Journal of Environmental Economics and Management 62 (2011) 166–179

Contents lists available at ScienceDirect

Journal of Environmental Economics and Management

journal homepage: www.elsevier.com/locate/jeem

On the economics of energy labels in the housing market ☆

Dirk Brounen [a], Nils Kok [b,*]

[a] Rotterdam School of Management, Erasmus University, The Netherlands
[b] School of Business and Economics, Maastricht University, PO BOX 616, 6200MD Maastricht, The Netherlands

ARTICLE INFO

Article history:
Received 20 May 2010
Available online 15 April 2011

Keywords:
Energy efficiency
Housing market
Energy labels
Environmentalism

ABSTRACT

Energy efficiency in the residential housing market can play an important role in the reduction of global carbon emissions. This paper reports the first evidence on the market adoption and economic implications of energy performance certificates implemented by the European Union. The results show that adoption rates are low and declining over time, coinciding with a negative sentiment regarding the label in the popular media. Labels are clustered among smaller, post-war homes in neighborhoods with more difficult selling conditions. We also document that geographic variation in the adoption rate of energy labels is positively related to the fraction of "green" voters during the 2006 national elections. Within the sample of labeled homes, the energy label creates transparency in the energy efficiency of dwellings. Our analysis shows that consumers capitalize this information into the price of their prospective homes.

1. Introduction

The current focus on carbon abatement has lead to increased attention on energy efficiency in the built environment, which offers substantial opportunities for the reduction of greenhouse gasses [12,28]. Although building codes have generally been mildly effective in reducing energy consumption [3,18], globally policy makers target the real estate sector with stricter energy-efficiency standards and mandates. For instance, the European Union implemented the Energy Performance of Buildings Directive (EPBD) in January 2003 with the explicit goal of promoting energy performance improvements in buildings. The Directive, which was recently recast, includes an explicit element on the disclosure of energy performance in buildings: "…Member states shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant."[1] The Directive has lead to the implementation of national Energy Performance Certificates (EPCs) for residential dwellings as well as utility buildings (e.g., office, retail, schools, and healthcare facilities) across the European Union.

The introduction of energy labels can be viewed as an additional step to enhance the transparency of energy consumption in the real estate sector. Greater transparency may enable private and corporate occupiers to take energy

☆ Financial support for this research has been provided by the Mistra Foundation, Sweden, the Royal Institution for Chartered Surveyors, and RSM Erasmus, the Netherlands. Nils Kok is grateful for the financial support from the Netherlands Organization for Scientific Research (NWO). We thank the editor, two anonymous referees, Christopher Knittel, Matthew Turner, John Quigley, and participants at the 2009 Berkeley Conference on "Green Building, The Economy, and Public Policy," for helpful comments. We are grateful to Agentschap NL, the Dutch Association of Realtors (NVM), and the Central Bureau of Statistics (CBS) for their generous supply of data. Jacco Menne provided excellent research assistance. All errors pertain to the authors.
* Corresponding author. Fax: +31 43 388 4875.
E-mail address: n.kok@maastrichtuniversity.nl (N. Kok).
[1] Article 7, Energy Performance of Buildings Directive, EU, 2009.

0095-0696/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.jeem.2010.11.006

efficiency into account when making housing decisions. Recent evidence shows that providing feedback to private consumers with respect to their energy consumption is an effective "nudge" to improve energy efficiency [4,8]. From an economic perspective, the energy label could have financial utility for both real estate investors and tenants, as the energy savings resulting from more efficient building may result in lower operating costs and higher property values.

However, evidence regarding the implementation and valuation of energy labels is limited, the diffusion and uptake of energy labels across Europe has been slow, and private consumers are uncertain about the value represented by labels that indicate some level of modeled energy efficiency.

This paper is the first to empirically address the implementation of energy labels under a large-scale certification program in the European Union. Using a standardized measure to reflect the thermal efficiency of a structure, we study the determinants of the adoption of energy performance certificates and the consequent economic implications in the residential housing market. We use the Netherlands as a laboratory, as energy performance certification for homes was introduced in the Netherlands in January 2008, one year before the official introduction date prescribed by the European Union. Energy conservation is presumably quite important for Dutch residents, as the average energy bill of a Dutch household was €152 per month in 2009 (€53 for electricity and €99 for gas), ranging from €105 for the most energy efficient homes to €231 for the least energy efficient homes. For some households, energy costs represent almost half of the total monthly housing expense.

Energy performance certification is not fully mandatory in the Netherlands: homebuyers are allowed to sign a waiver that obviates the seller's obligation to certify the dwelling. Based on some 177,000 housing transactions from January 2008 through August 2009, we find that during the first three months of 2008, more than 25 percent of all housing transactions had an energy label. Soon after, the adoption rate of energy labels started to decline, eventually reaching an adoption rate of less than seven percent of the 150,000 homes that were for sale as of September 2009. This sharp decrease in the adoption rate coincides with a negative sentiment created by the main bodies in the real estate industry, such as the Association of Realtors and the Association of Homeowners. Our "News Index," based on counts of negative or positive reporting on the energy label in the popular press, leads the energy label adoption curve by some three months.

Our empirical results show that the choice of certification is also determined by the quality of a dwelling. We find that more heterogeneous homes, constructed post-war and during the seventies and eighties, located in high-density and low-income areas are significantly more likely to obtain an energy label. The thermal characteristics of a dwelling, like insulation and the heating system, do not influence the certification decision. Our results also provide some indication of ideology as an explanation for the adoption of energy labels: adoption rates are higher among homeowners that voted for "green" political parties during the 2006 national elections.

We then turn to the market implications of the energy label. The label seems to fulfill its informational role and has a moderately powerful market signal. We track the transaction process of some 32,000 labeled homes and document a positive relation between the energy efficiency of a dwelling and its transaction price. Using the Heckman [17] two-step method, we find that homes with a "green" label sell at a premium of 3.6 percent relative to otherwise comparable dwellings with non-green labels. This transaction premium varies with the outcome of the label, and calculations indicate that this variation can be partially explained by the underlying energy consumption of the dwelling.

This paper contributes to the early literature on the capitalization of thermal efficiency in residential dwellings [9,14,22]. It also contributes to a more recent, growing literature on the economic implications of energy efficiency and sustainability labels in the real estate sector, which has thus far predominantly addressed the commercial property market [10,11,13]. The paper also relates to the fast-growing literature on environmentalism and consumer choice [16,19] that increasingly focuses on residential energy consumption [7,8]. For policy makers, the results of this paper may shed light on the main assumption underlying the widespread implementation of energy rating systems: the ability of the market to capitalize energy efficiency in investment decisions. It may also help to further refine energy performance certification programs and stimulate increased market demand for energy labels.

The next section of this paper is a brief review of the literature on energy efficiency in the built environment. Section 3 discusses the various programs of energy performance certification in the real estate sector and provides more details on the European energy performance certification program. Section 4 describes the data and provides descriptive statistics. Section 5 discusses the empirical results and Section 6 concludes.

2. Related literature

Models attempting to predict future residential energy consumption not only take the housing stock and its projected growth into account, but also demographic, social, and behavioral characteristics of the occupants [5,20]. To ultimately reduce the carbon footprint of the real estate sector, demand from occupiers and investors for more energy-efficient real estate is necessary. Glaeser and Kahn [15] argue that if the carbon externality were appropriately priced, costs per household would range from $830 to $1410 per year, depending on the climatic conditions and, more importantly, on a city's population and density. However, the early literature as well as more recent studies both show that households do not directly take carbon emissions into account in relocation decisions, but rather focus on environmental externalities, like pollution, traffic, and the availability of nature [1,6,16,25].

