REVALUE

Energy Performance and Valuation of Social housing in Europe: a quantitative analysis

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Executive summary

One of the key aims of European Union (EU) public policy is to increase the rate of market uptake of energy efficient construction and retrofit measures in the housing stock. Houses and their occupation are responsible for a large share (25 percent) of the total energy consumption in the EU-28 (Eurostat, 2017). The European Commission aims to incentivize the implementation of energy efficiency measures, i.e. to improve energy efficiency and to reduce energy demand from buildings, in the built environment through different financial and political stimulus initiatives, such as the Energy Performance of Buildings Directive (2003, 2010), the Energy Efficiency Plan (2011), and the Horizon 2020 energy efficiency stimulus package (2014).

Providers of rental housing, both social housing associations and private sector landlords, have a key role in achieving the ambitious targets set by the European Commission and member state Governments. However, the incentives that lead to energy efficiency improvements in the housing sector are not yet fully understood. The underlying assumption is that any investment owner will require a return on capital in the form of increased asset and/or rental values. Therefore, understanding the link between energy efficiency and these values is critical to help landlords, and in the case of this element of the Revalue project, housing associations, develop their investment strategies in this regard.

Assessment of any valuation impact of energy efficiency retrofits should be undertaken by valuers as they prepare valuations for monitoring asset performance or for anticipated transactions. However, whether property valuers take into account the level of energy performance will depend on instructions from their clients and from market pricing evidence. If energy efficiency impacts rents or capital values achieved in the market place, then valuers should and do take account of that. However, it is believed that a greater emphasis in the instructions on the impact and benefits of energy efficiency may provide an incentive towards sustainability investments by both private and social landlords. For this reason the leading professional body, the RICS strongly encourage valuers to collect such data where possible to inform their valuations.

This report aims to shed some light on the extent to which energy efficiency is associated with reported valuations undertaken for social housing landlords. The study is based first on international evidence from the academic literature and second on the results of an extensive regression analysis of social housing in selected EU countries. The results of the literature review show that a majority of quantitative studies find that overall housing market prices are influenced upwardly by the energy efficiency levels reflected in Energy Performance Certificates or their international equivalents; the extent of the influence depending on the extent of the levels and a range of other factors including geography and market conditions.

The quantitative analysis covered the reported valuations of thousands of dwellings owned by large social housing associations in different European countries (the Netherlands, the UK, Sweden and Germany) and conducted by independent valuers. Data was gathered on Energy Performance Certificates (EPC labels, EPC and SAP indexes), energy components (e.g. window frames or glazing types), technical characteristics and exact addresses of each of the dwellings in the dataset. In each of these settings, the relationship between energy efficiency (as measured by energy labels, energy components, or energy consumption) and the capital and rental value of affordable housing was analysed by employing the standard hedonic pricing model. The calculation of that value for social housing is by way of an assessed value rather than market prices because within the samples very few transactions had taken place. A further constraint on the study is the artificial restrictions placed on how social housing is valued and rented. This means that the data would not necessarily represent the situation for private sector or owner-occupied dwellings which do not suffer from the same rent controls, can be valued to market value and which transact more frequently. All data used was taken from the databases of maintained by

social housing providers in four countries: the Netherlands, the United Kingdom, Sweden, and Germany. The study took into account the building quality, location and local housing market conditions.

For **the Netherlands**, a large social housing provider provided data on external valuations by three professional valuation firms of over 40,000 dwellings in two years: 2010 and 2015. The energy performance of the dwellings in the sample was assessed based on the Energy Performance Certificate. Results from the regression analyses indicate that the relationship between value and energy efficiency changed over the study period. Whereas reported values did not show any discernible correlation with EPC ratings in 2011, this relationship was observable in 2015 and was very much in line with the findings from recent academic evidence on this topic for the Netherlands, also based on regression model (Chegut et al., 2016). In 2015, affordable dwellings with the best energy labels – A and B – had higher reported values than their otherwise comparable peers. For A-labelled dwellings, the valuation premium relative to dwellings without an Energy Performance Certificate was statistically significant at the 95 percent confidence and in line with premiums found in the Dutch real estate market. These findings are corroborated when the analysis was related to differently rated dwellings: A-labelled dwellings were valued more highly than those with C-rating and valued went down stepwise to discounts for dwellings labelled D and lower.

For **the UK**, three social housing providers, managing a total of about 160,000 dwellings, provided individual valuation and energy data for their dwellings in different regions across the country. The assessed value of dwellings was related to the energy label of the property and different energy related components. The results from the analysis of individual valuations from one large social housing provider operating across England suggested there are differences in value caused by energy efficiency measures. When focusing on the labelled sample of dwellings, the results suggest the presence of a 'brown discount' in the English market, reflected by the statistically significant lower valuations attached to D labelled dwellings with respect to C label dwellings. The results of the analyses suggested that one energy feature, i.e windows, had a bigger impact on value than other measures, such as the age of the boiler. In particular, houses with double glazing had higher values than those with single glazing, suggesting that this particular factor is an expectation in terms of building specification; dwellings that do not have double glazing therefore are likely to be discounted to reflect this. Our results are weaker for the London market, which has a well-documented shortage of stock leading to value compression. However, the statistical power of the dataset is also significantly lower so only limited reliance can be placed on the results.

In **Sweden**, one large social housing company provided a sample of valuations of individual dwellings in Stockholm. These valuations were undertaken by external valuers for the purposes of taxation and market value information. In all, the final dataset included a sample of over 7,000 rents and dwelling valuations for two years, 2015 and 2016. The results indicate higher values associated with high energy efficiency components (i.e. triple glazing) and lower energy consumption (i.e. lower heating costs). The analysis of rents in the portfolio shows similar patterns in terms of coefficients' sign and significance, but with lower magnitude.

In **Germany**, one large social housing company operating in the Berlin metropolitan area provided a large sample of external valuations of hundreds of their multifamily complexes. The valuations were based on automated discounted cash flow techniques. The results from our hedonic model indicate that the energy performance of apartment complexes was reflected in external valuations. Energy efficiency was significantly correlated with the level of rents, but not with the (long term) vacancy level of the properties nor the maintenance costs associated with these. When looking at the role of rents as link between energy efficiency and assessed value, the results indicate that rents play a significant role in influencing value but do not fully capture the total effect of energy efficiency on the assessed value level.

Overall, in summary, the results of the study point to energy efficiency beginning to be reflected within reported valuations of large social housing portfolios; these results may not apply to other housing sub-markets. The impacts may take the form of a ‘brown discount’ where buildings fail to meet average standards or where particularly desirable ‘visible’ features such as double (or in the case of colder climates triple) glazing. Where premium values were observed, these were small (1- 2% maximum) and put against the impact of traditional factors (79%) and factors unexplained by the analysis (20%) indicate that, whilst energy efficiency is gaining importance it is not a key value driver.

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Chapter 1 Energy Efficiency and Housing Values

The European affordable housing sector can play an important role in stimulating energy efficiency and a reduction in energy demand from buildings in the EU. Affordable housing accounts for 17 percent of the overall EU housing stock. Especially in the Netherlands, Austria, Sweden and the UK, social housing represents a major part of the housing stock: 28 percent, 22 percent, 20 percent and 18 percent, respectively. Whitehead and Scanlon (2007) showed that it was the dominant form of rental housing in many countries in the beginning of the century and that is likely to be still the case today. Yet, despite its importance, there has not been extensive literature investigation on the economic effects of energy efficiency on this housing market segment

For decision-making by housing landlords, whether social or otherwise, an important consideration is whether their investments towards the energy performance of their assets can somehow be recouped in the market, by higher rents, or in their balance sheets by higher values of their assets. This topic has received significantly more attention for housing than for commercial real estate.[1] Indeed, empirical studies providing guidance on the relationship between dwellings' energy efficiency and their economic performance – measured by rental value, occupancy rate, or transaction price – are numerous and show a clear consensus. The housing literature shows consistent economic impacts of energy efficiency in housing, finding higher transaction prices for energy efficient dwellings, with the size of the price premium depending on local market characteristics and the level of energy efficiency (Brounen and Kok, 2011; Hyland, et al., 2012; Feige, et al., 2013; Cerin, et al., 2014). Almost all of these studies employ hedonic modelling. These studies find generally that dwellings certified for energy efficiency have higher transaction prices and/or rents. However, there are important variations across studies regarding the type of environmental certification, the environmental performance measures linked to the certification, and the magnitude of the associated premium – or brown discounts. Geography, climate and market conditions also play a part.

The early studies, by Laquatra (1986), Gilmer (1989) and Dinan and Miranowski (1989) did not use large samples of housing transactions. The first two studies analysed the value implications of the Minnesota Housing Finance Agency's Energy Efficient Housing Demonstration Program. Laquatra found that energy efficiency was capitalized in the transaction price of a demonstration home and Dilmer showed that energy ratings had positive search benefits. Dinan and Miranowski (1989) studied transaction prices of homes in Des Moines, and concluded that energy efficiency improvements resulting in decreased energy expenditure significantly increased the expected transaction price.

European studies

The first study to employ a large sample of transaction prices to investigate the value consequences of sustainability in housing was carried out by Brounen and Kok (2011). They analysed the impact of Energy Performance Certificates on the price of Dutch housing in 2008 and 2009, and found that A-labelled Dutch homes sold at a 10.2% premium relative to otherwise similar but D-labelled homes. The premiums for homes with B and C labels were 5.5% and 2.1%, respectively. Dwellings with a label below D sold at a reduced price/discount. Exhibit 1 provides an overview of the main findings in the recent literature analysing the relationship between sustainability and house values, starting with Brounen and Kok (2011).

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[1] In studies of commercial real estate, the results point at higher rents and cash flows for environmentally certified buildings, higher and more stable occupancy rates, and higher transaction prices. Examples are Fuerst and McAllister (2011), Eichholtz et al. (2010, 2013), Kok and Jennen (2012), Bonde and Song (2013), and Chegut et al. (2014).

Hyland et al. (2012) performed a similar study using Irish housing transactions including housing rents in the analysis. They studied the effect of Ireland's Building Energy Rating on house prices and rents for the 2008-2012 period. Their price results were comparable to those found by Brounen and Kok (2011), both in direction and in magnitude. They also found that energy efficiency was more prominent as a factor when market conditions were poor (i.e. consumer choice was good) and for smaller dwellings. Also, they found a 1.9% higher rental value for an A-labelled dwelling compared to one with a D label, while the rental premium for a B-labelled dwelling was 4.2%. The lower E, F and G labels had rental discounts compared to the average.

Feige et al. (2013) studied the effect of a broad range of sustainability characteristics on the rent levels of Swiss dwellings in 2009. They found that environmental performance and rents were positively related. This held especially for the attributes of improved water efficiency, health and comfort levels, and the safety and security of a building. On the other hand, the energy efficiency of a dwelling was negatively related to the rent, which the authors explained by the Swiss practice of incorporating energy costs in the rent. Therefore energy was not a cost consideration for tenants.

Cerin et al. (2014) investigated the value effects of energy efficiency in Swedish homes using housing transactions in 2009 and 2010. They found that only the most energy efficient homes commanded a premium and then only a small one. A lower energy consumption by 1 percent yielded a price increase of 0.03 percent, which given potential inefficiencies in market pricing is minimal.

Fuerst et al. (2015) explored the impact of Energy Performance Certificates using a large sample of repeated sales in England in the period from 1995 to 2012. The results showed that A/B and C label dwellings commanded a premium of 5 and 1.8% respectively relative to otherwise similar homes with a D label. Those premiums were found mainly in the prices of flats and especially in terraced houses; detached and semi-detached houses did not show significant price differentials.

Cajias et al. (2016) gathered a large dataset of asking rents for dwellings in Germany from a leading online real estate portal. In line with the studies above, the authors documented significant differences in asking rents and time on the market between certified and non-certified dwellings. The paper found premiums for asking rents for A-, B- and C-labeled dwellings of 3.0, 1.8 and 0.6 percent rerspectively over similar D label dwellings. In addition, the authors found strong evidence of a shorter time on the market for energy efficient dwellings.

Social housing studies

The only two papers specifically analysing value effects in affordable housing are Copiello (2015) and Chegut et al. (2016). The former is a case study of one refurbished affordable apartment complex in Turin, Italy. The refurbishment increased the building's environmental performance, improving its insulation, heating systems and other installations. The author found that rents in the building went up substantially, suggesting a market-based incentive towards improvements in environmental performance in affordable housing.

The study by Chegut et al. (2016) focused on the transaction prices of Dutch affordable homes sold to the public. The authors found that sustainability was priced in these homes, with premiums between 2% and 6%, depending on the certification level. They also showed that the combined premium of environmental performance, optimal interior and exterior maintenance, and insulation was as high as 26% suggesting that environmental performance can contribute as part of a larger renovation.

International studies

This topic has also received research attention outside of Europe. Yoshida and Sugiura (2015) assessed house price effects of certification under the Tokyo Green Building Program,[2] studying condominiums sold between 2002 and 2009, and showed that certified new units sold at discounts, while certified dwellings did sell at a premium in the secondary market, suggesting that in energy efficiency is an expected and normal characteristic of new dwellings but may have a 'scarcity value on the second hand market.

For Singapore, Deng et al. (2012) investigated the effect of Green Mark certification on residential transaction prices.[3] The authors found a label premium ranging from 4% to 6%. This premium varied across certification categories. Platinum rated buildings commanded the average highest premium of 14% whereas very low label levels had no transaction premiums.

For China, the first study was Zheng et al. (2012), evaluating the impact of "marketing greenness" on housing transaction prices in Beijing. The authors studied the Google search rank of housing complexes with respect to green features for the 2003 to 2008 period to test whether the "greenness" of these properties was related to their initial asking price, and found that the greenest buildings in the sample sold at a premium compared to the least green buildings. More recent studies for China also found sustainability premiums in housing (Hu et al. 2014, Zhang et al. 2016).

For the United States, the two main studies are Dastrup et al. (2012) and Kahn and Kok (2013). The former study assessed the impact of solar panels on the transaction prices of owner-occupied homes in California. The authors found 3.6 to 4.0% price premiums, corresponding to increases in average transaction values of about 22,500 dollars. Premiums were higher in streets with fewer solar-powered homes.

Kahn and Kok (2013) investigated the impact of environmental home certification on transaction prices in California, using housing transaction data from 2007 to 2012. Green certified homes sold for 2 to 4% more compared to otherwise similar homes without a label. Premiums were higher for dwellings located in a hotter climate and in places with higher electricity prices. Similarly, Bond and Devine (2016) provided evidence of green premiums in the rental market for multi-family dwellings in the US; these premiums exist in urban and rural areas and are not restricted only to new construction apartments.

