	[0.85]	[0.89]	[0.85]	[0.86]	[0.83]	[0.79]
Number of rooms	3.24	3.34	3.76	4.05	4.13	4.21	4.20
	[1.04]	[1.17]	[1.09]	[1.10]	[1.03]	[0.97]	[1.10]
Basement	1.59	0.26	1.29	1.75	4.46	5.67	13.19

Notes: Standard deviations in brackets. All variables in percentages, unless indicated otherwise.

Table 2 (continued)

	A	B	C	D	E	F	G
Building Characteristics							
Attic	20.63	16.13	25.83	32.01	31.76	34.46	27.38
Garden	52.38	43.61	59.45	67.97	67.42	70.31	73.05
Parking	33.33	6.19	5.06	8.55	7.18	9.13	11.49
Monument	3.17	0.90	0.03	0.14	0.00	0.21	1.70
Ground lease	19.05	37.16	23.48	12.34	11.25	6.51	6.66
Partial lot	3.17	5.55	13.14	15.04	16.18	17.51	19.72
Thermal and quality characteristics							
Interior maintenance low[a]	0.00	1.55	2.64	3.90	5.11	6.44	10.21
Interior maintenance medium[b]	80.95	94.58	96.52	95.60	94.50	93.36	89.65
Interior maintenance high[c]	19.05	3.87	0.84	0.50	0.39	0.21	0.14
Exterior maintenance low[a]	0.00	0.13	0.45	0.70	1.25	1.87	3.26
Exterior maintenance medium[b]	74.60	94.32	97.71	98.33	97.40	97.16	95.74
Exterior maintenance high[c]	25.40	5.55	1.84	0.97	1.34	0.97	0.99
Insulation quality low[d]	28.57	54.97	63.80	73.34	85.46	89.20	93.90
Insulation quality medium[e]	15.87	13.03	20.26	20.70	12.42	10.17	5.11
Insulation quality high[f]	55.55	32.00	15.94	5.96	2.12	0.62	0.99
Heating information missing	7.94	4.77	3.77	7.69	8.39	10.59	22.55
Gas or coal heater	0.00	0.52	0.29	1.25	2.34	6.37	17.02
Central heating	92.06	94.71	95.94	91.06	89.27	83.04	60.43

Notes: Standard deviations in brackets. All variables in percentages, unless indicated otherwise.

[a] Rated 1 to 4 on a scale of 1 to 9

[b] Rated 5 to 7 on a scale of 1 to 9

[c] Rated 8 or 9 on a scale of 1 to 9

[d] 0 or 1 type of insulation out of 5

[e] 2 or 3 types of insulation out of 5

[f] 4 or 5 types of insulation out of 5

Descriptive Statistics by Energy Performance Certificate

Table 2 (continued)
Descriptive Statistics by Energy Performance Certificate

	A	B	C	D	E	F	G
Transaction characteristics							
Cost payable by vendor	7.94	21.03	14.88	10.92	12.16	7.89	7.66
Time on the market (days)	137.11	106.68	97.56	97.54	99.54	100.14	102.75
	[170.62]	[139.76]	[116.88]	[112.31]	[121.24]	[127.19]	[125.46]
# of Observations	63	775	3,105	3,590	2,311	1,445	705

Notes: Standard deviations in brackets. All variables in percentages, unless indicated otherwise.

Table 3
Transaction Value and Energy Performance Certificates
(dependent variable: log of transaction value per square meter)

	(1)	(2)	(3)	(4)
Energy label (1=yes)	-0.008**	-0.006**		
	[0.003]	[0.003]		
Energy label A or B (1=yes)			0.021***	
			[0.008]	
Energy label C to G (1=yes)			-0.009***	
			[0.003]	
Energy label (1=yes)				
A				0.072**
				[0.028]
B				0.019**
				[0.008]
C				0.001
				[0.004]
D				-0.011***
				[0.004]
E				-0.015***
				[0.004]
F				-0.016***
				[0.005]
G				-0.006
				[0.008]
Building characteristics				
Log dwelling size (square meter)	-0.577***	-0.586***	-0.585***	-0.586***
	[0.016]	[0.016]	[0.016]	[0.016]
Number of rooms	0.024***	0.026***	0.026***	0.026***
	[0.003]	[0.003]	[0.003]	[0.003]
Basement (1=yes)	0.021	0.024	0.025	0.025
	[0.015]	[0.015]	[0.015]	[0.015]
Attic (1=yes)	0.002	0.002	0.002	0.002
	[0.005]	[0.005]	[0.005]	[0.005]
Garden (1=yes)	0.030***	0.027***	0.027***	0.027***
	[0.003]	[0.003]	[0.003]	[0.003]
Parking (1=yes)	0.051***	0.049***	0.049***	0.049***
	[0.006]	[0.006]	[0.006]	[0.006]
Monument (1=yes)	0.107**	0.105**	0.103**	0.102**
	[0.051]	[0.051]	[0.051]	[0.050]
Ground lease (1=yes)	0.016**	0.015*	0.014*	0.014*
	[0.008]	[0.008]	[0.008]	[0.008]
Partial lot (1=yes)	-0.001	-0.003	-0.003	-0.003
	[0.004]	[0.004]	[0.004]	[0.004]

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.