There are a handful of papers that explicitly address the willingness to pay for energy efficiency in residential dwellings. Lacquatra [22] studies a small sample of newly constructed homes and documents that the Thermal Integrity Factor (TIF), a proxy for energy efficiency, has a positive relation to the transaction price. Dinan and Miranowski [9] find a similar relation between standardized energy consumption and prices of homes transacted in Des Moines, Iowa. In fact the documented relation is quite precise: one dollar of energy savings leads to a $11.63 increase in the transaction price. Gilmer [14] applies energy labels to a model of economic search and documents that benefits of labels are positive but modest, i.e., energy labels shorten the search process.

More recently, evidence on the willingness to pay for energy efficiency in the real estate sector has mostly focused on the commercial real estate sector. In a series of papers that study investor and tenant demand for "green" office space in the U.S. office market, Eichholtz et al. [10,11] show that buildings with an Energy Star label – indicating that a building belongs to the top 25 percent of the most energy-efficient buildings – have rents that are two to three percent higher as compared to regular office buildings. Transaction prices for energy-efficient office buildings are higher by 13–16 percent. Further analyses show that the cross-sectional variation in these premiums has a strong relation to real energy consumption, indicating that tenants and investors in the commercial property sector capitalize energy savings in their investment decisions.

To improve the energy performance of the built environment, building codes have become more stringent over the past decades and construction standards have improved. These mostly supply-side measures have lead to substantial energy savings [3,27]. However, other studies have documented a stagnating trend in the energy efficiency of buildings in Western economies. Nässén et al., [24] find that energy price elasticity has decreased over time, mainly due to a lack of understanding of the life cycle cost – or, the economic payoff – following investments in energy efficiency. This is in line with Kempton and Layne [21], who show that inefficient allocation of data on energy consumption restricts the energy savings behavior of consumers. Also, there is documentation that deficiencies in public policies regarding energy efficiency, limited regulation, and the conservatism in the building industry are to blame for the slow implementation of energy efficiency measures [26].

Increased information transparency in energy consumption can be instrumental as a "nudge" to encourage energy conservation among private consumers. Some recent experiments show that providing feedback to consumers on energy consumption can substantially reduce energy bills [4], although political ideology seems to be an important moderating factor [8]. Standardized energy performance certification programs can provide a cheap alternative to these small-scale experiments, but these programs for energy ratings rest on the assumption that the residential housing market can effectively incorporate information on thermal efficiency.

3. Energy performance certification and the EPBD

Various national governments have initiated rating systems that measure the extent to which both residential dwellings and commercial buildings adhere to energy efficiency standards. The Energy Star program, a joint initiative by the U.S. Department of Energy and the U.S. Environmental Protection Agency, is a long-running and notable example. Residential buildings can receive an Energy Star certification if they are at least 15 percent more energy efficient than homes built to the 2004 International Residential Code (IRC) and include additional energy-saving features that typically make them 20–30 percent more efficient than standard homes. For consumers, there should be a clear relation between investments in energy efficiency and the consequent savings, as stated by the EPA: "…energy efficiency improvements save homeowners money—about $200–$400 per year on utility bills. More importantly, monthly energy savings can easily exceed any additional mortgage cost for the energy efficiency improvements, resulting in a positive cash-flow from the first day of home ownership."[2] To date, close to a million dwellings have earned an Energy Star label.

Although numerous countries have introduced comparable initiatives to raise consumer awareness of energy consumption and carbon emissions resulting from their homes, until recently, none have had the scope of the Energy Star program. This changed in December 2002, when the European Parliament ratified Directive 2002/91/EC on the energy performance of buildings, which makes energy performance disclosure mandatory for all member states. The Directive argues that "a common approach […] will contribute to a level playing field as regards efforts made in member states to save energy in the buildings sector and will introduce transparency for prospective owners or users with regard to the energy performance in the Community property market."[3] This Directive mandates the introduction of comparable Energy Performance Certificates (EPCs) across the European Union. The Directive should have been formally implemented in January 2006 but member states were given an additional period of three years to fully adhere to the certification procedures, due to the lack of qualified and/or accredited experts. The recast of the Directive in 2009 expanded the existing legislation: the certificate now has to be included in all advertisements for selling or renting properties. Moreover, the certificate and its energy saving recommendations have to be part of the documentation accompanying a rental or sales transaction.

The European energy label has a common base across all member states and is derived from the thermal quality of the dwelling. It takes elements such as insulation quality, heating installation, (natural) ventilation and indoor air climate, solar systems, and built-in lighting into account. The certificate contains a simple universal indicator of the energy

[2] See http://www.energystar.gov/index.cfm?c=home_improvement.hm_improvement_index for more information.

[3] Press release MEMO/08/693, Brussels, 13 November 2008.

consumption – the energy index – based on *modeled* primary energy consumption under average conditions.[4] Based on the energy index, the energy performance certificate ranges from ''A++,'' for exceptionally energy-efficient dwellings, to ''G'' for highly inefficient dwellings. Besides an energy-efficiency score, the certificate also contains specific advice on how to improve the thermal performance of a building. Appendix A provides an example.

Professionally trained surveyors issue the certificates, with model inputs based on a physical inspection of the dwelling. The certificate is valid for 10 years and requires an investment of some €200, which is incurred by the seller of the building. Dwellings that have been constructed after 1999, or that have been officially registered as monuments, are exempt from mandatory disclosure of an energy performance certificate. Importantly, if the buyer of a dwelling signs a waiver, the seller is also exempt from providing the certificate at the time of the transaction.

The energy performance certificate offers a variety of benefits to private consumers. The certificate increases the transparency in the energy consumption of a specific dwelling and results in EU-wide recognition of investments in energy conservation. This recognition not only assures homeowners that energy-efficiency investments are recognized at the time of sale, but it may also lead to a lower cost of funding through more favorable mortgage terms for energy-efficient homes. An energy label may also shorten the economic search process by disclosing information to prospective homeowners [14]. This may be important in the opaque market for housing transactions.[5]

However, poorly defined label requirements and insufficient training of official certification agencies have characterized the recent introduction of energy performance certificates across the European Union. Also, the possibility of signing a waiver has allowed private consumers to circumvent the mandatory disclosure of energy performance certificates in housing transactions. In addition, industry bodies have openly questioned the reliability of the information provided by energy labels and the need for providing such information to consumers. The combination of these factors has lead to a slow implementation of energy labels across European residential housing markets and may affect the economic value of energy performance certificates in the market place.

In the remainder of this paper, we empirically address the patterns and determinants of label adoption, and the effectiveness of the energy label as a market signal. We use a large sample of housing transactions in the Netherlands, which in January 2008 was one of the first EU member states to introduce energy performance certificates.