Conclusion of this review of academic literature

There is an emerging consensus in the academic literature investigating the value effects of sustainability certification in Europe, Asia and America, pointing at the existence of some house price differentials associated with energy efficiency; higher energy efficiency is associated with higher value in most of the studies. This literature review covered hundreds of thousands of house price and rental observations in more than 10 countries and institutional settings pertaining to the housing market. However, the magnitude of the price differentials associated with energy

[2] 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.

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

efficiency varies with factors such as climatic conditions, energy prices and market conditions. Where energy is expensive, climate demand either a lot of heating or cooling and market demand for stock is weak, energy features or/and certification is likely to be a more material factor; however where energy is cheap, climates are mild and supply of housing is constrained, it is less likely to be a material consideration. On the basis of the academic studies, the conclusion is that the market will respond in varying ways depending on a range of factors. As energy becomes more of a political issue and prices rise, efficiency is likely to have a stronger bearing on the actions of market players and hence a factor that valuers will require to take into account the sustainability characteristics of dwellings in their valuations. However, one factor that is missing in the reviewed studies is any evidence as to which energy-related housing components are driving the value changes.

However, the literature reviewed is all fairly recent, starting with the study by Brounen and Kok in 2011. While the literature review has shown a clear, though variable, link, it has yet to be demonstrated clearly how this impacts on actual valuations – as opposed to transacted prices - in the field. If this link can be established though the hedonic price modelling, and higher book values are recorded for energy efficient homes, there is a business incentive for landlords to make energy efficiency investments. Additionally, delayed application of this knowledge might possibly lead to missed investment opportunities that would otherwise be beneficial both from a societal and an economic point of view.

To increase our understanding and impact of literature review results, the aim of this report is to assess whether the key findings of the empirical studies of housing transactions and rents are reflected in the (external) valuations of social housing dwellings which may be subject to different constraints, such as rent caps. The study used regression analysis to link energy performance certificates, specific energy-related housing components and energy consumption to assessed valuations of dwellings in the Netherlands, the UK, Sweden and Germany.

Exhibit 1 Empirical Studies on the Value of Energy-efficiency in the Residential Market

Study	Country	Transaction Type	Energy-Efficiency Measurement	Findings	Notes
Brounen and Kok (2011)	Netherlands	Sales	Energy Performance Certificates	+15 for a G to A label jump. Low label implies less liquidity	Dwellings with high-quality energy label, C and above, trade at premium
Chegut et al. (2016)	Netherlands	Sales	Energy Performance Certificates	+2-6 for label A and B	Label effects plus renovation effects up to 26
Cerin et al. (2014)	Sweden	Sales	Electricity consumption per sq.m	+0.03 for -1 in consumption	Only the most energy-efficient homes benefit from a slight transaction premium
Hyland et al. (2013)	Ireland	Sales, rents	Building Energy Ratings	+16.6 in price, +4.6 in rent for label G to A	The impact of a Building Energy Rating is stronger when selling conditions deteriorate
Feige et al. (2013)	Switzerland	Rents	Sustainability features	-2.9 for a +0.1 in the energy-efficiency rating	All sustainability features except energy-efficiency positively related to rent levels
Fuerst et al. (2015)	England	Sales	Energy Performance Certificates	+5 for a A/B, +1.8 for C label, −0.7, −0.9 for E, F	Energy premium highest for terraced dwellings and flats
Cajias et al. (2016)	Germany	Rents	Energy Performance Certificates	+0.6-4 for label A to C. Low label implies less liquidity	The energy premium is not confirmed for the largest metropolitan housing markets
Deng et al. (2012)	Singapore	Sales	Green Mark certification	+4-6 for certified buildings	Transaction premium varies with quality of label
Yoshida and Sugiura (2012)	Japan	Sales	Tokyo Green Building Program certification	-12 for certified buildings	Initially green apartments sell at a discount; slower depreciation rate leads to a premium
Zheng et al. (2012)	China	Sales	"Marketing greenness" (Google Green Index)	+17.7 for the greenest dwelling	Properties marketed as green sell at a premium, but resell and re-rent at a discount
Hu et al. (2014)	China	Sales	Willingness to pay Conjoint analysis	Willing to pay up to 1139 yuan/m^2 for efficient homes	Results based on survey data, mainly driven by upper class individuals
Zhang et al. (2016)	China	Sales	Energy Performance Certificates	+ 6.9 for certified dwellings	Analysis based on newly built housing projects
Dastrup et al. (2012)	U.S.	Sales	Solar panels	+3.5-4 for homes with a solar panel	Premium is higher in streets where fewer homes have solar panels installed
Kahn and Kok (2013)	U.S.	Sales	Energy Star, LEED GreenPoint	+2-4 for certified buildings	Certification matters more in hotter climates and in areas with higher energy prices
Bond and Devine (2016)	U.S.	Rents	LEED certificate	+7-9 for certified buildings	Sample consists of multi-family dwellings. LEED premiums in both urban and rural areas

Chapter 2 Research approach

A unique dataset was created based on agreements with large housing associations in four EU countries (the Netherlands, the UK, Sweden, and Germany). For each housing portfolio, the dataset contains dwelling-level energy efficiency measures based on energy performance certificates (i.e. energy label and energy performance index), energy consumption and/or technical components (e.g. glazing, heating, insulation, dwelling types).[4] In addition, each dwelling profile contains its exact address and a set of basic hedonic characteristics (i.e. size, number of rooms, period of construction, last renovation).

To investigate how energy efficiency influences the assessed value of affordable housing, the standard hedonic valuation framework proposed by Rosen (1974) was used.[5] In particular, the analyses in the report use a semi-log hedonic specification, which relate the log of the assessed value (or rent) per dwelling per square meter to its energy efficiency, the building characteristics, and location:

$$V_{i,t} = \alpha_t + \delta_t L_{i,t} + \beta_t X_i + \varepsilon_{i,t} \quad (1)$$

In Equation (1), the dependent variable is the assessed market value V of home i in time period t (specified as the natural logarithm of assessed value per square meter expressed in the local currency). The vector of interest is $L_{i,t}$, containing the information about energy efficiency of dwelling i that is available at the valuation date t. The list of energy efficiency characteristics includes whether the dwelling is labelled at the date of valuation, the Energy Performance Certificate (EPC)[6] label of the dwelling (or corresponding energy performance index), and different technical components that determine the energy efficiency of a dwelling (e.g. whether a dwelling has double glazing, or whether its walls are insulated). The parameter of interest δ_t describes the average differential (in percent) in external valuations attributed to energy efficiency. Last, α_t and β_t are estimated coefficients for the control variables (X_i), and $\varepsilon_{i,t}$ is an error term.

In a first specification $L_{i,t}$ contains only a dummy variable taking the value of one dwelling (i) which obtained a "green" energy label by the date of valuation t, and a value of zero otherwise. In this specification δ_t describes the average premium (in percent) that external valuations attribute to a labelled dwelling relative to non-labelled dwellings in period t. In a second specification of the model, vector $L_{i,t}$ includes a set of binary variables that represent the scores in the energy label, ranging from A to G. In this specification, δ_t describes the average premium (in percent) that external valuations attribute to each energy label in period t. In a final specification, $L_{i,t}$ contains different technical components of dwellings that affect their energy efficiency, such as window or heating system characteristics.[7]

Measuring the link between energy efficiency and assessed value is methodologically challenging. The presence of multiple variables, affecting both the energy efficiency performance of a dwelling and its reported (assessed) value would lead to overestimating the premiums in the assessed values. The academic literature identifies two major sources of variables in this type of analysis: locational attributes and dwelling quality. The location of a

[4] A detailed description of the list of technical and energy components included in the analyses can be found in the sections that present and discuss the analysis per country.
[5] For an overview of the assessed value measures considered in each country see the table in Appendix A.
[6] The assessment of energy performance in the UK is based on the Standard Assessment Procedure (SAP).
[7] The list of components included in this final specification varies across portfolios due to data limitations.

dwelling is a fundamental factor of its assessed valued, and highly energy efficient dwellings might be clustered in certain neighbourhoods (e.g. newly built or affluent neighbourhoods), corrupting our results. The common method in the real estate literature to control for location-specific variables is to include local area fixed effects (specified as dummy variables) in the model. In all model specifications, we include a set of binary variables indicating the dwelling's location, capturing the valuation average effect of each location using postal codes. This approach controls for all time-invariant unobserved characteristics related to the neighbourhood where each dwelling is located.

With regard to dwelling quality, residential hedonic price models include dwelling quality characteristics. These characteristics, such as size, building archetype, year of construction, or number of rooms, are included in the vector of hedonic characteristics X_i in all model specifications. However, this does not entirely rule out the possibility that unobserved quality differences between the houses in our labelled and non-labelled sample and within the different label categories determine the observed valuation differences. For example, building owners might choose to bundle high energy efficiency with other quality characteristics such as nicer kitchens or bathrooms or general cosmetic improvements such as decorative order. Nevertheless, by controlling for quality characteristics and modernizations at the dwelling level as much as we can, we minimize this potential source of biases.

A further complexity in this study is in relation to the valuations used. The portfolios are held for the long-term by social investors who do not generally trade individual units. Therefore, unlike many other studies, the data on value, is based not on transaction prices in the market (although valuers would have been aware of the likely potential sales price in many cases), but on expert opinions of value. In this study, the definition used of 'value' varied between countries (see Appendix A). The analyses are based on over five different bases of assessing value. In particular, in two countries (the Netherlands and Sweden), the measure was an accounting for taxation measure; in Germany, it was an automated model whilst in the UK, three different measures were used in the analysis.

Chapter 3 The Netherlands

A large Dutch affordable housing association provided a large sample of external valuations of their dwelling that were made for taxation purposes. These valuations were made by three different professional valuation organizations holding leading positions in the Dutch property valuation industry.

Description of the Dataset

In all, a sample of 43,809 dwelling valuations was collected for two different years, 2010 and 2015. These years span the period in which most of the empirical literature on this issue has been published. In 2010, there was no academic evidence that sustainability premiums existed; indeed a review of literature by Sayce et al. (2010) had concluded that, within the commercial field, evidence did not exist and that no studies had examined residential. On the other hand, by 2015 there was an emerging academic consensus that energy efficiency and transaction prices were positively linked.

For both these years, the impact of energy labels on rental housing valuations was estimated in the complete sample, by comparing the assessed values of certified dwellings (at different label quality levels) with those of non-certified ones. Thus, the non-certified dwellings were the control sample. The second step in the analysis studies the labelled sample separately. For this analysis, the C-label is set as the reference or comparison group. That allows for comparing valuations of very energy efficient homes (labelled A-B) with homes that are less energy efficient (labelled D-G).

In a robustness check, the proposed hedonic model is estimated for a constant set of dwellings that were not renovated between 2010 and 2015 and that had the same energy label in both years. In that way the polluting effects of house renovations or strategic labelling (e.g. for transaction purposes) are eliminated from the analysis.

Summary Statistics

A large affordable housing body owning approximately 53,000 dwellings in the metropolitan area of Amsterdam provided the valuation set by external valuers to each of these dwellings in 2010 and 2015 for taxation purpose together the exact address and a set of dwelling characteristics. The valuations were assessed by professional valuers working for three different professional RICS-certified companies, each of them with at least 7 years of experience. The dataset also contains the energy performance certificates for each labelled dwelling in the sample. Approximately 34 percent of the dwellings in the Dutch sample have an Energy Performance Certificate. This is above the market penetration of EPCs in the Netherlands. The overwhelming majority of dwellings in the sample had been owned by the social housing institution already well before 2010 and remained in possession through 2015.

Exhibit 2 provides information on the valuation and physical characteristics of the full, labelled and non-labelled samples. The average value per square meter is slightly lower than the average transaction price reported in previous studies for the Dutch affordable housing sector (e.g. Chegut et al. 2016). Simple comparisons indicate that labelled dwellings had a slightly lower value than their non-labelled counterparts. The dwelling type composition of the labelled sample is similar to the composition of the sample of non-labelled dwellings, with most of them being one-level multifamily apartments. The average dwelling in the labelled sample is slightly smaller, and was predominantly built in the 1980s. There are no major differences between samples with regard to renovations; most of the dwellings have not been renovated recently (over 90 percent most of them non-labelled dwellings). For those that have been renovated the average year of renovation is 2008.

Descriptive Statistics

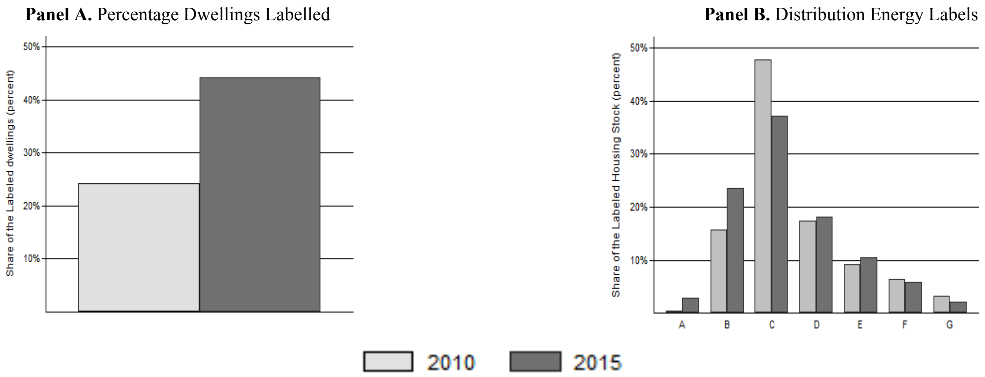
Exhibit 2 Descriptive Statistics in Dutch portfolio

	Total sample	Non-labelled dwellings	Labelled dwellings
Appraised value dwelling			
(euro per square meter)	1,580	1,606	1,543
	(449.20)	(441.60)	(457.80)
Dwelling type			
Multifamily on 1 level	59.00	57.60	61.60
Multi-family split-level	2.17	3.17	0.27
Townhouse corner	10.20	11.10	8.33
Townhouse between	28.40	27.70	29.60
Two under one roof	0.27	0.35	0.13
Detached house	0.02	0.03	0.01
Period of construction			
Pre 1930	12.80	15.70	7.11
1930-1944	4.46	5.08	3.30
1945-1960	18.00	23.00	8.53
1961-1970	12.30	14.14	8.84
1971-1980	9.89	9.89	9.89
1981-1990	25.40	16.90	41.60
1991-2000	12.70	9.10	19.60
After 2000	4.51	6.29	1.11
Building characteristics			
Size (in sqm.)	76.80	76.71	76.93
	(21.72)	(22.09)	(21.18)
Number of rooms	3.37	3.39	3.34
	(0.98)	(0.98)	(0.98)
Renovations			
Dwelling recently renovated	4.69	7.04	0.21
Year last renovation	2008	2009	2008
	(8.27)	(9.40)	(5.66)

Notes: Standard deviations in parentheses. Categories in *"Dwelling type"*, *"Period of construction"* and the variable *"Dwelling recently renovated"* expressed in percentages.