Table 3 (continued)
Transaction Value and Energy Performance Certificates
(dependent variable: log transaction value per square meter)

	(1)	(2)	(3)	(4)
Number of stories[a] (1=yes)				
One story	-0.057*	-0.054*	-0.053*	-0.052*
	[0.030]	[0.030]	[0.030]	[0.030]
Two stories	-0.028	-0.026	-0.025	-0.025
	[0.032]	[0.032]	[0.032]	[0.032]
Three stories	-0.032	-0.032	-0.032	-0.031
	[0.031]	[0.031]	[0.031]	[0.031]
Dwelling type[b] (1=yes)				
Apartment	-0.169***	-0.179***	-0.180***	-0.180***
	[0.014]	[0.014]	[0.014]	[0.014]
Duplex	-0.110***	-0.114***	-0.114***	-0.114***
	[0.009]	[0.009]	[0.009]	[0.009]
Semi-duplex	-0.072***	-0.076***	-0.076***	-0.076***
	[0.008]	[0.008]	[0.008]	[0.008]
Thermal and quality characteristics				
Interior maintenance medium[c]		0.039***	0.039***	0.039***
		[0.005]	[0.005]	[0.005]
Interior maintenance high[d]		0.127***	0.127***	0.127***
		[0.016]	[0.016]	[0.016]
Exterior maintenance medium[c]		0.023***	0.023***	0.023***
		[0.012]	[0.012]	[0.012]
Exterior maintenance high[d]		0.032***	0.032***	0.032***
		[0.016]	[0.016]	[0.016]
Insulation quality medium[e]		0.007*	0.006*	0.006*
		[0.004]	[0.003]	[0.003]
Insulation quality high[f]		0.016***	0.015***	0.014***
		[0.004]	[0.004]	[0.004]
Heating information missing[g] (1=yes)		0.026***	0.027***	0.027***
		[0.007]	[0.006]	[0.006]
Central heating[g] (1=yes)		0.055***	0.055***	0.055***
		[0.006]	[0.006]	[0.006]
Period of construction[h] (1=yes)				
1930-1944	-0.053***	-0.051**	-0.050**	-0.049**
	[0.020]	[0.020]	[0.020]	[0.020]
1945-1960	-0.044**	-0.037*	-0.036*	-0.036*
	[0.021]	[0.021]	[0.020]	[0.020]
1961-1970	-0.048***	-0.045**	-0.044**	-0.043**
	[0.019]	[0.018]	[0.018]	[0.018]
1971-1980	-0.034*	-0.033*	-0.032*	-0.033*
	[0.018]	[0.018]	[0.017]	[0.017]

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.

Table 3 (continued)
Transaction Value and Energy Performance Certificates
(dependent variable: log transaction value per square meter)

	(1)	(2)	(3)	(4)
Period of construction[h] (1=yes)				
1981-1990	-0.001	-0.001	-0.001	-0.003
	[0.017]	[0.016]	[0.016]	[0.016]
1991-2000	0.113***	0.099***	0.097***	0.096***
	[0.021]	[0.020]	[0.020]	[0.020]
> 2000	0.219***	0.177***	0.175***	0.173***
	[0.024]	[0.024]	[0.023]	[0.023]
Transaction characteristics				
Cost payable by vendor (1=yes)	0.052***	0.048***	0.048***	0.048***
	[0.005]	[0.005]	[0.005]	[0.005]
Time on the market (days)	-0.000	-0.000*	-0.000*	-0.000*
	[0.000]	[0.000]	[0.000]	[0.000]
Location fixed effects	yes	yes	yes	yes
Year-quarter fixed effects	yes	yes	yes	yes
Constant	10.044***	9.958***	9.957***	9.959***
	[0.077]	[0.082]	[0.082]	[0.081]
Observations	28,465	28,465	28,465	28,465
R^2	0.90	0.90	0.90	0.90
Adj. R^2	0.89	0.89	0.89	0.90

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.

[a] Default for number of stories is "Four stories"

[b] Default for dwelling type is "Semi-detached"

[c] Rated 5 to 7 on a scale of 1 to 9

[d] Rated 8 or 9 on a scale of 1 to 9

[e] 2 or 3 types of insulation out of 5

[f] 4 or 5 types of insulation out of 5

[g] Default is a gas or coal heater in place

[h] Default for construction period is "Pre 1930"

Table 4
Transaction Value and Label Quality within the EPC Labeled Sample
(dependent variable: log of transaction value per square meter)

	(1)	(2)	(3)
Energy label A or B (1=yes)	0.026***		
	[0.009]		
Energy performance index		-0.098***	
		[0.027]	
Energy performance index^2		0.019***	
		[0.006]	
Energy label (1=yes)			
A			0.070**
			[0.029]
B			0.019**
			[0.009]
C			
D			-0.009**
			[0.004]
E			-0.018***
			[0.006]
F			-0.018**
			[0.008]
G			-0.010
			[0.011]
Building characteristics	yes	yes	yes
Thermal and quality characteristics	yes	yes	yes
Transaction characteristics	yes	yes	yes
Location fixed effects	yes	yes	yes
Year-quarter fixed effects	yes	yes	yes
Constant	9.897***	10.024***	9.911***
	[0.081]	[0.083]	[0.081]
Observations	11,994	11,994	11,994
R^2	0.91	0.91	0.91
Adj. R^2	0.90	0.90	0.90

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.