4. Data

4.1. Data sources

Agentschap NL, an agency of the Dutch Ministry of Economic Affairs, exerts quality control and maintains registration of the energy performance certificates in the Netherlands. We have access to the database of this organization, which provides information on the energy performance rating, the address, and some physical building characteristics of all buildings with an energy performance certificate. As of September 2009, more than 100,000 residential homes (rental and owner-occupied) had been certified.[6]

To obtain information on housing transactions, we use the database of the Dutch Association of Realtors (NVM), which includes information on the dwelling address, the characteristics of the transaction, and a wide array of quality characteristics for each transacted dwelling.[7] As of September 2009, the NVM database contained 194,379 housing transactions since the introduction of energy performance certificates in January 2008.[8]

For a slightly smaller subset of our sample, we are able to collect economic data on the neighborhood characteristics of the home from the Central Bureau of Statistics (CBS). We collect information on housing density, as measured by the number of addresses within a one-kilometer radius, and on the average monthly household income, both for 2007. This information is available at the zip code level.[9] As a proxy for local housing market conditions, we calculate the average time on the market for homes transacted in 2006 and 2007, also at the zip code level.

To account for ideological heterogeneity of homeowners, we obtain voting data on the 2006 national elections and calculate the percentage of votes for ''green'' parties.[10] The Netherlands has two political parties that distinctly focus on animal rights and environmental conservation: the ''Green Party'' and the ''Party for the Animals.''

[4] The primary energy consumption of a dwelling is modeled based on occupancy by an average household under normal climatic conditions. The energy label thus provides an indication of energy consumption under standardized behavior and is not based on the *actual* energy consumption as measured by energy bills.

[5] There is a large body of literature that addresses the lack of information transparency in the residential housing market. See Levitt and Syverson [23] for one example.

[6] The sample of certified rental homes mostly consists of public housing owned by social housing corporations. As such, this sample is less suitable for a study on energy labels and private market rents.

[7] The members of the NVM collectively cover approximately 70 percent of all housing transactions in the Netherlands.

[8] We only include transactions for which all data are available and for which the transaction price ranges between €10,000 and €10,000,000.

[9] The zip code covers an area of less than a square mile around a home. Zip codes are of comparable size across our sample, and therefore a useful proxy for the quality of the immediate neighborhood.

[10] Data are obtained from http://www.verkiezingsuitslagen.nl.

The 2006 national elections had a turnout of more than 80 percent and are a proxy for the political balance at the city level.

4.2. Descriptive statistics

We match the various data sets based on address information. Approximately, 18 percent of the transaction sample – 31,993 residential dwellings – has an energy performance certificate. However, these certified transactions are not evenly distributed over the sample period. Fig. 1A presents the total number of transaction per month and the fraction of homes transacted with an energy label. The number of housing transactions provides an indication for the dry-up of liquidity in the housing market, with year-on-year transactions decreasing by some 35 percent. The graph also shows that the fraction of rated homes strongly decreased during the sample period, starting at a label adoption rate of 25 percent in January 2008 and decreasing to a label adoption rate of approximately 10 percent in the Summer of 2009. Anecdotally, we can explain this remarkable drop in the adoption rate by the initial problems surrounding the implementation of the energy label.

To more systematically address these initial problems, we assess the evolution of the public opinion regarding the energy label by constructing a quantitative measure: the "News Index." We use LexisNexis to collect all articles published in the four major Dutch newspapers between January 2007 and August 2009, using a Boolean search on "energy label" and related terms. In line with Antweiler and Frank [2] and Tetlock [29], we convert these newspaper articles into a numeric score by manually screening the articles on their sentiment regarding the energy label. Positive news receives a

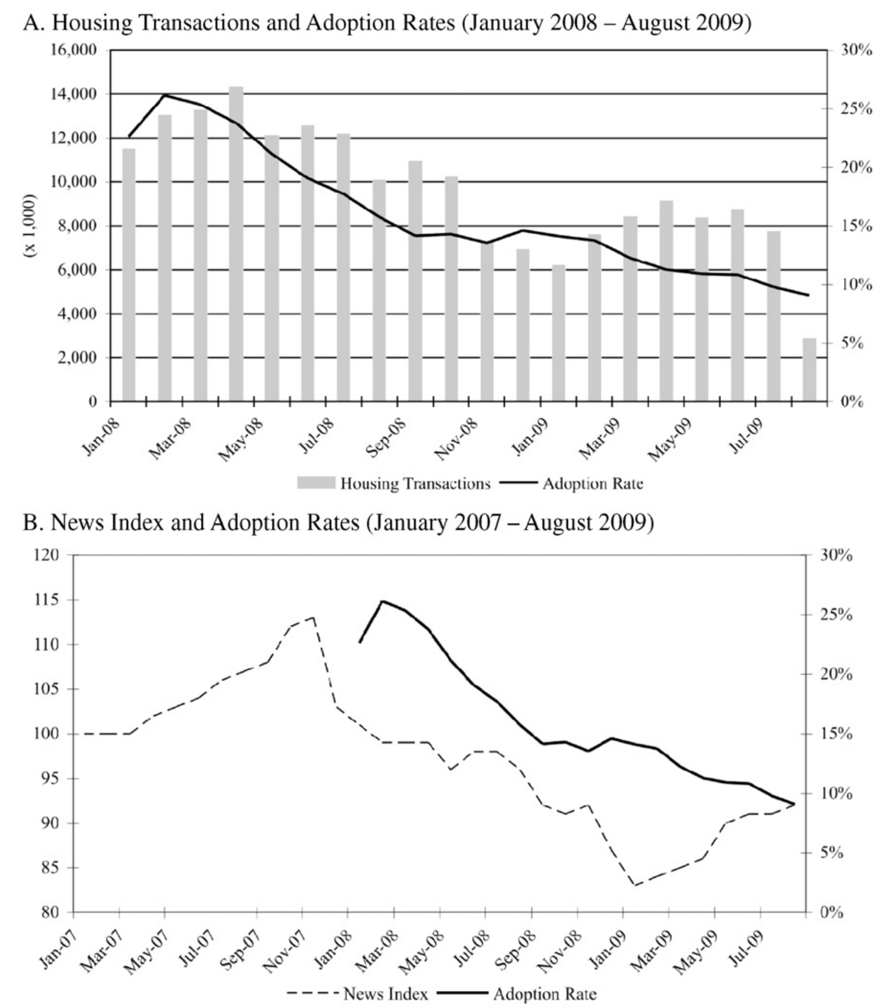

Fig. 1. Energy label dynamics housing transactions, adoption rates and the News Index.
Source: LexisNexis, Dutch Association of Realtors (NVM), and Agentschap NL.

score of 1, whereas negative news receives a score of −1. Front page news presumably has more impact and receives a score of 2 or −2, respectively.

Fig. 1B shows the News Index for the period January 2007–August 2009. The popular media was generally positive on the energy label in the run-up to the launch, but just before the official start of the labeling program, the Dutch Association of Homeowners launched a media campaign asserting the lack of consistency and reliability of the energy performance certification process. These critiques made headlines in the national press starting December 2007. During the Spring of 2008, several other important real estate bodies, including the Association of Realtors and the Association of Public Housing Corporations, fueled the skepticism regarding the quality of the signal conveyed by the energy label and questioned the need for an energy label in the housing market. This public dismay forced the Minister of Housing to admit that the implementation of the certificate left something to be desired. Subsequent program improvements included better training of certifying surveyors and enhancing the transparency of the labeling process. These advances were implemented during the Fall of 2008, which favorably changed the public opinion on the energy label after January 2009.