Exhibit 3 displays the distribution of labels in the sample in the two valuation rounds, with Panel A showing the incidence of energy labels in general, and Panel B providing information on the distribution across certification levels. The figure shows an increase in the number of labelled dwellings in the sample, going up from 24 percent in 2010 to almost 44 percent in 2015. It is important to note that most of these dwellings have not been refurbished between 2010 and 2015, as Exhibit 2 shows. The increased use of energy certificates may be an indication of increased awareness of the consequences of dwelling sustainability by the buildings' owner, which may be driven by changing government policy and emphasis on this topic. In addition, there is a significant improvement in energy efficiency, as reflected by the increase in the proportion of A- and B-labelled dwellings (and a decrease in the proportion of C-labelled dwellings) in the 2015 sample compared to 2010. No control exists as to whether there was any increase in accuracy of the labels over this period.

Exhibit 3 Distribution Energy Performance Certificates in Sample



Notes: The graphs display the proportion of dwellings labelled in the sample (Panel A), and the distribution across label categories in the labelled sub-sample (Panel B), both for 2010 and 2015.

Estimating the effect of energy efficiency on valuations for the Netherlands

First, the analysis focuses on the differences in assessed value related to energy efficiency in the complete sample of dwellings. After measuring the relative value of energy labels in the full sample, the sample is restricted to the labelled sample. Finally, in order to explore differences in the external valuation approach towards energy efficiency, the sample is restricted to those dwellings appearing in both valuation rounds in 2010 and 2015, whose energy label does not change, and which experience no renovation in that 5-year period.

Estimations full sample

All specifications presented in this section use the natural logarithm of the assessed value per square meter as the dependent variable. This dependent variable is regressed on an extensive set of hedonic and location characteristics, along with a set of dummy variables describing the years since the last renovation took place in the dwelling.

Exhibit 4 presents the proportion of variation in assessed valuations that the variables included in the model are able to explain. As described by the R-squared in column (1), just the location of dwellings, described by the postcode of the building, is able to explain over 63.6 percent of the variance in the assessed value in 2015.[8] The inclusion of the size of the dwelling, its hedonic characteristics, and energy efficiency increased the explanatory power by 15 percent.

Exhibit 4 Explanatory power of different variables for assessed valuations. Total Sample. (dependent variable: log of assessed value per square meter in 2015)

	(1)	(2)	(3)	(4)

[8] The results are comparable in magnitude for valuations in 2010.

R-squared	**0.636**	**0.698**	**0.765**	**0.783**
Observations	43,035	43,035	42,034	42,034
Postcode Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency	NO	NO	NO	YES

[a] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

Panel B of Exhibit 5 displays differences in valuation across dwelling types. Using "Multifamily one level" apartments as reference level, there are some significant differences in valuation outcomes between 2010 and 2015. For example, the estimation results indicate that the relative assessed values of "Two under one roof" and detached dwellings to "Multifamily one level" were higher in 2015 than they were in 2010.

Exhibit 5 displays the results of our regression analysis of the complete sample using the hedonic model specification presented in Equation (1). Exhibit 5 explores systematic differences in assessed value between labelled and non-labelled samples, after controlling for building characteristics, renovations and location of the dwellings. The reference or comparison group includes those dwellings in the sample that are not labelled at the date of valuation. The results presented in the first two columns of panel A indicate no significant differences in assessed value between labelled and non-labelled dwellings for 2010 or 2015, suggesting that the dwellings' owner did not systematically select high or low value dwellings for energy certification.[9]

The third and fourth columns in panel A in Exhibit 5 analyse the assessed values of the dwellings in the full sample, and includes a dummy for each EPC label category. Dwellings without an energy label are again set as reference or comparison group. Estimation results are provided for both valuation rounds, 2010 and 2015. The table shows significant differences between the 2010 and 2015 valuations with regard to dwellings' energy efficiency levels. Column 3 shows that assessed values for any of the energy label categories did not significantly differ from non-labelled dwelling values in 2010. In contrast, Column 4 displays significant differences in value between highly energy-efficient dwellings and non-labelled dwellings. Dwellings labelled A, B or C were valued significantly higher in 2015 relative to their non-labelled counterparts. The results indicate that an A-labelled affordable dwelling was valued at 7.1 percent higher value, compared to an otherwise similar non-labelled affordable dwelling in 2015. For an average dwelling in the sample, this implies a valuation premium of approximately 8,100 Euros relative to a non-labelled dwelling. Assessed valuation premiums for homes with an EPC label of B and C amount to 5.4 and 3.1 percent respectively. These percentages are in line with those found in the literature.

Panel B of Exhibit 5 displays differences in valuation across dwelling types. Using "Multifamily one level" apartments as reference level, there are some significant differences in valuation outcomes between 2010 and 2015. For example, the estimation results indicate that the relative assessed values of "Two under one roof" and detached dwellings to "Multifamily one level" were higher in 2015 than they were in 2010.

[9] As described in the table notes, asterisks in the regression table indicate the level of the statistical significance of each regression coefficient. See table notes for exact definition of number of asterisks.

Exhibit 5 Assessed Value and Energy Efficiency; Total Sample
(dependent variable: log of assessed value per square meter)

Panel A: Estimation results Energy Performance Certificates

	(1) Year valuation 2010	(2) Year valuation 2015	(3) Year valuation 2010	(4) Year valuation 2015
Dwelling Labelled (1=yes)	-0.004	0.023		
	[0.012]	[0.016]		
Energy label (1=yes)				
Label A			0.004	0.071***
			[0.018]	[0.016]
Label B			0.012	0.054**
			[0.013]	[0.022]
Label C			0.010	0.031**
			[0.009]	[0.015]
Label D			-0.028	0.001
			[0.023]	[0.017]
Label E			-0.016	0.014
			[0.017]	[0.027]
Label F			-0.004	-0.014
			[0.029]	[0.024]
Label G			-0.015	-0.011
			[0.019]	[0.022]
Observations	41,071	42,034	41,071	42,034
R-squared	0.774	0.781	0.775	0.784
Postcode fixed effects	YES	YES	YES	YES
Hedonic Control Variables [a]	YES	YES	YES	YES
Recent modernization controls [b]	YES	YES	YES	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request). Estimation results from coefficients of different dwelling types displayed in panel B.
[a] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[b] The list of modernization controls includes a set of two binary variables indicating whether the dwelling was renovated in the last 5 years, or whether it was renovated between 5 and 10 years before the sample year.

Exhibit 5 Assessed Value and Energy Efficiency; Total Sample
(dependent variable: log of assessed value per square meter)
Panel B: Estimation results dwelling types

	(1) Year valuation 2010	(2) Year valuation 2015	(3) Year valuation 2010	(4) Year valuation 2015
Type of dwelling [a]				
Multi-family split-level	-0.051***	-0.030	-0.051***	-0.031
	[0.017]	[0.023]	[0.017]	[0.022]
Townhouse corner	0.064***	0.081***	0.063***	0.080***
	[0.014]	[0.017]	[0.014]	[0.017]
Townhouse between	0.050***	0.066***	0.049***	0.065***
	[0.013]	[0.017]	[0.013]	[0.016]
Two under one roof	0.027	0.118***	0.025	0.108***
	[0.031]	[0.030]	[0.031]	[0.029]
Detached house	0.029	0.174**	0.028	0.168*
	[0.075]	[0.085]	[0.075]	[0.086]
Observations	41,071	42,034	41,071	42,034
R-squared	0.774	0.781	0.775	0.784
Postcode fixed effects	YES	YES	YES	YES
Hedonic Control Variables [b]	YES	YES	YES	YES
Recent modernization controls [c]	YES	YES	YES	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request).
[a] Default for dwelling type is "Label C."
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[c] The list of modernization controls include a set of two binary variables indicating whether the dwelling was renovated in the last 5 years, or whether it was renovated between 5 and 10 years before the ample year.

Estimations labelled sample

Exhibit 6 presents the results of the analysis for the labelled sample only. Columns 1 and 2 display the results for the analysis exploring valuation differences for the full sub-samples of labelled homes for both sample years: 12,486 dwellings in 2010 and 22,394 dwellings in 2015. For the second comparison, Columns 3 and 4 show the results for exactly the same sub-sample of dwellings in both years, i.e. employing the 2010 sub-sample of labelled dwellings also in 2015. That way, the results are certain to be the reflection of changes in valuation practices, without possible distortions caused by a changing sample due to renovations or selective energy labelling.

Columns 1 and 2 in Exhibit 6 display the estimated coefficients exploring the differences in valuation practices towards energy efficiency in the labelled sample. Relative to label C dwellings, there seems to be no significant value differentials for any EPC label category in 2010. In 2015, B-labelled dwellings show a marginally higher value of 1.9 percent and D-labelled a discount of 2.3 percent.[10] The coefficient for label A is also positive, but very slight, and the coefficients for the F and G labels are negative, but likewise small and not significant statistically.

Exhibit 6 Assessed Value and Energy Performance Certificates; Labelled Sample (dependent variable: log of assessed value per square meter)

	(1) Year valuation 2010	(2) Year valuation 2015	(3) Year valuation 2010	(4) Year valuation 2015
Energy label (1=yes) [a]				
Label A	-0.021	0.017	-0.017	0.065***
	[0.031]	[0.019]	[0.035]	[0.022]
Label B	-0.004	0.019*	-0.000	0.031**
	[0.012]	[0.010]	[0.014]	[0.014]
Label C				
Label D	-0.026	-0.023**	-0.027	-0.037**
	[0.022]	[0.011]	[0.022]	[0.016]
Label E	-0.025	0.005	-0.031	-0.005
	[0.020]	[0.019]	[0.021]	[0.038]
Label F	-0.011	-0.028	-0.020	-0.038
	[0.028]	[0.028]	[0.029]	[0.046]
Label G	-0.031	-0.056	-0.042	-0.070
	[0.031]	[0.041]	[0.031]	[0.051]
Observations	12,486	22,394	12,289	12,289
R-squared	0.833	0.874	0.834	0.879
Postcode fixed effects	YES	YES	YES	YES
Hedonic Control Variables [b]	YES	YES	YES	YES
Recent modernization controls [c]	YES	YES	YES	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request).
[a] Default for dwelling type is "Label C."
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[c] The list of modernization controls include a set of two binary variables indicating whether the dwelling was renovated in the last 5 years, or whether it was renovated between 5 and 10 years before the ample year.

However, when the sample is restricted to those dwellings that have not been renovated, and whose label remain constant between the two valuation rounds in 2010 and 2015 the picture changes. The results in Columns 3 and 4 again show that label levels did not play a role in assessed values in 2010. In 2015, that had changed considerably, with significance at the 95%

[10] We also perform an analysis on the differences in value along the energy performance index. The estimation results indicate no significant differences in value along the energy performance index (estimation results available upon request).

confidence level.. This shows a value premiums for label A and B dwellings, and a discount for label D dwellings, all relative to label C dwellings. The estimation results suggest that label A dwellings are valued 6.5 percent higher than comparable label C dwellings, and the B label is associated with a lower premium of 3.1 percent. D-labelled dwellings have a 3.7 valuation discount with respect to label C dwellings[11]. The discounts are even higher for F- and G-labelled buildings, but these are not statistically significant. Given the label distribution in the sample, this may be due to lack of statistical power, since the number of dwellings with these labels is relatively small in the sample. Overall this suggests that reported values became 'sensitised' to labels during the period 2010-2015.

Regional differences in energy efficiency valuation

Exhibit 7 presents the results of the analysis by different regions. In this part of the analysis, the sample is divided into two subsamples: (1) dwellings located in the city of Amsterdam, and (2) dwellings located in different cities. The estimation results for the sample inside Amsterdam are presented in Columns (1) and (2). In comparison to label-C dwellings, dwellings in Amsterdam with a poorer energy performance where systematically valued lower, both in 2010 and 2015. In 2015, dwellings with an energy label B and A were valued at a premium with respect to those labelled C. In 2015, the premiums associated with A-label and B-label dwellings increased, and so did the discounts for low energy performance dwellings, reaching 20 percent for dwellings having a G label.

The estimation results for the sample outside Amsterdam are presented in Columns (3) and (4). The estimation results show that the only dwellings that were valued at a premium were A-labelled dwellings, and only in 2015. For the rest of dwellings, there were no significant differences in valuation with respect to the reference dwellings – i.e. C-label dwellings. The premiums associated with A-label dwellings inside and outside Amsterdam reflect similar premiums: 7.2 percent outside and 7.7 percent inside Amsterdam.

Energy efficiency valuation by archetype

The last step in the analysis focuses on the differences across dwelling types. The estimation results for the sample of multi-family apartments are presented in Columns (1) and (2) in Exhibit 8. The results show significant differences in valuation of multifamily apartments driven by energy efficiency in both valuation rounds, 2010 and 2015. In 2015, A- and B-labelled apartments were valued at a 6 and 3 percent premium, correspondingly.

The estimation results for the sample of town houses are presented in columns (3) and (4) in Exhibit 8. While valuations of label B, D, E, and F do not reflect any significant differences with respect to C-labelled dwellings, A-labelled dwellings have a significant valuation premium of 17 percent.

[11] We also perform an analysis on the differences in value along the energy performance index. In line with the results for the full sample, there are no significant changes in assessed valuations in 2010 linked to changes in the energy performance index level. The results show some impact of the energy performance index on the 2015 valuation (estimation results available upon request).

Exhibit 7 Assessed Value and Energy Performance Certificates; Labelled Sample; sub-analysis by different regional real estate markets (dependent variable: log of assessed value per square meter)

	Amsterdam		Outside Amsterdam	
	(1)	(2)	(3)	(4)
	Year valuation 2010	Year valuation 2015	Year valuation 2010	Year valuation 2015
Energy label (1=yes) [a]				
Label A	0.073	0.077**	0.020	0.072***
	[0.045]	[0.029]	[0.023]	[0.025]
Label B	0.014	0.029**	0.013	0.008
	[0.016]	[0.014]	[0.015]	[0.013]
Label C				
Label D	-0.050**	-0.131***	-0.007	-0.017
	[0.023]	[0.041]	[0.024]	[0.014]
Label E	-0.054*	-0.140**	-0.045	0.064*
	[0.027]	[0.054]	[0.036]	[0.038]
Label F	-0.059**	-0.164**	-0.041	0.053
	[0.027]	[0.071]	[0.053]	[0.037]
Label G	-0.064**	-0.203**	-0.062	0.070*
	[0.028]	[0.098]	[0.049]	[0.035]
Observations	4,938	4,938	7,351	7,351
R-squared	0.881	0.941	0.780	0.773
Postcode fixed effects	YES	YES	YES	YES
Hedonic Control Variables [a]	YES	YES	YES	YES
Recent modernization controls [b]	YES	YES	YES	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request).
[a] Default for dwelling type is "Label C."
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[c] The list of modernization controls include a set of two binary variables indicating whether the dwelling was renovated in the last 5 years, or whether it was renovated between 5 and 10 years before the ample year.