Table 5
Household Characteristics

	Total Sample	Non-Labeled Buildings	Labeled Buildings	Label A – B	Label C – G
Income (euro per annum)	41,386.50	41,255.94	41,541.56	42,698.57	41,449.17
	[19,719]	[19,915]	[19,484]	[21,294]	[19,330]
Wealth (in euro)	23,356.31	23,282.05	23,444.52	27,610.29	23,111.87
	[61,184]	[61,577]	[60,716]	[95,099]	[57,079]
# of Household members	1.90	1.93	1.88	1.75	1.89
	[1.04]	[1.07]	[1.01]	[0.98]	[1.01]
# of Children	0.34	0.35	0.33	0.25	0.33
	[0.71]	[0.73]	[0.70]	[0.64]	[0.70]
# of Female	0.92	0.93	0.91	0.85	0.91
	[0.76]	[0.76]	[0.75]	[0.71]	[0.75]
# of Elderly	0.02	0.02	0.01	0.03	0.01
	[0.15]	[0.016]	[0.14]	[0.19]	[0.13]
# of Observations	24,378	13,235	11,143	824	10,319

Notes: Standard deviations in brackets.

Table 6
Transaction Value and Household Characteristics
(dependent variable: log transaction value per square meter)

	(1)	(2)	(3)
Energy label (1=yes)	-0.015**		
	[0.006]		
Energy label A or B (1=yes)		0.019	0.046***
		[0.012]	[0.013]
Energy label C to G (1=yes)		-0.016***	
		[0.005]	
Energy label * Income (middle)	0.007*		
	[0.004]		
Energy label * Income (high)	0.009*		
	[0.005]		
Energy label * Wealth (middle)	0.001		
	[0.003]		
Energy label * Wealth (high)	-0.003		
	[0.004]		
Energy label * # of Household members	-0.000		
	[0.003]		
Energy label * # of Children	0.003		
	[0.004]		
Energy label * # of Female	0.001		
	[0.003]		
Energy label * # of Elderly	-0.004		
	[0.010]		
Energy label A or B * Income (middle)		-0.016	-0.030***
		[0.011]	[0.013]
Energy label A or B * Income (high)		0.004	-0.016
		[0.013]	[0.013]
Energy label A or B * Wealth (middle)		0.012	0.002
		[0.010]	[0.011]
Energy label A or B * Wealth (high)		-0.005	-0.018*
		[0.011]	[0.011]
Energy label C to G * Income (middle)		0.009**	
		[0.004]	
Energy label C to G * Income (high)		0.010**	
		[0.005]	
Energy label C to G * Wealth (middle)		0.000	
		[0.003]	
Energy label C to G * Wealth (high)		-0.003	
		[0.004]	

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.

Table 6 (continued)
Transaction Value and Household Characteristics
(dependent variable: log transaction value per square meter)

	(1)	(2)	(3)
Income (middle)	0.009***	0.009***	0.012***
	[0.002]	[0.002]	[0.004]
Income (high)	0.031***	0.031***	0.030***
	[0.003]	[0.003]	[0.005]
Wealth (middle)	0.008***	0.008***	0.005*
	[0.002]	[0.002]	[0.003]
Wealth (high)	0.022***	0.022***	0.017***
	[0.002]	[0.000]	[0.003]
# of Household members	-0.005***	-0.005***	-0.002
	[0.002]	[0.002]	[0.003]
# of Children	0.007***	0.009***	0.007*
	[0.003]	[0.002]	[0.004]
# of Female	0.004*	0.004***	0.005**
	[0.002]	[0.002]	[0.002]
# of Elderly	0.033***	0.032***	0.035***
	[0.009]	[0.007]	[0.010]
Building characteristics	yes	yes	yes
Thermal and quality characteristics	yes	yes	yes
Transaction characteristics	yes	yes	yes
Location fixed effects	yes	yes	yes
Year-quarter fixed effects	yes	yes	yes
Constant	9.997***	9.994***	9.776***
	[0.086]	[0.085]	[0.094]
Observations	24,378	24,378	11,577
R^2	0.91	0.91	0.92
Adj. R^2	0.90	0.90	0.91

Notes: Robust standard errors clustered at the postcode level in brackets. Significance at the 0.10, 0.05, and 0.01 level are indicated by *, **, and ***, respectively.