The dynamics of the News Index are leading the adoption rate of the energy label in housing transactions. Simple calculations show that the correlation is highest when the News Index is lagged by one quarter. Thus, public opinion and media sentiment seem to be important determinants of the adoption rate of the energy performance certification program.

There is also substantial regional variation in the market penetration of energy labels. Fig. 2 shows labeled housing transactions as a fraction of the total transaction volume for the 12 provinces in the Netherlands. The two main provinces that form the economic core of the Netherlands (the so-called "Randstad"), North-Holland, which includes Amsterdam, and Utrecht, both have relatively low adoption rates of energy performance certificates. These rates are in contrast to the high adoption rates in more distant provinces like Zeeland and Limburg.

Table 1 provides descriptive statistics on the physical characteristics of the labeled and non-labeled sample. Simple comparisons show that labeled dwellings sell for slightly lower prices and are on the market six days longer, on average. The dwelling type composition of the labeled sample is comparable to the composition of the sample of non-labeled dwellings. There are some quality differences between labeled homes and non-labeled homes: the former are smaller by about six square meters and are predominantly constructed between 1960 and 1990. Maintenance of the interior and

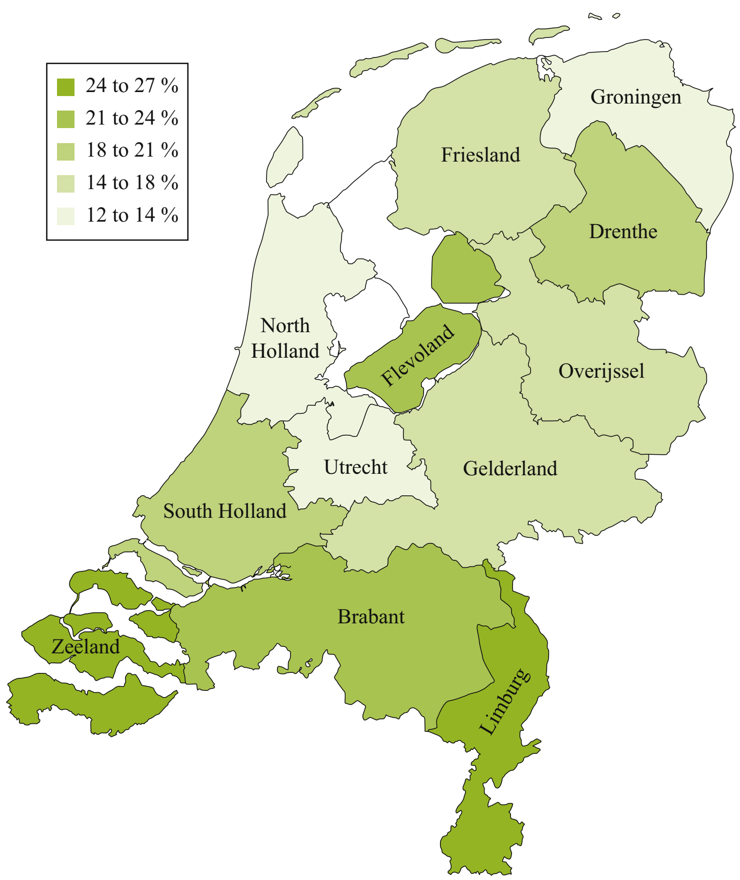

Fig. 2. The geography of energy label adoption rates (The Netherlands, January 2008–August 2009).
Source: Dutch Association of Realtors (NVM) and Agentschap NL.

Table 1
Comparison of labeled and non-labeled dwellings (January 2008–August 2009).

Sample size	Labeled dwellings 31,993		Non-labeled dwellings 145,325	
	Mean	St.Dev.	Mean	St.Dev.
Transaction price (€/square meter)	2,003.04	691.24	2,202.06	836.96
Time on market (days)	137.79	154.73	131.63	153.12
Dwelling type (percent)				
Apartment	30.82	46.17	32.34	46.78
Duplex	45.89	49.83	42.07	49.37
Semi-detached	13.26	33.92	13.44	34.11
Detached	10.03	30.05	12.15	32.67
Period of construction (percent)				
Pre-1930	12.76	33.37	18.60	38.91
1930–1944	6.32	24.34	8.35	27.66
1945–1960	9.80	29.73	7.55	26.42
1960–1970	18.57	38.88	15.48	36.18
1970–1980	22.19	41.55	15.64	36.32
1980–1990	17.79	38.24	12.85	33.47
1990–2000	11.84	32.31	14.29	34.99
>2000	0.70	8.36	7.11	25.69
Thermal and quality characteristics				
Dwelling size (square meters)	114.01	46.15	119.82	55.69
Central heating (1=yes)	91.00	28.62	91.08	28.51
Insulation quality (1–5)	2.13	1.76	2.21	1.82
Interior maintenance (1="Good")	86.95	33.68	88.44	31.97
Exterior maintenance (1="Good")	91.45	27.96	91.73	27.54
Neighborhood characteristics[a]				
Housing density (dwellings in 1 km radius)	1,962.40	1,731.65	2,105.82	1,990.42
Average time on market (days)[b]	129.20	46.69	126.44	49.28
Average monthly household income (€)	2,087.21	616.37	2,201.67	660.23
Political ideology (percent)				
Green vote[c]	6.96	3.18	7.37	3.49
Period of transaction (percent)				
Q1 2008	28.06	44.93	17.60	38.08
Q2 2008	25.03	43.32	19.20	39.39
Q3 2008	15.91	36.58	17.42	37.93
Q4 2008	10.25	30.33	13.06	33.70
Q1 2009	8.89	28.46	12.04	32.54
Q2 2009	8.66	28.13	14.61	35.32
Q3 2009	3.19	17.58	6.07	23.89
Energy label (percent)				
A	0.60	7.73		
B	8.19	27.43		
C	24.15	42.80		
D	26.95	44.37		
E	19.25	39.43		
F	13.27	33.92		
G	7.45	26.26		

[a] neighborhood characteristics are all at the zip code level.
[b] calculation based on dwellings transacted in 2006 and 2007 at the zip code level.
[c] the calculation of *Green Vote* is based on the total votes for the Green Party and the Party for the Animals as a fraction of the total votes during the 2006 national election.

exterior and the insulation are of slightly lower quality as compared to the non-labeled transaction sample. The neighborhood characteristics show that labeled dwellings are located in less dense areas with lower average household incomes, and where homes are on the market longer.

Within the sample of labeled dwellings, about one third of the transactions has been awarded a "green" label—corresponding to a rating of A, B, or C. About a quarter of the certified homes have a D rating, where D indicates that there is room for improvement in energy efficiency. Thirty-nine percent of the certified dwellings have a red label (E or lower), which indicates that there are considerable opportunities to increase the energy performance of these particular dwellings. Last, the economic downturn is clearly reflected in the distribution of the transactions over the sample period: more than half of the transactions took place in the first two quarters of 2008, with transactions in the housing market virtually grinding to a halt in the third quarter of 2009.