Exhibit 8 Assessed Value and Energy Performance Certificates; Labelled Sample; sub-analysis by archetype
(dependent variable: log of assessed value per square meter)

	Multifamily apartment		Townhouse	
	(1) Year valuation 2010	(2) Year valuation 2015	(3) Year valuation 2010	(4) Year valuation 2015
Energy label (1=yes) [a]				
Label A	0.001	0.060**	-0.073	0.170***
	[0.039]	[0.026]	[0.062]	[0.037]
Label B	0.012	0.031**	-0.066	-0.070
	[0.012]	[0.014]	[0.071]	[0.044]
Label C				
Label D	-0.058**	-0.059**	0.009	0.004
	[0.023]	[0.025]	[0.010]	[0.008]
Label E	-0.062***	-0.047	-0.027	-0.005
	[0.021]	[0.049]	[0.019]	[0.011]
Label F	-0.061***	-0.070	-0.023	0.029
	[0.021]	[0.060]	[0.030]	[0.018]
Label G	-0.061**	-0.095	-0.051*	0.028
	[0.025]	[0.079]	[0.028]	[0.018]
Observations	7,515	7,515	3,686	3,686
R-squared	0.869	0.916	0.873	0.823
Postcode fixed effects	YES	YES	YES	YES
Hedonic variables controls [a]	YES	YES	YES	YES
Recent modernization controls [b]	YES	YES	YES	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request).
[a] Default for dwelling type is "Label C."
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[c] The list of modernization controls include a set of two binary variables indicating whether the dwelling was renovated in the last 5 years, or whether it was renovated between 5 and 10 years before the ample year.

The impact of energy efficiency on Dutch social housing valuations

The analysis based on a portfolio of a 53,000-unit rental housing portfolio in the Amsterdam area indicate the existence of differences in the valuation approach towards energy efficiency between the sample years 2010 and 2015. The analysis is based on external valuations for tax purposes in 2010 and 2015 by three reputable Dutch firms.

In 2010, the Energy Performance Certificate was not seen to have played any role in reported housing valuations, and that holds for its presence as well as for its level. By 2015, however, that had changed. The level of the Energy Performance Certificate had an impact in rental housing valuations in that year, with the different certificate levels having comparable values as those found in the academic literature for the Dutch transaction market. Results from subsample analyses indicate that these differences are stronger within Amsterdam than outside of the city. Overall this indicates that valuers were reported the presence of some green premium and brown discounting within the housing association stock.

Chapter 4 The United Kingdom

A large sample of external valuations was gathered of individual dwellings owned by three large English social housing providers across the United Kingdom. These three housing portfolios offer a picture of London and smaller markets across England.

The next sections present the characteristics of the three different portfolios in the sample and the results from the analysis exploring the link between energy efficiency and dwelling valuations, based on multiple valuation approaches measures of energy performance. The first analysis is based on the largest housing portfolio in the dataset, belonging to a housing provider with over 150,000 dwellings under management across England. The second analysis is based on dwellings owned by a smaller housing corporation operating in North West England. Finally, some insights regarding the London market are shown, based on a smaller portfolio of just over 200 dwellings.

England

In this section, the analysis of the impact of energy efficiency on building valuation relies on a large sample of dwellings across England owned by a large social housing corporation. For this sample, the assessed values of labelled dwellings are compared with those of non-labelled ones. The non-certified dwellings are the control sample. The second step in the analysis is to study the labelled sample separately. For this analysis, and to enable easy comparison with the results for the other countries, the C-label is set as the reference or comparison group. That allows to compare valuations of very energy efficient homes (labelled B) with homes that are less energy efficient (labelled D-G). It also allows to study the relationship between the energy index – on which the energy labels are based – and the external valuations of rental homes. Finally, this section presents the estimation results regarding the valuation effect of structural dwelling components having to do with energy efficiency (i.e. dwelling archetype, wall cavity, glazing, window frame, boiler characteristics and heating systems).

In each of these settings, the analysis of the relationship between energy efficiency and the assessed market values of affordable housing is based on the standard hedonic pricing model, explained in the research approach section. The energy efficiency of each dwelling in the sample is described based on the Energy Performance Certificates (EPCs) awarded to these dwellings and energy components.

Description Dataset

The dataset is gathered from a large affordable housing association owning approximately 150,000 dwellings across England. The valuations were made primarily to provide information to support corporate loans and were not necessarily on the basis of Market Value, as detailed in the Red Book (2003 and 2008 editions). Instead values were primarily based on cashflow approaches. The dataset also contains the energy performance certificates and structural energy components for each labelled dwelling in the sample. Approximately 25 percent of the dwellings in the sample had an Energy Performance certificate in 2013.[12]

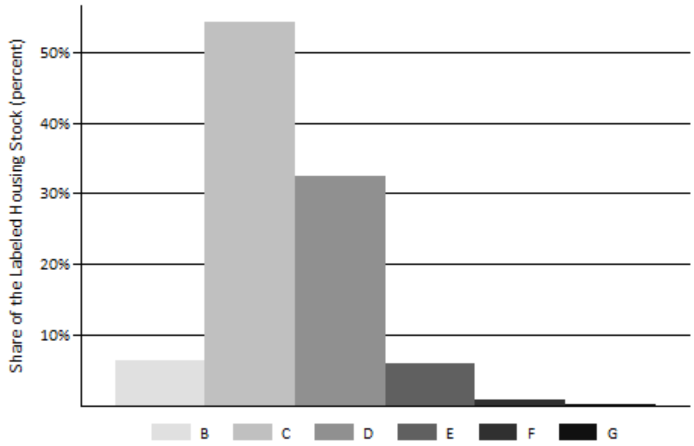
Summary statistics

Exhibit 9 displays the distribution of labels in our sample in the last year of the sample, 2013; most of the dwellings in the sample are C- or D-labelled dwellings, with no dwelling labelled A in the

[12] We have no information regarding the decisions or motivations of the dwelling owner to select dwellings for energy efficiency labelling.

sample.[13] This distribution is similar to the distribution of dwellings appearing in previous studies analysing the value of energy efficiency in the British residential real estate market (Fuerst et al., 2015).

Exhibit 9 Distribution Energy Performance Certificates in Sample



Notes: The graph displays the distribution across label categories in the labelled sub-sample.

Exhibit 10 presents the descriptive statistics of the sample of dwellings considered for the analysis. The average assessed value per square meter is lower than the average transaction price reported in previous studies for the UK housing sector (e.g. Fuerst et. al 2015), which may be caused by the fact that these dwellings are let at rents below market level. In addition, the dwellings in the sample exhibit a poorer energy performance as reflected in the lower number of dwellings with label A and B and a higher proportion of labels C and D than found in the literature (e.g. Fuerst et. al 2015).

Simple comparisons indicate that labelled dwellings were given a slightly lower value than their non-labelled counterparts. The dwelling type breakdown of the labelled sample is similar to the composition of the sample of non-labelled dwellings, with most of them being flats. However, the proportion of flats relative to the remaining dwelling archetypes is higher in the labelled sample.

The average dwelling in the labelled sample is slightly smaller, and is predominantly built in the late 1970s and 1980s. There are no major differences between the labelled and non-labelled samples with respect to the components related to their energy performance – i.e. window frames, glazing, boiler, or heating system. Most of dwellings have cavity walls, double glazing, PVCu window frames, and wall mounted boilers[14].

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13 All dwellings in the sample were labelled between 2006 and 2009.

14 We have no information regarding the technical specifications of these boilers.

Exhibit 10. Descriptive Statistics Portfolio England (year2013)

	(1) All sample	(2) Labelled Dwellings	(3) Non-Labelled Dwellings
Appraised value per square meter [a]	1,081.08	1,062.93	1,087.44
	(843.90)	(859.14)	(838.44)
Dwelling type			
Flat	42	57	37
Detached	1	1	2
Semi Detached	17	10	19
Type Mid Terrace	25	21	27
End Terrace	13	10	14
Type Maisonette	2	1	2
Construction Period			
Pre 1900	6	5	6
1900-1929	11	8	12
1930-1949	4	3	4
1950-1965	3	2	3
1966-1976	13	13	13
1977-1981	17	27	13
1982-1989	12	17	11
1990-1995	20	12	22
Post 1995	15	13	15
Building characteristics			
Size (m^2)	67.18	62.15	68.94
	(22.76)	(22.65)	(22.87)
Number of rooms	6.28	6.01	6.38
	(1.48)	(1.31)	(1.52)
Energy Components			
Wall insulation type			
Cavity	84	87	83
Solid	15	12	16
Timber Frame	1	1	1
Glazing			
Double Glazing	86	87	85
Window Frames			
PVCu	75	79	74
Metal	1	1	1
Timber	24	20	25
Heating system			
Combi boiler	20	19	20
Gas floor boiler	9	11	8
Wall mounted (post 1998)	17	15	18
Wall mounted (pre 1998)	42	38	43
Storage heater old	5	8	4
Storage heater new	7	10	6
Boiler			
Combi boiler	19	18	19
From boiler	60	59	61
Gas back boiler	7	5	7
Immersion	14	19	13

Notes: Standard deviations in parentheses. Categories in *"Dwelling type"*, *"Period of construction"* and the variable *"Energy Components"* expressed in percentages.

[a] The valuations are made following the “Lending Value” approach, as described in the in the Red Book (201).

Estimating the effect of energy efficiency on dwelling valuations for England

The differences in assessed value linked to energy efficiency are first explored in the complete sample of dwellings. After measuring the relative value of energy labels in the full sample, the sample is restricted to the labelled sample. Finally, the analysis focuses on the change in value associated with components related to energy efficiency.

Estimations full sample

All specifications presented in this section use the natural logarithm of the assessed value per square meter as the dependent variable.[15] This dependent variable is regressed on a set of hedonic and location characteristics, along with a set of dummy variables describing the years since the last renovation took place in the dwelling.

As before, the first step is to perform regressions of the model while stepwise introducing the control variables and the energy efficiency indicators to assess the explanatory power of the different sets of variables on the assessed dwelling valuations. As described by the R-squared in column (1) in Exhibit 11, just the location of dwellings, described by the postcode of the building, is able to explain 67 percent of the variance in the assessed value. The inclusion of the size of the dwelling, its hedonic characteristics, and energy efficiency increased the explanatory power by just 6 percent, as described by the difference between columns (4) and (1) to 73%.

Exhibit 11 Explanatory power of different variables for assessed valuations. Total Sample. (dependent variable: log of assessed value per square meter in 2015)

	(1)	(2)	(3)	(4)
R-squared	**0.67**	**0.72**	**0.73**	**0.73**
Observations	14,614	14,212	14,203	12,767
Postcode Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency Components [b]	NO	NO	NO	YES

[a] The hedonic control variables are the natural logarithm of dwelling size in square meters, year of construction, number of rooms, and dwelling type.
[b] The list of energy components includes wall cavity type, window frame characteristics, glazing, boiler and heating system characteristics.

Exhibit 12 displays the results of the regression analysis in the complete sample using the hedonic model specification presented in Equation (1). Column (1) in Exhibit 12 explores systematic differences in assessed value between labelled and non-labelled samples, after controlling for building characteristics, energy components, location of the dwellings,[16] and year of valuation fixed effects.[17] In this specification, non-labelled dwellings are set as reference or comparison groups. The results presented in the first column in Panel A of Exhibit 12 indicate the existence of differences which are significant in statistical terms, in assessed value between labelled and non-labelled dwellings, suggesting that the labelled dwellings were of higher value than the non-labelled ones.[18]

The second and third columns in panel A of Exhibit 12 show the results of the model exploring the assessed values of the dwellings in the full sample, based on the Standard Assessment Procedure energy performance index (SAP index) and a set of dummy variables describing, each being a EPC label category. The SAP is the method employed by the British government for the

[15] For this sample we use "lending value" as valuation method.
[16] For all specifications in the UK we use a set of 3-digit postcode fixed-effects to control for location.
[17] "Year of valuation fixed effects" includes a series of dummy variables taking the value of 1 for the year in which the valuation took place, and zero otherwise. These variables capture general differences in valuation approach for each year.
[18] As described in the table notes, asterisks in the regression table indicate the level of the statistical significance of each regression coefficient. See table notes for exact definition of number of asterisks.

assessment of energy efficiency of dwellings in the UK. Energy performance is based on energy consumption, fuel cost and carbon dioxide emissions.[19] Dwellings without an energy label are again set as reference or comparison group. Column 2 shows that the SAP index is directly linked to the assessed value of the dwelling: we observe higher assessed values for those dwellings having a higher energy performance index. Column 3 shows that these differences are mainly driven by highly energy efficient dwellings (i.e. B- and C-labelled dwellings). A D-label or poorer energy efficiency did was not associated with significantly different value than non-labelled dwellings in our sample. The premium of 6 percent and 2.5 percent associated with B- and C-labelled dwellings, are slightly higher than the premiums based on market transactions reported by Fuerst et al., (2015) – i.e. 5 and 1.8 percent, respectively. It should be noted that in the UK, a D is an average EPC rating, with few buildings other than new builds achieving an A/B rating.

Exhibit 12. Assessed Value and Energy Efficiency; Total Sample

Dependent Variable: log of assessed value per square meter

Panel A: Estimation results Energy Performance Certificates

	(1)	(2)	(3)
Dwelling Labelled (1=yes)	0.016**		
	[0.007]		
Log of Energy Index		0.004**	
		[0.002]	
Energy label (1=yes)			
B			0.060*
			[0.035]
C			0.025***
			[0.008]
D			-0.003
			[0.009]
E			0.006
			[0.013]
F			0.009
			[0.030]
G [b]			-
Observations	12,767	12,767	12,767
R-squared	0.78	0.78	0.79
Year Fixed Effects	YES	YES	YES
Postcode Fixed Effects	YES	YES	YES
Hedonic controls [b]	YES	YES	YES
Energy component controls [c]	YES	YES	YES

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.

Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request). Estimation results from coefficients of energy efficient certificates are displayed in panel A.

[a] "Label-G" dummy excluded from the regression model due to the low number of observations.

[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

[c] The list of energy component controls includes wall cavity type, window frame characteristics, glazing, boiler and heating system characteristics.

[19] For additional information about the construction of the SAP index, please see https://www.gov.uk/guidance/standard-assessment-procedure

Panel B in Exhibit 12 shows differences in valuation across different archetypes. Flats are set as control or reference category. Thus, the coefficients displayed in the table show the average differences in assessed valuation with respect to flats. The results show statistically significant differences in valuation across archetypes. These differences go up to 8.9 percent associated with detached houses, of which there were limited numbers in the sample.

Exhibit 12. Assessed Value and Energy Efficiency; Total Sample

Dependent Variable: log of assessed value per square meter

Panel B: Estimation results Dwelling Types

	(I)
End of terrace	0.059**
	[0.024]
Mid terrace	0.060***
	[0.023]
Maisonette	-0.015
	[0.036]
Semi detached	0.085***
	[0.026]
Detached	0.089**
	[0.037]
Observations	12,767
R-squared	0.78
Year Fixed Effects	YES
Postcode Fixed Effects	YES
Hedonic controls [b]	YES
Energy component controls [c]	YES

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.
Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request). Estimation results from coefficients of energy efficient certificates are displayed in panel A.
[a] "Label-G" dummy excluded from the regression model due to the low number of observations.
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.
[c] The list of energy component controls includes wall cavity type, window frame characteristics, glazing, boiler and heating system characteristics.

Estimations labelled sample

Exhibit 13 presents the results for the analysis for the labelled sample only. Label C dwellings are set as the comparison or reference group. Columns 1 and 2 show the existence of some differences in valuation practices towards energy efficiency. Relative to label C dwellings, there are only assessed value differentials for D-labelled dwellings, which have a 2.8 percent discount.[20] The coefficient for label B is positive, but not significant, and the coefficients for the F and G labels are negative, but not significant either.

[20] We also perform an analysis on the differences in value along the energy performance index. The estimation results indicate no significant differences in value along the energy index (estimation results available upon request).

Exhibit 13 Assessed Value and Energy Performance Certificates; Labelled Sample

Dependent Variable: log of assessed value per square meter

	(1)	**(2)**
Dwelling Labelled (1=yes)		
Log of Energy Index	0.056 [0.041]	
Energy label (1=yes) [a]		
B		0.053 [0.034]
C		
D		-0.028*** [0.010]
E		-0.016 [0.022]
F		-0.013 [0.033]
G [b]		-
Observations	3,102	3,102
R-squared	0.86	0.86
Year Fixed Effects	YES	YES
Postcode Fixed Effects	YES	YES
Hedonic controls [c]	YES	YES
Energy component controls [d]	YES	YES

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

Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request)

[a] Default for dwelling type is "Label C".

[b] "Label-G" dummy excluded from the regression model due to the short number of observations

[c] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

[d] The list of energy component controls includes wall cavity type, window frame characteristics, glazing, boiler and heating system characteristics

Estimations energy components

Exhibit 14 displays the estimation results from the analysis exploring systematic differences in assessed value driven by different dwelling components related to energy efficiency after controlling for building characteristics, location of the dwellings, and differences in valuation across different years. Those dwellings in the sample with cavity wall insulation, PVCu window frames, a wall-mounted/back gas boiler (pre-1998), and domestic water heating from a boiler are set as reference or comparison group. Given the high correlation between energy efficiency components, the model first includes one energy component at a time (Columns (1), (2), (3), (4), and (5) in Exhibit 14) and then all components together (Column (6) in Exhibit 14).

The results indicate statistically significant differences associated to improvements in glazing, showing a 5.2 percent premium associated to going from single to double glazing (see Column (6) in Exhibit 14). The estimation results show no significant differences in the log of assessed value per square meter along any of the remaining components (i.e. walls, heating system, nor water boilers). This finding may have something to do with the much better visibility of double glazing as compared to the other energy-related characteristics of dwellings.

Exhibit 14 Assessed Value and Energy Components; Full Sample

Dependent Variable: log of assessed value per square meter

	(1)	(2)	(3)	(4)	(5)	(6)
Wall Type [a]						
Solid	-0.005					0.006
	[0.029]					[0.032]
Timber frame	0.003					-0.017
	[0.044]					[0.040]
Glazing [b]						
Double Glazing		0.037*				0.052**
		[0.021]				[0.023]
Window frames [c]						
Metal			0.045			0.066
			[0.052]			[0.042]
Timber			0.025			0.019
			[0.021]			[0.021]
Heating System [d]						
Combi boiler				0.004		-0.001
				[0.017]		[0.019]
Floor boiler				0.041		0.033
				[0.051]		[0.056]
Gas wall mounted/back boiler (post 1998)				0.007		0.003
				[0.016]		[0.017]
Storage heater (old)				-0.069		-0.047
				[0.052]		[0.092]
Storage heater (new)				0.049		0.059
				[0.050]		[0.096]
Water boiler [e]						
From gas back boiler system					-0.021	-0.013
					[0.019]	[0.023]
Immersion heater					-0.006	-0.017
					[0.035]	[0.077]
Observations	14,201	14,189	14,184	13,208	13,735	12,767
R-squared	0.78	0.78	0.79	0.79	0.78	0.78
Year Fixed Effects	YES	YES	YES	YES	YES	YES
Postcode Fixed Effects	YES	YES	YES	YES	YES	YES
Hedonic Controls [f]	YES	YES	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, hedonic controls and modernizations omitted due to space limitations (available upon request)

[a] Default for wall type is cavity

[b] Default for glazing is single glazing

[c] Default for window frames is PVCu frames

[d] Default for heating system is "gas wall mounted/back boiler (pre 1998)"

[e] Default for water heating system is "from boiler"

[f] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

Estimations energy efficiency across archetypes

This section presents the results of the analysis exploring the differences in valuation of energy efficiency across archetypes. In particular, Equation (1) is estimated for two different subsamples, flats and non-flat dwellings (i.e. detached, semi-detached, maisonette, mid and end-terrace dwellings).

Columns (1) and (2) in Exhibit 15 display the results for the regression of differences in value driven by energy efficiency components, after controlling for building characteristics, location of the dwellings, and year of valuation fixed effects. Those dwellings in the sample with cavity walls, single glazing, PVCu window frames, gas wall mounted/back boiler (pre 1998)", and water heating from boiler are set as comparison or reference group.

The results show significant differences across archetypes in the value assigned to different components. In particular, while double glazing is associated with a premium of 7.4 percent with respect to single glazed dwellings (Column (1) Exhibit 15), no significant differences are observed in houses (Column (2) Exhibit 15). In addition, while valuation of flats did not attach significant differences to window frames (Column (1) Exhibit 15), in houses the value of metal-framed houses was 12.6 percent higher than those with PVCu window frames (Column (2) Exhibit 15).

Finally, Columns (3) and (4) in Exhibit 15 explore differences in the value of energy labels across different archetypes. Again, label C dwellings are set as comparison or reference group for the two subsamples (i.e. flats and non-flat dwellings). The results show marginally significant differences (at 10 percent level). While for flats there are no significant differences between any label and the reference category, we observe that in the non-flat sample those dwellings that were labelled D have a marginally significant 2.1 percent lower value than C-labelled dwellings.

Exhibit 15 Energy Efficiency by archetypes [flats vs. non-flats]

Dependent Variable: log of assessed value per square meter

	(1) FLATS	(2) NO FLATS	(3) FLATS	(4) NO FLATS
Wall Type [a]				
Solid	-0.027	0.021		
	[0.085]	[0.018]		
Timber frame	-0.079*	-0.012		
	[0.044]	[0.031]		
Glazing [b]				
Double Glazing	0.074**	-0.005		
	[0.032]	[0.030]		
Window frames [c]				
Metal	0.005	0.126***		
	[0.066]	[0.047]		
Timber	0.010	0.032		
	[0.035]	[0.020]		
Heating System [d]				
Combi boiler	-0.026	-0.005		
	[0.031]	[0.016]		
Floor boiler	0.050	-0.040		
	[0.065]	[0.061]		
Gas wall mounted/back boiler (post 1998)	-0.042	0.024*		
	[0.028]	[0.014]		
Storage heater (old)	0.129	-0.045		
	[0.115]	[0.064]		
Storage heater (new)	0.194*	-0.128*		
	[0.116]	[0.066]		
Water boiler [e]				
From gas back boiler system	-0.059	-0.031		
	[0.043]	[0.020]		
Immersion heater	-0.177*	0.017		
	[0.100]	[0.051]		
Energy label (1=yes) [f]				
B			0.046	-0.000
			[0.029]	[0.031]
C				
D			-0.014	-0.021*
			[0.011]	[0.011]
E			-0.014	-0.008
			[0.023]	[0.021]
F			0.017	-0.007
			[0.032]	[0.051]
G			0.070	-0.032
			[0.097]	[0.028]
Observations	5,155	7,612	1,704	1,398
R-squared	0.83	0.80	0.88	0.90
Year Fixed Effects	YES	YES	YES	YES
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [g]	YES	YES	YES	YES

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 .
Coefficients associated with time and locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)
[a] Default for wall type is cavity.
[b] Default for glazing is single glazing.
[c] Default for window frames is PVCu frames
[d] Default for heating system is "gas wall mounted/back boiler (pre 1998)"
[e] Default for water heating system is "from boiler"
[f] Default for dwelling type is "Label C".
[g] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

North West England: Secondary market in the UK

This section presents the analysis of the link between energy efficiency and residential valuations in an urban area in the UK outside London. The dataset includes multiple valuations of a portfolio of a housing provider with 12,000 dwellings operating in North West England. The company's housing portfolio has a mix of flats and houses, and 17 multi-storey apartment blocks.

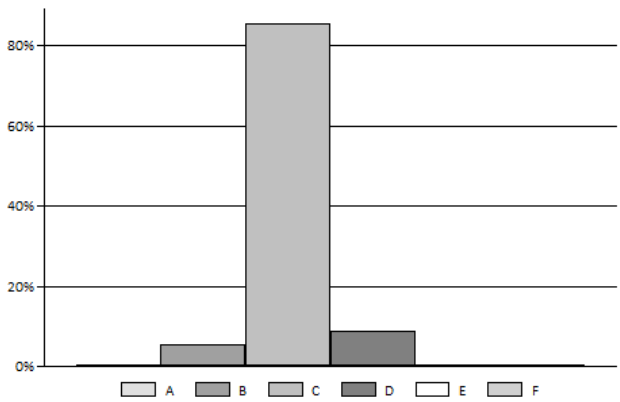
Description dataset

The dataset contains detailed information on dwelling quality characteristics and energy performance of all dwellings in the sample. The measurement of energy efficiency of the dwellings in the sample is based on Standard Assessment Procedure (SAP) and energy labels.[21] At the time of data collection (i.e. 2016), the vast majority of dwellings in the portfolio had filled cavity wall insulation, a gas-fuelled heating system and no alternative source of energy production (i.e. solar panels). The dwelling value is assessed based on the rents and two different valuation approaches: (1) market valuation and (2) Existing Use Value for Social Housing (EUV-SH).[22]

Summary Statistics

The dwellings in the sample exhibit a relatively poor energy performance as reflected in the lower number of dwellings labelled A and B and higher proportion of C and D labels compared to the literature (e.g. Fuerst et. al 2015). The distribution of energy labels indicates the high degree of homogeneity in the portfolio in terms of energy efficiency, with most of the dwellings having label C (see Exhibit 16).

Exhibit 16 Distribution Energy Performance Certificates in North West England Sample



Notes: The graph displays the distribution across label categories in the labelled sub-sample.

Exhibit 17 depicts the characteristics of the labelled and the non-labelled samples. Simple comparisons indicate that labelled dwellings were attached slightly higher rents and values than their non-labelled counterparts. The dwelling type composition of the labelled sample is different to the composition of the sample of non-labelled dwellings. The proportion of "cottage flats" relative to the remaining archetypes is significantly higher in the labelled sample. The average dwelling in the labelled sample is slightly smaller than the average non-labelled dwelling, and is predominantly built in the late 1960s and 1970s.

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21 Energy labels are based on the SAP index, following UK government guidelines (see http://projects.bre.co.uk/sap2005/pdf/SAP-Guidance-document.pdf).
22 The method used for the calculation of the EUV-SH is the discounted cash flow method (Red Book, 2008 and 2014).

Exhibit 17 Descriptive statistics

North West England portfolio

	Total Sample	Non-labelled dwellings	Labelled Dwellings
Value measures			
EUV-SH value per square meter 2012	733.7	639.1	756.5
	(248.9)	(256)	(241.7)
EUV-SH value per square meter 2015	726.1	670.8	739.3
	(174.3)	(161.9	(174.6)
Market value per square meter 2015	1,628	1,469.86	1,666.65
	(569.1)	(620.77)	(549.14)
Rent per square meter 2012	1.7	1.6	1.7
	(0.4)	(0.4)	(0.4)
Rent per square meter 2015	1.7	1.6	1.7
	(0.4)	(0.4)	(0.4)
Building characteristics			
Size	47.5	48.6	47.2
	(9.5)	(7.6)	(9.9)
Rooms	2.2	1.9	2.3
	(0.9)	(1.1)	(0.9)
Construction Period			
Pre-1919	4	6	3
Inter-War	30	11	34
1945-60	5	5	5
1961-70	13	5	15
1971-80	40	54	37
1981-90	7	11	6
1991-2000	1	1	1
2001-13	1	8	0
Dwelling type			
Cottage Flat	17	43	12
Detached	0	0	0
End Terraced	18	11	20
Flat	17	14	17
House	4	2	5
Maisonette	1	0	1
Mid Terrace	8	2	9
Multi Storey	3	3	3
Semi-Detached	13	7	15
Terraced	17	17	17
Walk Up Flat	1	1	1

Notes: Standard deviations in parentheses. Categories in *"Dwelling type"* and *"Period of construction"* expressed in percentages

Estimating the impact of energy efficiency for the West England Portfolio

This section first explores the differences in assessed value linked to energy efficiency in the complete sample of dwellings. After measuring the relative value of energy labels in the full sample, the analysis focuses on the labelled sample.

Estimations full sample: energy efficiency and value

All specifications presented in this section use the natural logarithm of the rents or assessed value per square meter as the dependent variable.[23] This dependent variable is regressed on a set of hedonic and location characteristics. As before, we first assess the explanatory value of the different sets of model components by stepwise introducing them in the regression. As shown by the R-squared in column (1) in Exhibit 18, the location of dwelling alone, described by the postcode of the building, is able to explain 75 percent of the variance in the assessed value. The inclusion of the size of the dwelling and its hedonic characteristics increases the explanatory power by over 20 percent, as described by the difference in R-squared between columns (3) and (1). Finally, energy efficiency has only a marginal contribution in explaining the variation in dwelling values, as reflected in the almost identical values in columns (3) and (4).