5. Method and results

5.1. The adoption process of energy performance certificates

To better understand the adoption process of energy performance certificates in the Dutch housing market, and to more formally explore the determinants of label adoption, we estimate the following logit model:

$$\Pr(EPC)_i = \alpha + \beta_i X_i + \delta_n L_n + \rho g_c + \sum_{p}^{p=1} \lambda_p p_p + \varepsilon_i \quad (1)$$

where EPC_i is the binary variable with a value of one if transacted dwelling i has an energy performance certificate, and zero otherwise. X_i represents a vector of quality characteristics of a dwelling, such as size, age, and building quality. L_n is a vector of variables that reflect the neighborhood characteristics of each individual dwelling in cluster n; such as density, average monthly household income, and the average time on the market. These variables are all at the zip code level and vary per neighborhood n. g_c is the fraction of votes for "green" parties during the 2006 national elections that varies per city c. To further control for geographical effects, p_i is the dummy variable with a value of one if a dwelling is located in province p, and zero otherwise.

Table 2 presents the results of the logit estimation of Model (1). Results are provided for four different specifications. All specifications include the News Index to control for time-variation in the adoption of energy labels, and province-fixed effects to control for regional variation in the adoption rate. In the first Column, we include housing type, dwelling size and the period of construction. Relative to detached dwellings (the default category), semi-detached dwellings, and especially duplex dwellings are significantly more likely to have an energy performance certificate. In contrast, apartments are

Table 2
Logit regression results. The determinants of label adoption.

	(1)	(2)	(3)	(4)
Dwelling type[a]				
Apartment	−0.120*** [0.029]	−0.119*** [0.029]	−0.184*** [0.033]	−0.195*** [0.034]
Duplex	0.082*** [0.023]	0.082*** [0.023]	−0.019 [0.026]	−0.018 [0.026]
Semi-detached	0.059** [0.027]	0.059** [0.027]	0.032 [0.028]	0.037 [0.028]
Dwelling size (log)	−0.431*** [0.023]	−0.430*** [0.024]	−0.264*** [0.025]	−0.259*** [0.025]
Period of construction[b]				
1931–1944	0.068** [0.030]	0.068** [0.030]	0.074** [0.030]	0.079*** [0.030]
1945–1960	0.557*** [0.027]	0.558*** [0.027]	0.557*** [0.027]	0.565*** [0.027]
1960–1970	0.494*** [0.023]	0.495*** [0.023]	0.503*** [0.023]	0.515*** [0.024]
1971–1980	0.685*** [0.022]	0.686*** [0.022]	0.738*** [0.023]	0.754*** [0.023]
1981–1990	0.646*** [0.023]	0.647*** [0.023]	0.688*** [0.024]	0.702*** [0.024]
1991–2000	0.161*** [0.025]	0.162*** [0.025]	0.272*** [0.026]	0.281*** [0.026]
> 2000	−1.953*** [0.070]	−1.952*** [0.070]	−1.911*** [0.070]	−1.904*** [0.070]
Monument	−0.103 [0.078]	−0.103 [0.078]	−0.078 [0.078]	−0.080 [0.078]
Thermal and quality characteristics				
Central heating		−0.019 [0.023]	−0.016 [0.023]	−0.016 [0.023]
Insulation quality		0.000 [0.004]	0.001 [0.004]	0.001 [0.004]
Exterior maintenance		−0.001 [0.023]	0.006 [0.023]	0.006 [0.023]
Neighborhood characteristics				
Housing density (in thousands, logs)			0.046*** [0.009]	0.037*** [0.009]
Average time on market (in hundreds of days, logs)			0.011 [0.021]	0.046** [0.023]
Average monthly household income (in €thousand, logs)			−0.718*** [0.030]	−0.727*** [0.030]
Green vote[c]				1.263*** [0.309]
News index	0.041*** [0.001]	0.041*** [0.001]	0.042*** [0.001]	0.042*** [0.001]
Constant	−3.681*** [0.145]	−3.669*** [0.146]	−4.226*** [0.202]	−4.440*** [0.209]
Sample size	177,318	177,318	177,318	177,318
Pseudo R^2	0.055	0.055	0.059	0.059

Notes:
models also include province-fixed effects.
* significance at the 0.10 level.
[a] default for dwelling type is "Detached."
[b] default for period of construction is "Pre-1930."
[c] the calculation of *Green Vote* is based on the total votes for the Green Party and the Party for the Green Party and the Party for the Animals as a fraction of the total votes during the 2006 national election.
** significance at the 0.05 level.
*** significance at the 0.01 level.

significantly less likely to be labeled. The relative homogeneity of apartments as compared to other housing types may decrease the need to disclose information about the thermal performance of the dwelling to the seller. The square footage of a dwelling significantly decreases the likelihood of energy performance certification—larger dwellings are less likely to be labeled.

The period of construction has a distinct influence on the likelihood of energy performance certification. Relative to the reference period, which consists of all dwellings constructed before 1930, only dwellings constructed after 2000 are significantly less likely to be labeled. This is in line with the legislation regarding the certification process: dwellings that have been constructed after 1999 are exempted from energy performance certification in the transaction process. The coefficients further indicate that post-war homes and dwellings constructed between 1970 and 1990 are especially more likely to be certified. Monuments are less likely to be certified (albeit insignificantly): current legislation does not require an energy performance certificate for dwellings that have been awarded the official "monument" status.

Importantly, the coefficient on the lagged News Index has a significant and positive relation to the label adoption rate. Thus, sentiment in the public media has a distinct influence on the likelihood of label adoption during the sample period.

In Column (2), we add thermal and quality characteristics of the dwelling to the model. It seems that the odds of label adoption are not simply a reflection of the thermal characteristics of the dwelling. The presence of central heating and the quality of insulation – two factors that are directly reflected in the modeled energy efficiency that determines the outcome of the certification process – do not significantly increase the likelihood of energy performance certification. The label does not seem to be systematically used by private consumers to disclose information on the thermal quality of a dwelling to the market. Other quality attributes of certified dwellings, measured by the maintenance of the exterior, also lack a consistent effect on label adoption.[11]

Column (3) of Table 2 includes neighborhood characteristics in the analysis. The results show that adoption rates are highest among homes that are located in neighborhoods with higher densities and populated by households with lower average incomes. Difficult selling conditions, as measured by average time on the market, are also associated with higher adoption rates.

In the last Column, we address the environmental ideology of homeowners as a determinant of label adoption. The literature on ideology and consumer choice provides evidence that "green" consumers are more likely to adopt environmental innovations [19] and are more responsive to energy conservation "nudges" [8]. As a proxy for environmental ideology, we include the fraction of votes for "green" parties in the 2006 national elections. This variable is available for 479 cities. The results on voting preferences and label adoption show a significantly positive coefficient on our measure of voting "green", which provides some indication that the choice for adopting the energy label may also be driven by ideological beliefs.[12]

Summarizing, recently introduced energy labels are adopted at a steadily decreasing rate in the Dutch housing market, which is partially driven by media sentiment. However, we also find evidence that dwelling and neighborhood-specific characteristics significantly influence the likelihood of label adoption. Households living in more heterogeneous dwellings (as opposed to apartments) of moderate size are more likely to have their home certified. The propensity to take out a label also increases in neighborhoods where density is high, average monthly income is low, and voting for "green" political parties is more common. Difficult housing market conditions have an association with higher adoption rates, which could be an indication that sellers use label adoption as a "strategic" tool – regardless of the outcome – to resolve part of the asymmetric information problem to facilitate the transaction process. However, sellers do not seem to adopt an energy label to signal superior building quality to prospective buyers.

5.2. The market pricing of energy performance certificates

The premise of residential energy performance disclosure is that increased transparency through reliable information on energy efficiency leads to the capitalization of energy efficiency in housing transactions. This capitalization should translate into a price discount for less energy efficient homes or a premium for more energy efficient homes, where the price effect partially depends on the discount rates used by private consumers.[13]

In estimating the effects of energy performance certification on the transaction process, we face a sample selection issue because we observe the thermal efficiency just for a subset of the total sample of transacted dwellings. We have reason to believe that this subset of labeled dwellings is nonrandom due to self-selection or sorting of particular homes, in particular locations, into the sample. This sorting might bias the regression results, and we, therefore, use the Heckman [17] two-step method that includes our self-constructed News Index as an exogenous determinant of label adoption. Presumably, this variable is unrelated to the transaction price.[14] We first estimate a probit model on the probability of receiving certification, similar to the model estimated in Column (4) of Table 2. We then construct consistent estimates of

[11] A robustness check (results not reported) indicates that the maintenance of the interior is not related to the likelihood of label adoption either.

[12] We note that we cannot control for the individual demographic characteristics of voters. Also, the voting data provides just a reflection of political preferences at the city level, rather than political preferences of individual voters.

[13] There is a large body of literature on the capitalization of energy savings in prices of appliances and homes and the discount rate used therein. See Train [30] for an early discussion.

[14] The correlation between average monthly transaction prices and the News Index is very low—0.17.

Table 3
Heckman two-step estimation results. Energy labels and transaction prices (dependent variable: natural logarithm of transaction price per square meter).

	(1)	(2)	(3)	(4)
"Green" energy label (A, B, or C)	0.037*** [0.003]		0.036*** [0.003]	
Energy label score				
A		0.102*** [0.021]		0.102*** [0.021]
B		0.056*** [0.006]		0.055*** [0.006]
C		0.022*** [0.004]		0.021*** [0.004]
E		−0.005 [0.004]		−0.005 [0.004]
F		−0.025*** [0.004]		−0.023*** [0.004]
G		−0.051*** [0.006]		−0.048*** [0.006]
Thermal and quality characteristics				
Central heating			0.014*** [0.005]	0.012** [0.005]
Exterior maintenance			0.027*** [0.005]	0.024*** [0.005]
Insulation quality			0.003*** [0.001]	0.002*** [0.001]
Dwelling type[a]				
Apartment	−0.386*** [0.011]	−0.388*** [0.011]	−0.387*** [0.011]	−0.388*** [0.011]
Duplex	−0.358*** [0.007]	−0.358*** [0.007]	−0.358*** [0.007]	−0.358*** [0.007]
Semi-detached	−0.223*** [0.007]	−0.221*** [0.007]	−0.223*** [0.007]	−0.221*** [0.007]
Dwelling size (log)	−0.266*** [0.012]	−0.268*** [0.012]	−0.268*** [0.012]	−0.269*** [0.012]
Number of rooms	0.003*** [0.001]	0.003*** [0.001]	0.003*** [0.001]	0.003*** [0.001]
Monument	0.051*** [0.016]	0.051*** [0.016]	0.055*** [0.016]	0.055*** [0.016]
Neighborhood characteristics				
Housing density (in thousands, logs)	−0.016*** [0.003]	−0.016*** [0.003]	−0.016*** [0.003]	−0.016*** [0.003]
Average time on market (in hundreds of days, logs)	−0.177*** [0.004]	−0.176*** [0.004]	−0.177*** [0.004]	−0.176*** [0.004]
Average monthly household income (in €thousand, logs)	0.538*** [0.023]	0.537*** [0.023]	0.536*** [0.023]	0.535*** [0.023]
Selection variable ($\hat{\lambda}$)	−0.329*** [0.071]	−0.322*** [0.071]	−0.326*** [0.071]	−0.319*** [0.071]
Constant	9.941*** [0.069]	9.938*** [0.069]	9.903*** [0.069]	9.904*** [0.069]
Sample size	31,993	31,993	31,993	31,993
R^2	0.525	0.527	0.526	0.528
R^2-adj	0.524	0.526	0.525	0.527

Notes: models also include time-fixed effects, province-fixed effects, and period of construction controls. News index is included as the selection variable in a first stage probit regression. Estimation results of the first stage are not reported.
Standard errors are corrected for heteroskedasticity and stated in brackets.
* significance at the 0.10 level.
[a] Default for dwelling type is "Detached."
** Significance at the 0.05 level.
*** Significance at the 0.01 level.

the inverse Mills ratio, and include this selection variable as an instrument in the following model:

$$\log P_i = \alpha + \beta_i X_i + \delta_n L_n + \rho G_i + \sum_{p}^{p=1} \gamma_p p_p + \theta \hat{\lambda}_i + \varepsilon_i \tag{2}$$

In the formulation represented by Eq. (2), the dependent variable is the logarithm of the transaction price per square foot of dwelling *i*. X_i is the vector of the hedonic characteristics of building *i*.[15] To control for local economic conditions, L_n is the vector of variables capturing the attributes of neighborhood n in which a dwelling is located. G_i is the dummy variable with a value of one if building i is rated A, B, or C, indicating that the home obtained a "green" energy label, and a value of zero otherwise. Alternatively, G_i represents the vector of the scores in the energy label, ranging from A to G (where the D-label serves as the reference group). $\hat{\lambda}_i$ is the inverse Mills ratio constructed based on the first step of the estimation. To further control for locational variation in transaction prices, p_p is the dummy variable with a value of one if building i is located in province p, and zero otherwise.

Table 3 presents the results of the second stage of the Heckman model in which the logarithm of transaction price per square foot has is related to a set of hedonic characteristics, including the inverse Mills ratio. Results are corrected for heteroskedasticity [31] and all specifications include province-fixed effects, monthly time-fixed effects and controls for the period of construction.

[15] In line with a suggestion of one referee, we estimate Eq. (2) without transactions of dwellings constructed post-2000, because the number of labeled observations in this cohort is very small.

The model in Column (1) explains some 52 percent of the natural logarithm of the transaction price based on 31,993 labeled observations. Duplex dwellings and apartments transact at discounts of 36–39 percent, relative to detached dwellings. Selling prices are higher for smaller dwellings, although the number of bedrooms has a significantly positive effect on price. An additional bedroom adds some 0.3 percent to the transaction price, *ceteris paribus*.

Age becomes valuable once it is officially recognized: dwellings that are registered as monuments sell at a premium of about five percent.

The variables that reflect local economic conditions mostly show the expected signs: the average monthly household income in the neighborhood has a positive relation to the transaction price, and the average time on the market in the neighborhood has a negative relation to the transaction price. House prices seem to be lower in high-density areas.

Most importantly, within the sample of certified dwellings, we document that homes with a label A, B, or C, which are generally referred to as "green" labels, transact at an average price premium of 3.7 percent, *ceteris paribus*. Considering that the average transaction price of a dwelling in the certified sample equals €231,000, the euro value of the "green" price premium amounts to €8449, at the point of means.

The coefficient on the selection variable, the inverse Mills ratio, is negative and significant. This result indicates that the error terms in the selection equation and the primary equation are negatively correlated. So, (unobserved) factors that make energy labeling more likely tend to be associated with lower transaction prices of dwellings.[16]

The second Column of Table 3 presents the results when the specific score of the energy label is included in the model. We document that the premium for energy efficiency constitutes a series of positive price effects that correspond to the outcomes of the different label categories. We find that A-labeled homes transact at a price premium of 10.2 percent as compared to similar homes with the intermediate D-label, and dwellings with a G-label transact at a discount of some 5 percent.