Exhibit 18 Explanatory power of different variables for assessed valuations.
Total portfolio in North West England.
(Dependent variable: log of assessed EUV-SH value per square meter in 2015)

	(1)	(2)	(3)	(4)
R-squared	**0.758**	**0.788**	**0.983**	**0.988**
Observations	5,286	5,286	5,286	4,693
Postcode Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency	NO	NO	NO	YES

[a] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

Exhibit 19 displays the results of the regression analysis in the complete sample, using the hedonic model specification presented in Equation (1). Column (1), (4) and (7) in Exhibit 19 show systematic differences in assessed value (EUV-SH and market value) between labelled and non-labelled samples, after controlling for building characteristics, energy components, as well as location of the dwellings.[24] In all analyses, the results for EUV-SH are shown for two separate years, 2012 and 2015. We set as reference or comparison group those dwellings in the sample that are not labelled at the date of valuation. The results presented in columns (1), (4) and (7) in Exhibit 19 indicate the absence of differences in assessed value between labelled and non-labelled dwellings in EUV-SH or market value for any of the valuation years.[25] Thus, the labelled (83.62 percent) and non-labelled (16.38 percent) dwellings obtained comparable valuations in all value measures considered in the analysis.

Columns (2), (5) and (8) in Exhibit 19 focus on the labelled sample to explore the existence of potential changes in assessed valuation driven by energy efficiency. The energy efficiency of dwellings is measured by the natural logarithm of the Standard Assessment Procedure energy performance (SAP) index, which assigns a higher index to dwellings with higher energy performance. The results suggest that there are no significant differences in dwellings' assessed

[23] For this sample, we use EUV-SH and market value as the basis for the valuations.

[24] We included for all specifications in the UK a set of 3-digit postcode fixed-effects.

[25] As described in table notes, asterisks in the regression table indicate the level of the statistical significance of each regression coefficient. See table notes for exact definition of number of asterisks.

values driven by energy performance, as reflected by the non-significant coefficient associated with the SAP index parameter.

Columns (3), (6) and (9) in Exhibit 19 display the estimation results in the labelled sample, setting label C dwellings as comparison or reference group in our analysis. The estimation results using the natural logarithm of the assessed value per square meter based on EUV-SH as outcome indicate changes in the approach towards energy efficiency over time. While there are no statistically significant differences between label C dwellings and any labels in 2012 (columns (3) in Exhibit 19), the results indicate the existence of a brown discount in EUV-SH values in 2015. In particular, dwellings with the label D, E or F were attached 0.4 percent lower EUV-SH value than otherwise comparable label C dwellings. Similarly, dwellings with poor energy performance (i.e. label D, E or F) obtained 1.74 percent lower assessed market values in 2015 than otherwise comparable label C dwellings (column (9)).

Exhibit 19 Assessed Value and Energy Efficiency Indexes.

Full portfolio in North West England.

(Dependent variable: log of EUV-SH and market value per square meter)

	(1) EUV Value 2012	(2) EUV Value 2012	(3) EUV Value 2012	(4) EUV Value 2015	(5) EUV Value 2015	(6) EUV Value 2015	(7) Market Value 2015	(8) Market Value 2015	(9) Market Value 2015
Dwelling Labelled (1=Yes)	0.000			-0.00761			-0.0316		
	(0.004)			(0.00434)			(0.0165)		
Ln (SAP Score)		-0.0489			-0.00567			-0.0351	
		(0.108)			(0.00893)			(0.0510)	
Energy Label (1=yes) [a]									
A-B			-0.00397			0.00239			0.00889
			(0.0212)			(0.00304)			(0.0152)
C									
D-E-F			-0.00231			-0.004**			-0.0174**
			(0.00984)			(0.00134)			(0.00617)
Observations	6,185	7,568	6,185	6,186	7,569	6,186	6,186	7,569	6,186
R-squared	0.980	0.982	0.980	0.994	0.992	0.994	0.947	0.941	0.947
Postcode Fixed Effects	YES	YES	YES	YES	YES	YES	YES	YES	YES
Hedonic Controls [g]	YES	YES	YES	YES	YES	YES	YES	YES	YES

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
Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)
[a] Default for dwelling type is "Label C".

Estimations full sample: energy efficiency and rents

This section presents the analysis exploring the link between rents and energy efficiency, as a potential source of change in valuations. The analysis is based on Equation (1), using the natural logarithm of rents per square meter in 2012 and 2015 as dependent variables.

Exhibit 20 shows the estimation results linking energy efficiency to dwelling valuations. Columns (1) in Exhibit 20 explores differences in rents between the labelled and non-labelled sample. The estimated coefficients indicate no significant differences between the two subsamples; therefore, there is no indication of higher rents in the labelled sample. Column (2) in Exhibit 20 displays the estimation results for the model linking the rental prices of dwellings to their values in the SAP index, as a measure of energy efficiency. The results show no significant differences in rents along the SAP index. Thus, within the labelled sample we see no differences in rents related to the SAP index. Similarly, column (3) in Exhibit 20 shows the analysis of differences in rents across energy labels. The results indicate no significant differences in rents between label C and the average rents of the remaining labels. Thus, the results indicate that the changes in assessed value appearing in Exhibit 19 do not seem to be determined by changes in rents to any noticeable degree, if at all. The differences in assessed value we observe in that table must therefore come from other factors, like the discount rate applied to the cash flow. This might indicate that dwellings which are above average in terms of energy efficiency may be regarded as less risky investments.

Exhibit 20 Rents and Energy Efficiency Indexes.
Full portfolio in North West England.
(Dependent variable: log of rents per square meter).

	(1) Rent 2015	(2) Rent 2015	(3) Rent 2015
Dwelling Labelled (1=Yes)	-0.0159		
	(0.0103)		
Log of SAP Score		0.0675	
		-0.0938	
Energy Label (1=yes) [a]			
A-B			0.0204
			(0.0185)
C			
D-E-F			-0.0117
			(0.009)
Observations	6,186	7,569	6,186
R-squared	0.971	0.968	0.971
Postcode Fixed Effects	YES	YES	YES
Hedonic Controls [b]	YES	YES	YES

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.
Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)
[a] Default for dwelling type is "Label C".
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

Estimations energy efficiency across archetypes

Finally, this subsection presents the differences in valuation that may be related to energy efficiency characteristics across dwelling archetypes. In particular, Equation (1) is estimated for two different subsamples, flats (i.e. flats and cottage flats) and non-flat dwellings (i.e. detached, semi-detached, maisonette, mid and end-terrace dwellings).

Panel A in Exhibit 21 shows the estimation results linking energy efficiency to EUV-SH and market value for the subsample of flats, and Panel B in Exhibit 21 shows the estimation results for the subsample excluding flats. The estimation results indicate that flats command a discount for dwellings with poor energy performance. The results indicate that flats with an energy label D, E, or F were assigned 0.6 percent and 3.6 percent lower 2015 EUV-SH and market values than otherwise comparable C-labelled dwellings.

On the other hand, the estimation results from the analysis excluding flats from the sample (Panel B in Exhibit 21) indicate that the valuation discounts for dwellings with poor energy efficiency are lower in magnitude than in the flat subsample and not significantly different from 0 at the 5 percent significance level.

In sum, when the total sample is divided in flats and houses, the estimation results suggest that the discounts for poor energy performance (i.e. Label D, E or F) appear to be higher in flats than in single family housing valuations.

Exhibit 21 Assessed Value and Energy Efficiency Indexes in North West England.

(Dependent variable: log of EUV-SH and market value per square meter).

Panel A: Only flats in the sample.

	(1) 2015 EUV Value	(2) 2015 EUV Value	(3) 2015 Market Value	(4) 2015 Market Value
Ln (SAP Score)	0.0474*		0.286	
	(0.0239)		(0.150)	
Energy Label (1=yes) [a]				
A-B		-0.001		-0.003
		(0.00373)		(0.0214)
C				
D-E-F		-0.006**		-0.036**
		(0.002)		(0.015)
Observations	1,493	1,493	1,493	1,493
R-squared	0.996	0.996	0.876	0.873
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [b]	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

[a] Default for dwelling type is “Label C”.

[b] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type

Exhibit 21 Assessed Value and Energy Efficiency Indexes North West England.
(Dependent variable: log of EUV-SH and market value per square meter).
Panel B: Excluding flats from the sample.

VARIABLES	(3) 2015 EUV Value	(4) 2015 EUV Value	(5) 2015 Market Value	(6) 2015 Market Value
Ln (SAP Score)	-0.0196		-0.135	
	(0.0283)		(0.155)	
Energy Label (1=yes) [a]				
A-B [b]		-		-
C				
D-E-F		-0.00401*		-0.0178
		(0.00206)		(0.00952)
Observations	4,693	4,693	4,693	4,693
R-squared	0.988	0.988	0.919	0.919
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [c]	YES	YES	YES	YES

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. Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request).

[a] Default for dwelling type is “Label C”.

[b] Coefficients associated with label A and label B dwellings excluded from estimation due to insufficient number of dwellings with those labels in the estimation sample.

[c] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

London: UK's Capital

This section presents the analysis of the link between energy efficiency and residential valuations in London. The dataset contains multiple valuations of a housing portfolio of over 200 dwellings.

Description dataset

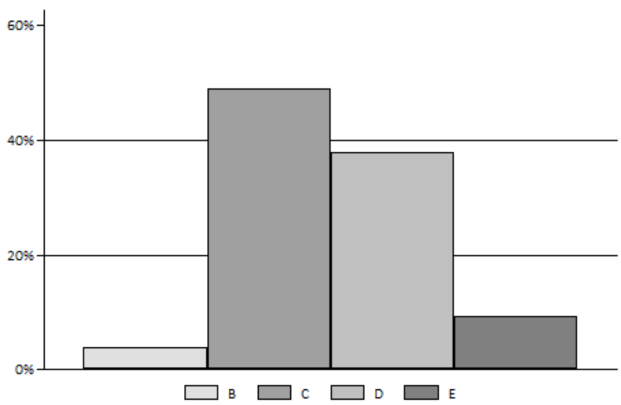
The dataset contains detailed information on dwelling quality characteristics and the energy performance of the dwellings in the portfolio. In addition, different value measures are collected for each dwelling. In particular, the dataset contains the purchase price and the value of the dwelling as assessed by external valuers on the basis of Market Value in 2015 and 2016.

The energy efficiency of the dwellings in our analyses is based on EPC labels.[26] At the time of data collection (i.e. 2017), most of the dwellings in the portfolio have double glazed windows (83 percent), and their heating systems are gas fuelled (73 percent).

Summary Statistics

The dwellings in the London sample exhibit a poorer energy performance on average than those shown in previous studies of the UK residential market, as reflected in the lower number of dwellings having label A and B and the higher proportion of dwellings with label C and D (e.g. Fuerst et. al 2015). The distribution of labels in the portfolio is comparable to the distribution of labels in the whole English territory and higher in energy performance than the portfolio concentrated in North West England.

Exhibit 22 Distribution Energy Performance Certificates in Sample



Notes: The graph displays the distribution across label categories in the complete sample.

Exhibit 23 describes the characteristics of the London housing portfolio considered for the analysis. Column (1) in Exhibit 23 shows that the average market value in 2015 and 2016 of the sample is significantly higher than the average market value attached to the portfolio in North West England (£3,751 per square meter in London vs. £1,628 per square meter in North West). The average purchase price is significantly lower than the average asked price in the UK market, as reported by Fuerst et al. (2013) (£197,448 versus £302,672).[27]

26 Energy labels based on the SAP index following UK government guidelines (see http://projects.bre.co.uk/sap2005/pdf/SAP-Guidance-document.pdf).

27 Average price in the UK market extracted from "Advertised sales price (all properties)" in Table 2 in Fuerst et al. (2013).

The summary statistics from the labelled sample shows that label B and label C dwellings have been constructed more recently than the rest of the dwellings in the sample. Furthermore, label B dwellings tend to be significantly larger and all of them are low-rise properties. Finally, low-rise dwellings (single family housing) are the predominant dwelling type in the sample and in each of the subsamples.

Exhibit 23 Descriptive statistics by EPC label in London portfolio

	All sample (1)	EPC label B (2)	C (3)	D (4)	E (5)
Number of Dwellings	259	10	127	98	24
Value					
Market value per square meter in 2015	3,751	3,001	3,685	3,942	3,752
	(1,055)	(1,336)	(1,016)	(1,027)	(1,145)
Market value per square meter in 2016	4,181	3,294	4,124	4,310	4,178
	(1,009)	(1,533)	(991.3)	(989.2)	(925.0)
Price per square meter	3,539	2,279	3,554	3,652	3,380
	(928.6)	(701.2)	(908.7)	(960.8)	(632.8)
Property Characteristics					
Construction year	1967	2000	1972	1961	1957
	(27.00)	(17.16)	(27.62)	(24.73)	(21.44)
Size (in m2)	57.30	86.40	55.64	56.81	58.13
	(13.02)	(24.92)	(13.01)	(10.43)	(7.411)
Dwelling Type					
Flat	10	0	2	6	17
Freehold house	3	0	3	4	0
Low rise	88	100	91	86	83
Med-high rise	3	0	4	4	0

Notes: Standard deviations in parentheses. Categories in *"Dwelling type"* expressed in percentages.

Estimating the impact of energy efficiency for London

All specifications presented in this section use the natural logarithm of the purchase price or assessed value per square meter as the dependent variable.[28] This dependent variable is regressed on a set of hedonic and location characteristics, along with a set of dummy variables describing the year that the last major renovation took place in the dwelling.

Exhibit 24 presents the proportion of variation in assessed value that the explanatory variables included in the model are able to explain. As described by the R-squared in column (1), the location of the dwellings alone, described by the 3-digit postcode of the property, is able to explain 34 percent of the variance in the assessed value. The inclusion of the size of the dwelling increases the explanatory power of the model by 43 percent, its hedonic characteristics, and energy efficiency increase the explanatory power by 10 percent and 1 percent, correspondingly (columns (2) and (3) and (4) in Exhibit 24). The remaining 12 percent is unexplained.

[28] For this sample, "market value" is used as valuation method.

Exhibit 24 Explanatory power of different variables for assessed valuations.
Total portfolio in North West England.
(Dependent variable: log of assessed EUV-SH value per square meter in 2015)

	(1)	(2)	(3)	(4)
R-squared	**0.340**	**0.773**	**0.879**	**0.882**
Observations	161	160	144	144
Postcode Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency	NO	NO	NO	YES

[a] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

Exhibit 25 describes the impact of energy efficiency on assessed value and purchase price for the complete sample.[29] The analysis is based on Equation (1), using the natural logarithm of purchase price and market value per square meter (in 2015 and 2016) as dependent variables. The results suggest no differences in value driven by energy efficiency in 2015 or 2016 (columns (1) and (2) in Exhibit 25). On the other hand, when exploring the appreciation of dwellings in the portfolio, computed as the differences in dwelling value between 2016 and 2015, the results suggest the existence of a higher depreciation (or lower appreciation) of dwellings with label D and label E with respect to label C dwellings (column (3) in Exhibit 25).[30] However, these results should be interpreted with caution. First, the statistical significance levels of the coefficients are quite low (10 percent). Second, the London sample contains only a small number of dwellings, with a high concentration of label C dwellings. Thus, these results may be caused by a few outliers.