The variation in the premium for energy efficiency seems to be related to the present value of future energy savings resulting from higher energy efficiency. In 2009, a standardized Dutch dwelling had an average monthly energy bill of €152, ranging between €105 for energy label A, to €231 for energy label G. Capitalizing the difference in the energy bill of an F-labeled dwelling, compared to a G-labeled dwelling, results in a present value of €4000.[17] This is about 1.8 percent of the average transaction price and slightly lower as compared to the average price difference between F- and G-labeled dwellings documented in Table 3. Comparing the capitalized energy savings of A-labeled dwellings with G-labeled dwellings yields a present value of about €16,000, or 7.2 percent of the average transaction price. Hence, the 15 percent price premium for A-labeled dwellings (compared to G-labeled dwellings, based on coefficients reported in Table 3) seems to reflect more than just future energy savings alone.

Part of the "green" increment might be explained by the better building quality of homes with an A, B, or C label. Therefore, Columns (3) and (4) more explicitly control for differences in thermal characteristics and dwelling quality.

The results in Column (3) show that the quality of thermal characteristics has a positive effect on home prices: the presence of central heating – now prevalent in most homes in the Netherlands – and better insulation both have significant and positive relations with the transaction price. Central heating leads to an average increase in transaction prices of 1.4 percent. In line with expectations, high-quality exterior maintenance positively affects property prices. This effect is substantial: well-maintained homes transact at a price premium of 2.7 percent.

When controlling for the quality of the dwelling, the "green" increment decreases slightly to 3.6 percent, but it remains statistically and economically significant. The coefficients on the energy ratings in Column (4) are slightly smaller as well, but remain equally significant both economically and statistically.

Further, we test for the robustness of the "green" transaction premium over the sample period by including interaction terms of "green" and quarterly time dummies in Model (2). We hypothesize that, with decreasing consumer confidence in the energy performance certificate, the signaling value of the label might be negatively affected. Fig. 3 reports point estimates for the average "green" premium per quarter, including the 95 percent confidence interval for each coefficient. Controlling for differences in location and quality, the average price premium for homes with an A, B, or C certificate remains relatively constant during the first year of the sample period, but drops to about zero in the first quarter of 2009. However, the "green" premium increases again to 1.5 and 2 percent in the second and third quarter of 2009, respectively. This rebound might have a relation with increased consumer confidence in the energy label following some months of positive media coverage.

Summarizing, our results provide an indication that private consumers use the information disclosed by the energy label and take the relative energy efficiency of their prospective home into account when making investment decisions. This evidence adds to the small number of studies that have addressed the empirical relation between characteristics of thermal efficiency and transaction prices of residential dwellings [9,14,22] and to studies on energy efficiency, labels, rents, and prices in commercial buildings [10,11].

---

[16] The regression results change slightly when the analysis is repeated without including the inverse Mills ratio. Results of this robustness check are available from the authors upon request.

[17] To calculate the present value of future energy savings, we capitalize the monthly difference between the average energy bills of dwellings with different energy labels (A through G), assuming a duration of twelve years (the average holding period of Dutch homeowners), and a four percent discount rate (assuming homeowners treat proceeds from future energy savings as risk-free). The Dutch Ministry of Housing provided the data on the average energy bills of dwellings in different labels classes based on a sample of 4750 homes.

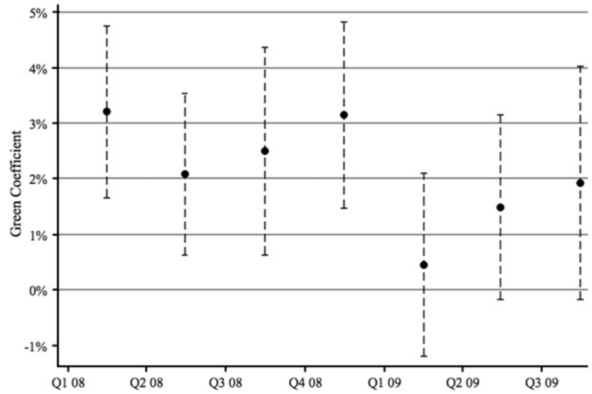

Fig. 3. Dynamics of the "green" premium (Q1 2008–Q3 2009).
Notes: coefficients on quarterly premiums based on interaction terms included in Eq. (2). 95 percent confidence intervals indicated by dotted lines.

6. Conclusions

Energy efficiency improvements in the residential housing market can play an important role in the reduction of global carbon emissions. Besides more traditional policies, such as stricter buildings codes, energy labels can be instrumental in resolving information asymmetries regarding the energy performance of private dwellings and commercial buildings. The information provided by energy labels may thus encourage energy conservation in the housing sector. This paper reports the first evidence on the market adoption and economic implications of energy performance certificates using a large-scale mandatory labeling program in the European Union. We exploit the residential sector in the Netherlands as a laboratory, as the Dutch housing market was one of the first to experience the formal introduction of energy labels for residential dwellings in January 2008.

Using a data set of some 177,000 transactions, we first address the implementation of energy labels in the housing market. We find that energy labels are adopted at a declining rate, lead by negative sentiment in the public media. More heterogeneous dwellings of moderate size, constructed post-war, and between 1970 and 1990, are most likely to be labeled, but thermal and other quality characteristics of the home have no relation to the label adoption rate. The label is not systematically used to signal superior dwelling quality. Neighborhood characteristics have a distinct influence on the propensity to adopt a label: labeled dwellings are mostly located in neighborhoods where density is higher, monthly household incomes are lower, and voting for "green" parties is more common. Some of the neighborhood characteristics and the regional variation in label adoption have a relation to less competition in local housing markets (i.e., where the average time on the market is longer). Our results imply that the initial lack of transparency in labeling practices, in combination with the current legislation regarding energy performance certification that provides a simple escape clause, hinders a complete uptake of energy labels in the market. As a result, the energy label is adopted in a nonrandom way.

We also study the effects of energy performance certification on the outcome of the transaction process. Controlling for thermal and other hedonic characteristics of residential dwellings, we document that homebuyers are willing to pay a premium for homes that have been labeled as more energy efficient, or "green". Our results show that this price premium varies with the label category of the energy performance certificate and is robust to variations in housing quality. The energy performance certificate is instrumental in creating transparency in the energy performance of a dwelling and seems to be an effective signaling device that is capitalized into home prices.

These findings contain some important lessons for homeowners – private as well as institutional. When improving the energy efficiency of a dwelling, there is not only an immediate financial benefit from lower energy expenses, but the increased energy efficiency is also recognized at the time of sale, which leads to a higher transaction price. Although we provide some intuition on relation between the size of the energy-efficiency increment and real energy savings, we are ultimately not able to distinguish between the intangible effects of labeling itself and the economic effects of energy savings per se. Detailed information on energy consumption of the individual households would allow us to further disentangle these effects.

For policy makers, the results of this paper may help in refining energy performance certification programs and in stimulating more extensive dissemination of the energy labels. This paper shows that current legislation regarding the adoption of the label is not strong enough. The numerous opt-outs allow homeowners to avoid certification of dwellings. For the energy performance of the complete residential stock to improve, all homes should have an energy performance certificate.[18]

[18] In fact, at the time of writing, the European Parliament had just approved new legislation to make the energy performance certificate fully mandatory across the European Union, including elimination of the waiver-option.

The case of the Netherlands demonstrates that start-up problems surrounding the implementation of the energy label were neither adequately tackled, nor clearly communicated by policy makers. The negative publicity that surrounded the energy performance certification process hindered the market uptake. The resulting lack of confidence in the energy label is costly to repair. Other governments should learn from these mistakes, because the information conveyed by a well-regarded energy labeling system seems to represent an effective market signal. This effectiveness might trigger investments in more energy-efficient buildings, thereby reducing energy consumption and carbon emissions.

Appendix A

See appendix Fig. A1 below.

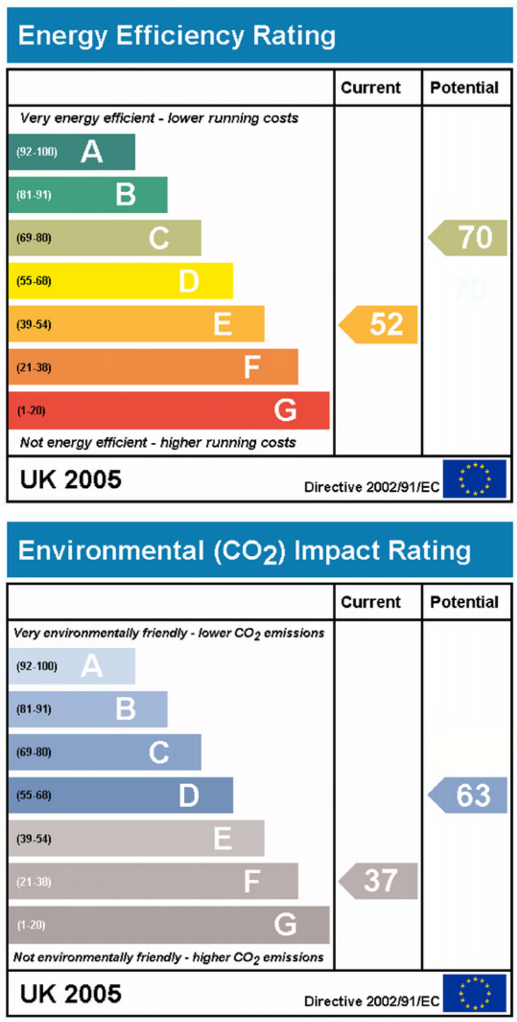

Fig. A1. Energy labels in the European Union (example from the United Kingdom).

References

[1] P.W. Abelson, Property prices and the value of amenities, Journal of Environmental Economics and Management 6 (1979) 11–28.
[2] W. Antweiler, M.Z. Frank, Is all that talk just noise? The information content of Internet stock message boards, Journal of Finance 59 (2004) 1259–1294.
[3] A. Aroonruengsawat, M. Auffhammer, The Impact of Buildings Codes on Residential Electricity Consumption. in: G. Libecap, and R.H. Steckel, (Eds.), The Economics of Climate Change: Adaptations Past and Present, University of Chicago Press, Chicago, forthcoming.
[4] I. Ayers, S. Raseman, A. Shih, Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Residential Energy Usage, NBER Working Paper 15386 (2009).

[5] P.G.M. Boonekamp, Price elasticities, policy measures and actual developments in household energy consumption: A bottom up analysis for the Netherlands, Energy Economics 29 (2007) 133–157.
[6] S.C. Bourassa, M. Hoesli, J. Sun, What's in a view, Environment and Planning 36 (2004) 1427–1450.
[7] D. Costa, M.E. Kahn, Why Has California's Electricity Consumption Been So Flat Since the 1980s? A Microeconometric Approach NBER Working Paper 15978 (2010).
[8] D.L. Costa, M.E. Kahn, Energy Conservation "Nudges" and Environmentalist Ideology: Evidence From a Randomized Residential Electricity Field Experiment, NBER Working Paper 15939 (2010).
[9] T.M. Dinan, J.A. Miranowski, Estimating the implicit price of energy efficiency improvemens in the residential housing market: A hedonic approach, Journal of Urban Economics 25 (1989) 52–67.
[10] P.M.A. Eichholtz, N. Kok, J.M. Quigley, Doing well by doing good: Green office buildings, American Economic Review 100 (2010) 2494–2511.
[11] P.M.A. Eichholtz, N. Kok, J.M. Quigley, The Economics of Green Building, Working Paper, Berkeley Program on Housing and Urban Policy, Berkeley (2010).
[12] P.-A. Enkvist, T. Naucler, J. Rosander, A cost curve for greenhouse gas reduction, The McKinsey Quarterley 1 (2007) 35–45.
[13] F. Fuerst, P. McAllister, Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values, Real Estate Economics 39 (2011) 45–69.
[14] R.W. Gilmer, Energy labels and economic search, Energy Economics (1989) 213–218.
[15] E.L. Glaeser, M.E. Kahn, The greenness of cities: Carbon dioxide emissions and urban development, Journal of Urban Economics 67 (2010) 404–418.
[16] B.G. Hanna, House values, incomes, and industrial pollution, Journal of Environmental Economics and Management 54 (2007) 100–112.
[17] J.J. Heckman, Sample selection bias as a specification error, Econometrica 47 (1979) 153–161.
[18] G.D. Jacobsen, M.J. Kotchen, Are Building Codes Effective at Saving Energy? Evidence From Residential Billing Data in Florida, Working Paper, Yale University, New Haven, CT (2009).
[19] M.E. Kahn, Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice, Journal of Environmental Economics and Management 54 (2007) 129–145.
[20] D.R. Kamerschen, D.V. Porter, The demand for residential, industrial and total electricity, 1973–1998, Energy Economics 26 (2004) 87–100.
[21] W. Kempton, L. Layne, The consumer's energy analysis environment, Energy Policy 22 (1994) 857–866.
[22] J. Laquatra, Housing market capitalization of thermal integrity, Energy Economics 8 (1986) 134–138.
[23] S.D. Levitt, C. Syverson, Market distortions when agents are better informed: The value of information in real estate transactions, The Review of Economics and Statistics 90 (2008) 599–611.
[24] J. Nässén, F. Sprei, J. Holmberg, Stagnating Energy Efficiency in the Swedish Building Sector—Economic and Organisational Explanations, Energy Policy 36 (2008) 3814–3822.
[25] J.P. Nelson, Airport noise, location rent, and the market for residential amenities, Journal of Environmental Economics and Management 6 (1979) 320–331.
[26] M. Ryghaug, K.H. Sorensen, How energy efficiency fails in the building industry, Energy Policy 37 (2009) 984–991.
[27] L. Schipper, Improved energy efficiency in the industrialized countries: Past achievements CO_2 emission prospects, Energy Policy 19 (1991) 127–137.
[28] N. Stern, The economics of climate change, American Economic Review 98 (2008) 1–37.
[29] P.C. Tetlock, Giving content to investor sentiment: The role of media in the stock market, Journal of Finance 62 (2007) 1139–1168.
[30] K. Train, Discount rates in consumers' energy-related decisions: A review of the literature, Energy 10 (1985) 1243–1253.
[31] H. White, A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity, Econometrica 48 (1980) 817–838.