Exhibit 25 Assessed Value, purchase price, and Energy Efficiency Indexes in London portfolio
(Dependent variable: log of market value and purchase price per square meter).

	(1) Market Valuation 2015	(2) Market Valuation 2016	(3) Dif. Valuation 2016-2015
Energy Label (1=yes)[a]			
B	0.0110	0.00154	-0.177
	(0.0555)	(0.0346)	(0.199)
C			
D-E	0.0250	-0.0333	-0.235*
	(0.0395)	(0.0220)	(0.118)
Observations	71	144	85
R-squared	0.894	0.882	0.265
Postcode Fixed Effects	YES	YES	YES
Hedonic Controls [b]	YES	YES	NO
Year Fixed Effects	NO	NO	NO
Renovation Year	YES	YES	YES

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. Coefficients associated with locational and time fixed effects, and hedonic controls, and renovation year omitted due to space limitations (available upon request).
[a] Default for dwelling type is "Label C".
[b] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of rooms, and dwelling type.

[29] All dwellings in the London portfolio are labelled.
[30] It is worth noting that the coefficient associated with label D and E dwellings in column (3) and (4) in Exhibit 26 are not significant at the 5% level (only at the 10% level).

The impact of energy efficiency on UK social housing valuations

This section presents an overview of the main results of the analysis of the three different portfolios considered for the UK. These three portfolios include a relatively small sample of dwellings in London, and two larger samples of dwellings across England.

When focusing on the labelled sample of dwellings, the estimation results suggest the presence of a brown discount in the assessed social housing values in the English market, as reflected by the significantly lower valuations attached to D-labelled dwellings with respect to C-labelled dwellings. The results hold when focusing on a smaller portfolio concentrated in an urban area in North West England. The analysis of the London sample shows no significant differences. However, it is worth noting that the small number of dwellings in the portfolio together with the high concentration of label C dwellings reduces the statistical power of our test, and therefore the probability of detecting value changes across labels. It may also be pertinent that in London during the study period there was an extreme shortfall of supply against demand; therefore, following the findings of other studies, the market conditions would be unlikely to show differentiation on the grounds of energy efficiency.

We find evidence supporting the existence of differences in approach in North West England between 2012 and 2015. While there is no difference in value across the different energy labels in 2012, the analysis for 2015 indicate initial brown discounts associated with dwellings with energy label D, E and F. The brown discounts are apparent in both of the two valuation principles considered in the analysis: EUV-SH and Market Value. The analysis of rents shows no differences across energy labels, suggesting that the change we find in assessed values is not driven by rental cash flows.

Finally, the results of the analyses of the salience of energy-related dwelling components like heating systems and insulation suggest the existence of differences in assessed value related to windows. In particular, at a high level of statistical significance confidence, those flats with double glazing were attached higher values than those with single glazing.

Chapter 5 Sweden

This section presents the results for Sweden. The dataset is provided by a large social housing provider operating in Stockholm. The valuations considered for the analysis are made by professional external valuers for tax and market valuation purposes.

Description Dataset

In all, the dataset contains the rents and assessed values of 7,886 dwellings. For each dwelling in the portfolio, the natural logarithms of the assessed market value and tax value per square meter are computed. In addition, the dataset contains a set of hedonic characteristics including the year of construction, size, number of rooms, maintenance costs per square meter and the major last renovation completed in the dwelling.

The analysis of the impact of energy performance on rental housing rents and valuations is based on Equation (1). In particular, the analysis explores differences in valuations in low- and high-energy consuming buildings (based on actual heating and electricity consumption). The subsequent analysis focuses on the impact of different energy components on dwellings' assessed values. All of the dwellings are flats, and almost all of these are connected to the district heating system (98.22 percent) and do not have any alternative source of energy generation (93.42 percent).[31]

Summary Statistics

Exhibit 26 provides a statistical description of the Swedish portfolio considered for the analysis. The assessed market value per square meter in our sample is slightly higher than those included in the study of the impact of energy efficiency on transaction prices by Cerin et al. (2014) (i.e. 16,071 SEK in our sample versus 15,520 SEK in theirs).[32] Moreover, the dwellings are significantly smaller than those considered in the study by Cerin et al. (2014). The portfolio is composed of dwellings built over the current and previous century – with construction years ranging from the 1920s to 2016.

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31 Approximately 4 percent of dwellings in the portfolio have photo voltaic panels, and around 2 percent have a solar water heating system in place.

32 The transaction price per square meter was extracted from Table 2 "Descriptive statistics and correlations" in Cerin et al. (2014).

Exhibit 26. Descriptive Statistics in Sweden.

	(1)
Rent levels	
Rent Square per square meter 2015	1224.68
	(333.67)
Rent Square per square meter 2016	1134.33
	(249.30)
Value measures (in SEK)	
Taxation value per square meter 2015	16,071
	6,825
Taxation value per square meter 2016	16,212
	6,690
Market value per square meter 2015	26,516
	10,245
Market value per square meter 2016	34,765
	12,705
Energy consumption (in SEK)	
Electricity kwh per square meter 2015	18.41
	10.00
Electricity kwh per square meter 2016	19.06
	10.74
Heating cost per square meter 2015	112.57
	41.82
Heating cost per square meter 2016	106.32
	40.36
Dwelling Characteristics	
Maintenance cost per square meter (in SEK)	154.7
	69.02
Size	70.42
	22.22
Number rooms	2.512
	1.080
Construction period	
Pre 1936	21
1937-1958	20
1959-1981	20
1982-1993	20
1994-2016	19

Notes: Standard deviations in parentheses. Categories in *"Period of construction"* expressed in percentages

Estimating the impact of energy efficiency in Sweden

All specifications presented in this section use the natural logarithm of the rents or the assessed market value per square meter as the dependent variable.[33] This dependent variable is regressed on a set of hedonic and location characteristics, along with a set of dummy variables describing the year that the last major renovation took place in the dwelling.

Energy efficiency and assessed value

As before, we start our regression analysis with an assessment of the explanatory power of the different model components. Exhibit 27 presents the proportion of variation in assessed value that the different sets of explanatory variables are able to explain. As described by the R-squared in column (1), the location of dwellings alone, here described by the 3-digit postcode of the property, is able to explain a whopping 94 percent of the variance in the assessed value. So more than anywhere else in this study, valuation in the Stockholm rental housing market seems to be determined by the old adage "location, location, location."

The inclusion of the size and the other hedonic characteristics of the dwelling increases the explanatory power of the model by 0.2 percent, and that also holds for the energy efficiency information (columns (2), (3) and (4) in Exhibit 27). These results indicate that the overriding determinant of the assessed market value in our Swedish sample is the location of the dwelling, leaving a very marginal contribution in valuation for any other characteristics of the dwelling – including energy efficiency.[34]

Exhibit 27 Explanatory power of different variables for assessed valuations in 2016. Total Sample. (Dependent variable: log of assessed market value per square meter in 2016)

	(1)	(2)	(3)	(4)
R-squared	**0.947**	**0.947**	**0.949**	**0.951**
Observations	7,809	7,809	7,809	7,655
Postcode Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency	NO	NO	NO	YES

[a] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction and number of rooms.

Exhibit 28 shows the estimated coefficients of Equation (1), linking dwelling energy performance to its value as assessed by external valuers. The energy performance of the dwellings is assessed based on the property's energy-related components and its energy consumption – measured by the natural logarithm of heating and electricity costs per square meter. Finally, the analysis focuses on energy-related components. In particular, it considers changes in value linked to window-related characteristics (i.e. glazing and window frames).[35]

Columns (1) and (2) in Exhibit 28 show the impact of window characteristics on the assessed market value. While the results indicate no difference in valuation driven by window frame materials, the results indicate that those dwellings with triple glazing were valued at a very slightly higher level than those with double glazing (set in the analysis as reference group): we find an assessed market value of 0.33 percent higher than otherwise comparable dwellings with double glazed windows.

33 For this sample "market value" and "taxation value" are used as valuation methods.

34 Estimation results for 2015 are similar to those in 2016 in magnitude and sign. The 2015 results are excluded from the tables due to space limitations (available upon request).

35 The exclusion of other energy related components from the analysis is due to the lack of differences in the other energy components across dwellings in the portfolio (e.g. over 98 percent of dwellings are connected to district heating).

Columns (3) to (4) in Exhibit 28 show the results estimating the impact of energy consumption on dwellings' assessed market values. The results suggest that energy efficiency played a significant role in assessed valuations. In particular, Column (3) in Exhibit 28 suggests the existence of a significantly negative link between log of heating cost per square meter of a dwelling and its assessed market value. Specifically, the estimation results describe a 1 percent increase in heating costs per square meter was associated with a 0.3 percent lower value in 2016 (column (3) in Exhibit 28). The estimated coefficients associated with the electricity consumption per square meter indicate no significant impact on external market valuations (column (4)).

Exhibit 28 Assessed Market Value and Energy Efficiency Components and Energy Consumption; Full Sample

(Dependent variable: log of assessed market value per square meter)

	(1) Market Value 2016	(2) Market Value 2016	(3) Market Value 2016	(4) Market Value 2016
Energy components				
Window frame wood (1=yes) [a]	-0.0790			
	(0.0902)			
Window glazing triple (1=yes) [b]		0.00335**		
		(0.00154)		
Energy Consumption				
Log heating cost per square meter			-0.342**	
			(0.156)	
Log electricity cost per square meter				-0.306
				(0.235)
Observations	6,036	3,240	7,809	7,655
R-squared	0.992	0.990	0.951	0.951
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [a]	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

[a] The reference group of dwellings are those with aluminium frames.

[b] The reference group of dwellings are double-glazed.

[c] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, and number of rooms.

Exhibit 29 presents the estimated coefficients of Equation (1) linking the energy performance of dwellings to their taxation value, as assessed by external valuers. In each of the estimations, we use the natural logarithm of assessed taxation value per square meter as dependent variable. The results indicate the existence of differences in approach towards energy efficiency with the market valuation approach. In the analysis of taxation value, we observe no significant differences in valuation linked to energy consumption (heating and electricity) or to the type of glazing (columns (2) to (4) in Exhibit 29). On the other hand, the estimation results indicate the existence of a significant impact of window frames in the final taxation value assessed by external valuers (column (1) in Exhibit 29). In particular, dwellings with wooden window frames were assessed a taxation value 4.5 percent higher than otherwise comparable dwellings with metal window frames (set in the analysis as the reference group).

Exhibit 29 Assessed Taxation Value and Energy Efficiency Components and Energy Consumption; Full Sample

(Dependent variable: log of assessed taxation value per square meter)

	(1) Taxation Value 2016	(2) Taxation Value 2016	(3) Taxation Value 2016	(4) Taxation Value 2016
Energy components				
Window frame wood (1=yes)	0.0472***			
	(0.0121)			
Window glazing triple (1=yes)		0.00456		
		(0.00362)		
Energy Consumption				
Log heating cost per square meter			0.0413	
			(0.0380)	
Log electricity cost per square meter				-0.00981
				(0.0376)
Observations	5,689	3,076	7,462	7,308
R-squared	0.986	0.978	0.988	0.987
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [a]	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

[a] The reference group of dwellings are those with aluminium frames.

[b] The reference group of dwellings are double-glazed.

[c] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, and number of rooms

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Energy efficiency and rents

The final step of the analysis for Sweden looks at changes in rents associated with energy efficiency, since rental cash flows are a key component in the valuation of rental homes. Exhibit 30 presents the estimated coefficients of Equation (1) linking the energy performance of dwellings to their rents per square meter. In each of the estimations, the natural logarithm of rent per square meter is used as dependent variable.

Columns (1) and (2) link different window characteristics to the rents per square meter. Column (1) in Exhibit 30 shows the estimated coefficient of the regression model linking the window frame material to the property rents. The estimated coefficients show no significant differences in rents driven by differences in window frame materials (columns (1) in Exhibit 30).

The results presented in Column (3) and (4) in Exhibit 30 indicate that those dwellings with triple glazing were rented at a small premium. In particular, those dwellings with triple glazing were rented in 2016 at 0.14 percent higher rents than otherwise comparable dwellings.

Columns (3) and (4) explore the connection between energy consumption and rental prices. The results indicate the existence a positive link between energy performance, measured by a lower energy consumption, and rents. Column (3) presents the connection between rental prices and heating costs. The estimated coefficients indicate that dwellings with higher heating costs were rented at significantly lower rents in 2016. In particular, the results suggest that a 1 percent increase in annual heating costs per square meter is associated with a 0.14 percent drop in rents (column (3) in Exhibit 30). The analysis for electricity consumption shows a similar pattern. The estimated coefficients indicate that those dwellings with higher electricity costs were rented at significantly lower rents. In particular, the results suggest that a 1 percent increase in annual electricity costs per square meter is associated with a 0.18 percent drop in rents (column (4) in Exhibit 30). However, the electricity effects are statistically weaker, since they are only significant at the 10% level.

It is worth noting that while the results from the market valuations and rents are highly aligned, the magnitude of the estimated coefficients associated with energy components and energy consumption in the rent analysis tend to be smaller in magnitude. These differences suggest that the impact of energy efficiency on rents is not fully reflected in rent levels, indicating the existence of other factors affecting assessed market values of dwellings beyond rents.

Exhibit 30 Rents and Energy Efficiency Components and Energy Consumption; Full Sample

(Dependent variable: log of rents per square meter)

	(1) Rents 2016	(2) Rents 2016	(3) Rents 2016	(4) Rents 2016
Energy components				
Window frame wood (1=yes)	0.00187 (0.047)			
Window glazing triple (1=yes)		0.0014** (0.0006)		
Energy Consumption				
Log heating cost per square meter			-0.135** (0.0665)	
Log electricity cost per square meter				-0.177* (0.0898)
Observations	6,036	3,240	7,809	7,655
R-squared	0.992	0.988	0.978	0.977
Postcode Fixed Effects	YES	YES	YES	YES
Hedonic Controls [a]	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

a The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, and number of rooms.

The impact of energy efficiency on Swedish social housing valuations

For Sweden, the analysis of the effect of energy efficiency on assessed valuations is based on a large sample of over 7,000 external valuations of individual dwellings owned by a large Swedish social housing provider operating in Stockholm. In the analysis, the energy performance of dwellings, measured by actual energy costs and the presence of specific energy-related structural dwelling components, is linked to market and taxation values, assessed by external valuers. In addition, the link between energy efficiency and rents is explored, as a key channel for determining dwelling value.

The results suggest statistically significant differences in value associated with energy efficiency. In particular, we find small premiums associated with energy-efficiency components (i.e. triple glazing) and lower energy consumption (i.e. lower heating costs). When analysing the rents paid on the dwellings in the portfolio, similar patterns emerge in terms of coefficients' sign and significance, but with a lower magnitude.

Chapter 6 Germany

This section presents the results for the analysis of energy efficiency on assessed rental housing value in Germany. The analysis is based on a large sample of external valuations of hundreds of multifamily houses owned by a large German social housing provider operating in the metropolitan area of Berlin. These valuations were based on automated valuation discounted cash flow techniques.

Description Dataset

In all, the sample contains 56,689 dwellings clustered in 1,550 properties (i.e. blocks). The housing provider provided valuations for two years, 2014 and 2016, at the property (or block) level. These valuations are the outcome of an automated valuation discounted cash flow (DCF) valuation exercise. In addition to the final value of the dwelling, the dataset contains information on the level of rents, long term vacancy levels, as well as maintenance costs in the property. These three indicators allow for exploring the effect of energy efficiency on the different cash flow components used for the calculation of the value of the property.

The energy performance of dwellings is measured by the Energy Performance Certificate (EPC), ranging from 0 (highly efficient dwellings) to 400 (poor energy performance).[36] Together with the EPC rating, we gather a set of hedonic characteristics of the properties, including the number of units in the property (block), location, year of renovation and year of construction.

Exhibit 31 presents the results for the description of the German portfolio considered for the analysis. The levels of rents per square meter in our sample are lower than those considered in the study of the impact of energy efficiency on transaction prices by Cajias et al. (2016) in their analysis of energy efficiency in German housing (i.e. € 5.95 in our study versus € 7.10 in theirs).[37] The dwellings are also slightly smaller and older than those considered in the study by Cajias et al. (2016).

Exhibit 31 Descriptive Statistics in German Portfolio

	(1)
Value	
Assessed value per square meter 2012	5500.80
	(9030.96)
Assessed value per square meter 2014	6566.73
	(9528.55)
Assessed value per square meter 2016	9164.43
	(12857.83)
Current rent per square meter	5.95
	(0.82)
Property Characteristics	
Average size (in square meters)	65.45
	(16.27)
Construction Period	
Before 1905	20.41
1906-1957	21.12
1958-1964	20.81
1965-1975	19.90
After 1977	17.77

Notes: Standard deviations in parentheses. Categories in *"Period of construction""* expressed in percentages

[36] In order to guarantee the representativeness of our sample for the German residential sector, we exclude those properties (blocks) with commercial space. The final sample includes a total of over 950 properties (vs 1,550 initial properties).
[37] The transaction price per square meter was extracted from Exhibit 2 "Descriptive statistics" in Cajias et al. (2016).

Estimating the impact of energy efficiency in Germany

The energy performance of dwellings is linked to their assessed valuations following the model stated in Equation (1), using as dependent variable the natural logarithm of the assessed value based on the automated DCF analysis. In a second stage of the analysis, energy efficiency is linked to two important value cash flow components –i.e. rents, operating costs, and (long term) vacancy rates.

Energy efficiency and assessed value

We begin with an assessment of the explanatory power of the different model components. Exhibit 32 presents the proportion of variation in assessed value that the explanatory variables included in the model are able to explain. As described by the R-squared in column (1), the location of dwellings, as described by the neighbourhood of the property, is able to explain only 32.5 percent of the variance in the assessed value. The inclusion of size does not add much in terms of explanatory power, but the hedonic characteristics of the dwelling increase the explanatory power of the model by 20.3 percent, and energy efficiency increases the explanatory power by 3 percent more (columns (2), (3) and (4) in Exhibit 32).

Exhibit 32 Explanatory power of different variables for assessed valuations in 2016.

Total Sample Germany

(Dependent variable: log of assessed value per square meter in 2016)

	(1)	(2)	(3)	(4)
R-squared	**0.325**	**0.335**	**0.538**	**0.565**
Observations	985	985	985	984
Neighbourhood Fixed Effects	YES	YES	YES	YES
Size	NO	YES	YES	YES
Hedonic Control Variables [a]	NO	NO	YES	YES
Energy Efficiency	NO	NO	NO	YES

[a] The list of hedonic control variables includes natural logarithm of size of the dwelling in square meters, year of construction, number of units in building, and years since last renovation

Exhibit 33 shows the estimated coefficients of Equation (1), linking dwellings' energy performance to their value assessed through an automated DCF. In each of the estimations, the natural logarithm of assessed market value per square meter is used as dependent variable. The energy performance of the dwellings is assessed based on the natural logarithm of the property's EPC index per square meter. Columns (1) and (2) in Exhibit 33 show the impact of changes in the EPC rating on the assessed value in 2014 and 2016, correspondingly. The results indicate that changes in the energy performance of dwellings were reflected in statistically significant changes in assessed valuation. A one percent increase in the EPC index (implying a decrease in energy performance) translated in 0.56 percent lower values in 2014 and 0.72 percent lower in 2016.

Exhibit 33 Assessed value and Energy Efficiency;

Total Sample Germany

(Dependent variable: log of assessed value per square meter)

	(1) Valuation 2014	(2) Valuation 2016
Log of EPC rating	-0.561**	-0.721***
	(0.264)	(0.225)
Observations	782	926
R-squared	0.614	0.542
Neighbourhood Fixed Effects	YES	YES
Size	YES	YES
Hedonic Control Variables [a]	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

[a] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of units in building, and years since last renovation

Energy efficiency and cash flow components

The final step in the analysis for Germany looks at changes in rents, vacancy rents, and operating costs (i.e. maintenance costs) associated with energy efficiency, as drivers for change in valuations. Exhibit 34 presents the estimated coefficients of Equation (1) linking the energy performance of dwellings to the different cash flow components.

Column (1) in Exhibit 34 links the EPC rating of the property to its rents. In this specification, the natural logarithm of the rent per square meter is used as dependent value. The results indicate the existence of a decrease in rents associated with poorer energy performance. In particular, a one percent increase in the EPC rating is associated with a 0.04 percent drop in the average rent of the property. Column (2) in Exhibit 34 links the EPC rating of the property to its long-term vacancy rents, as reflected by the percentage of square meters not rented for a long period of time over the total area of the property. The estimates indicate no significant differences in long term vacancy rates associated with the energy performance of the property. Column (3) in Exhibit 34 shows the estimated effect of changes in EPC ratings on the natural logarithm of the maintenance costs per square meter. The estimates indicate no statistically significant differences in maintenance costs associated with the energy performance of the property.

Finally, in order to explore the role of rents as mediating channel between energy efficiency and assessed valuations, rents are included as explanatory variable in our regression model estimating the effect of EPC rating levels on the assessed valuation. Thus, the same model presented in column (2) in Exhibit 33, is modified with the inclusion of the natural logarithm of rents per square meter. Column (4) in Exhibit 34 shows the effect of energy performance on assessed valuations controlling for level of rents. The results indicate that while the magnitude of the coefficient associated with the EPC rating of the property goes down, the coefficient remains highly statistically significant. This result indicates the existence of additional channels mediating the impact of energy efficiency on assessed valuations beyond the rent levels.

Exhibit 34 Cash flow components and Energy Efficiency;

Total Sample Germany

(Dependent variable: log of rents per square meter, long term vacancy,

Log of maintenance cost per square meter, and log of assessed value per square meter)

	(1) Rent 2016	(2) Long term Vacancy 2016	(3) Maintenance costs 2016	(4) Valuation 2016
Log of EPC rating	-0.0466**	0.00594	-0.323	-0.661***
	(0.0209)	(0.00463)	(0.211)	(0.212)
Log of rent per square meter				1.284**
				(0.523)
Observations	926	926	926	926
R-squared	0.455	0.313	0.577	0.552
Neighbourhood Fixed Effects	YES	YES	YES	YES
Size	YES	YES	YES	YES
Hedonic Control Variables [a]	YES	YES	YES	YES

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

Coefficients associated with locational fixed effects, and hedonic controls omitted due to space limitations (available upon request)

[a] The list of Hedonic variables controls includes natural logarithm of size of the dwelling in square meters, year of construction, number of units in building, and years since last renovation

The impact of energy efficiency on German social housing valuations

The analysis for Germany is based on hundreds of valuations of single properties in the Berlin metropolitan area together with the EPC rating of these properties as a measure of their energy performance. The analysis involves the assessed valuations of properties based on an automated DCF method, property rents, vacancy levels and maintenance costs. We explore both the final impact of energy performance of properties on assessed valuations, as well as on the potential value channels for such change.

The results from the hedonic model indicate that energy performance of rental houses in the German sample was reflected in dwellings' assessed valuations. In particular, one percent increase in the EPC index (i.e. decrease in energy performance) translated in 0.56 percent lower rents in 2014 and 0.72 lower rents in 2016. When analysing specific cash flow components, results indicate that a main value channel is rents. Energy efficiency was statistically significantly correlated with the level of rents, but not with the (long term) vacancy level of the property, nor the maintenance costs associated with the property. When modelling rents as mediator in the link between energy efficiency and assessed value, the results indicate that rents play a significant role as value channel, but do not fully capture the total effect of energy efficiency. This result indicates the existence of other mediators in the connection between energy efficiency and assessed value (based on automated DCF) beyond rents and maintenance costs.

Chapter 7 Limitations

The analyses and results described in this study are based on self-collected data from housing institutions. In all, the final results are based on six datasets containing assessed valuations, location, hedonic characteristics and energy performance.

There is a wide heterogeneity in data quality and completeness across countries and over time. In particular, there are differences in the methods for assessing energy efficiency in the different portfolios considered in the analysis. While in some portfolios we assess energy efficiency through energy consumption, in others we use energy performance indicators (EPC or equivalent) in which there is documented heterogeneity in methods and procedures in the energy professional assessments, impeding the direct extrapolation of the estimation results to other markets.[38] Further there were differences in the purpose and bases of valuations undertaken.

The number of dwellings with an EPC label and the distribution of energy labels varied over time and across countries. The assessment of value by professionals in some cases was based on the information available on comparable dwellings; in other cases they were conducted on a cash flow basis; whilst most were undertaken by valuers, in one case automated models were used. Thus, the variation in the information set available to valuers might potentially change the outcome or assessment of valuers towards specific energy-related characteristics. The extrapolation of the estimation results to other market conditions should be made with caution. Further it should be borne in mind that in all cases valuations can be subject to error with up to 10 per cent being widely regarded as a market norm in variance.

The analyses of the effect of energy components on dwelling-assessed value faced significant information constrains. There is a lack of documentation of physical attributes related to energy efficiency and of the renovation programs undertaken in their portfolios by housing institutions. In addition, the smaller portfolios considered for the analysis are usually rather homogeneous in the energy components installed in the dwellings of the portfolio. The lack of variation in some dwelling characteristics within portfolios makes impossible any regression exercise.

Chapter 8 Conclusions

Residential real estate is central to the EU goal of reducing the greenhouse emissions in the region. There is an extensive and emerging literature base which demonstrates existence price differentiation for both rents and transaction values associated with sustainability in Europe, the US and Asia.

This report focuses on social housing institutions which are key players in residential real estate markets across Europe. These institutions generally face considerable constraints in rationalising investments in energy efficiency-related building improvements, experiencing rental caps or significant limitations on their ability to sell their stock in the open market. Understanding the link between energy efficiency and the assessed value of their dwellings is helping these institutions shape and assess the implications of their energy efficiency investment plans. This link is also important in acquiring debt funding to finance their sustainability investments.

This report describes the results of a quantitative analysis of the link between the energy efficiency and the external valuations of dwellings in four different European countries: the

[38] See http://bpie.eu/uploads/lib/document/attachment/81/BPIE_Energy_Performance_Certificates_EU_mapping_-_2014.pdf for an overview of energy certificates accross the EU.

Netherlands, the United Kingdom, Sweden and Germany. In all, the analysis is based on data gathered from six social housing portfolios, covering over 120,000 individual valuations assessed by professional valuers over the last 7 years.

The link between energy efficiency and the external valuations was assessed through a standard hedonic regression framework, where the assesssed value of an individual property is regressed on the energy performance of the dwelling, its location, and different quality characteristics (e.g. size, dwelling type, construction year). The level of energy efficiency of dwellings is asssessed using multiple measures such as energy performance indexes, energy efficiency labels, gas and/or electricity consumption and physical attributes (i.e. glazing, insulation, heating system).

In all the models considered in the analysis, energy efficiency played a statistically significant but mainly marginal role in explaining the final assessed value of the property relative to the location or size of the dwelling. The analysis of the explanatory power associated with energy efficiency in predicting assessed valuations indicate that energy efficiency played a marginal role in explaining the final assessed value of the property relative to traditional value factors, such as the location or size of the dwelling.

However, when looking at recent valuations (i.e. 2015), there is evidence that those dwellings with poorer energy performance had a lower value than otherwise comparable dwellings with average energy performance. The estimation results also indicate that this differential relates to those dwellings with a higher actual energy consumption. For two of the six portfolios in the analysis, we gathered valuations in earlier years (2010 and 2012). For those portfolios, external valuations did not show any links between levels of energy efficiency in reported values. It is only in more recent years, such as 2015 and 2016 when a link begins to emerge. Results from subsample analyses suggest that the documented valuation differentials are present in both capital cities and secondary urban markets, and that they are strongest in multi-family dwellings and flats.

When exploring the value impacts of different physical attributes of dwellings related to their energy effiency performace, the analysis shows that window insulation was the feature with the most influence on value. In particular, triple and double glazed dwellings were valued at statistically significantly higher value than comparable single glazed dwellings. On the other hand, energy-related components such as boilers or heating systems were not associated with valuation differentials. This could suggest that the visual impact of windows may influence opinions of value more than those physical attributes of the dwelling, which have less visual impact.

In summary, the results of the statistical analyses provide evidence of the genesis of a links between energy efficiency and assessed valuations of social housing portfolios across Europe. In particular, the estimated coefficients in a standard hedonic price model indicate the existance of systematic value differentials across dwellings with different energy labels and (some) physical attributes related to energy efficiency. These value differentials appear in different markets and dwelling types. However, whilst there can be statistical confidence in the results of most of the analyses given the size of portfolios, the power of energy efficiency in explaining property valuations is still small, when placed against the impact of traditional factors, the size of the unexplained element and the natural variance between valuations and prices achieved in the market place.

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Chapter 10 Appendix A

Exhibit 35. Overview valuations considered for the analysis

	Valuation Technique	Year
The Netherlands	Taxation Value	2012 and 2015
The UK		
England	Lending Value	From 2008 to 2015
North West England	EUV-SH and Market Value	2012 and 2015
London	Market Value	2014 and 2015
Sweden	Market and Taxation Value	2015 and 2016
Germany	Automated DCF	2014 and 2016