Is energy efficiency capitalized in the value of real estate? – an analysis of the affordable housing sector in Groningen.

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Summary

This study on residential properties owned by affordable housing corporations (sociale *woningbouw corporaties*) consists of 37,000 observations in Groningen, The Netherlands. Affordable housing corporations are specifically studied in this paper, as they are seen as the drivers of the current energy transition due to capital availability, their mandate and the scale advantages they enjoy.

Results find non-linear value increases for all energy labels relative to label C properties, except label D. Energy label category A> is expected to see a 4,65% increase in EUR/M2 translating to a value increase of 71 EUR/M2. B labelled dwellings see a 3,5% premium, translating into a price premium of 53,75 EUR/M2 relative to the holdout C. Label D, E, F and G dwellings also see price premiums of 0,29% (not-significant), 1,7% 1,25% and 4,89% respectively (figure 10).

The hedonic regression model was controlled for location, size of the dwelling, type of dwelling, ownership and construction date. In the context of the challenge of the CO2 reduction goals of the municipality of Groningen, this study offers insights into the value of properties' energy efficiency. But also highlights the complexity of value predictions based on energy label renovations. But also highlights the complexity of value predictions based on EPC renovations alone. Assuming the renovate-to-sell approach is taken, energy efficiency is insufficiently capitalized by itself into the value of real estate. The outcome of this research suggests that investments into energy-efficient renovations are profitable for affordable housing properties only under certain conditions such as availability of state financial instruments and that energy efficiency renovations be coupled with other renovation types and objectives in the property to increase the value of the renovations.

Introduction

Background

There are a number of studies investigating the impact of energy performance on the economic performance of real estate. These impacts can be seen by changes in rental value, occupancy and transaction price. Most studies find a price premium for energy efficiency in real estate and more stable occupancy (Brounen & Kok (2011); Chegut et al. (2016); Deng et al. (2012); Eichholtz et al. (2010); Fuerst et al. (2016); Walls et al. (2017); Zhang et al. (2018)). Current literature on the topic of energy efficiency and value of real estate however, focusses primarily on owner occupied real estate or commercial (office-) buildings. With the costs associated with an energy efficient renovation ranging from 170-770 EUR/M2 or 60-80,000 EUR for each dwelling (Cerin et al., 2014, Chegut et al., 2016, Milieu Centraal, 2018), these renovations are likely unaffordable for most of the population. There is little research on the effect that the energy efficient renovations will have on the affordability of lower income households living in affordable housing.

The real estate rental sector is of particular interest due to the split-incentive problem; energy costs are not suffered by the buyer or owner of the property but by the tenant or occupier. Therefore, owners of rental real-estate may view energy performance differently than the tenants do; they may charge higher rents, shorter times in between occupancies or otherwise have greater returns on the property, only if (large) investments are made first, whilst tenants enjoy lower energy costs for heating (Fuerst et al., 2016). The rewards for renovation are thus not shared equally, as rent increases are capped or prohibited (Chegut et al., 2016). Affordable housing corporations are seen as the drivers of the energy transition, but they also deal with the split-incentive problem, however; due to their mandate of social responsibility are partially acting contra-intuitively on the phenomenon.

This paper investigates the effect that an energy label has on the price of real estate, with a focus on the affordable housing sector (*woningcorporaties*). At 33% of the total housing stock, The Netherlands has the largest relative affordable housing sector in the whole of the European Union (with an European average of 17%) making it a significant area of study, which is currently understudied (Chegut et al., 2016; Thomsen & Flier, 2009). The focus on the affordable housing sector is due to their frontrunner position (NOS, 2018) and also due to the proportionally high effect of energy costs on low income households, which in some extreme cases constitutes half of the household's disposable income (Brounen & Kok, 2011). To tackle the challenges associated with the European 2050 and municipal 2035 carbon abatement targets (EC, 2018; RTV Noord, 2018), this paper hopes to give better insights into the real costs of energy efficient renovations.

Research Questions

- *How does the energy label affect the price of real estate?*

Roughly 27% of aggregate energy use within the European Union is spent within the residential sector (Chegut et al., 2016). Within the E.U., the building sector alone contributes 36% of all greenhouse gasses (Cerin et al., 2014). In the framework of the Paris Climate Agreement (PCA) which aims to reduce CO2 emissions by 2050 with 80%, there is an increased focus on carbon emissions reduction (EC, 2018), specifically within the built environment as the carbon abatement potential is high and also leads to the lowest CO2 total emission (Brounen & Kok, 2010; De Jonge, 2006).

To reduce carbon emissions in the built environment, the EPC energy labels were introduced as a way to stimulate green thinking and improve transparency on potential energy savings (Brounen et al., 2013; 2018). The question is; is the EPC successful in this by capitalizing energy savings in the value of real estate? The central research problem of this paper is to investigate if and to what degree energy labels (EPC) affect the value of real estate.

- *Is a renovate-sell approach economically sustainable for social housing corporations?*
    - *Which renovation (label-jumps) leads to the highest value increases?*

Several studies highlighted the mechanism of energy efficiency certifications; the cost of energy-efficient renovations can be financed through the reduction in energy consumption, and their associated costs. However, due to excessive costs and exceedingly long return's on the investment of the renovation, many households do not invest substantially into energy efficiency (Walls et al., 2017). For affordable housing corporations this is also valid as subsidies and other financial constructions by the central government to allow affordable housing corporations to recoup some of their renovation costs are woefully inadequate (Aydin et al., 2017; RVO, 2018a; 2018b; 2018c). Building codes alone may not be sufficient to reduce energy consumption, as their effects on energy consumption are inconclusive (Aydin et al., 2017; Mense, 2017). It is most effective to adopt a holistic approach to energy efficiency, combining technical, legislative and behavioral aspects, to achieve energy reductions (Sunnika-Blank et al., 2012), but this is not entirely in the domain of affordable housing corporations.

To finance (comprehensive energy) renovations, Dutch affordable housing corporations often sell part of their housing stock to improve their cash flows. Additionally, less profitable affordable housing properties are sometimes sold as a way to cut spending (Chegut et al., 2016; Copiello, 2015). In light of the PCA, the issue with this system of selling to improve an affordable housing corporations' cash flows, is that the sale of (possibly old, energy wasteful) affordable housing stocks by said corporation would entail a shift of the energy efficient renovations to the new owners. A considerable financial responsibility. These new owner occupiers would, due to the on average lower value housing, and assuming less financial resources, be financially trapped in the ambitions of the municipality and PCA, making the municipality's CO2 reduction targets tougher to achieve (Chegut et al., 2016).

The second research question therefore is to investigate whether fundraising by a renovate-to-sell approach for affordable housing corporations is financially justifiable. The sub question of this is to investigate which degree of renovation (for example, C to B or C to A) yields the highest returns. Keeping in mind the social mandate of the corporations, profit maximizing shouldn't be desirable, however, if the options are: sell in current state, demolish or partial renovation, insight into which (partial) renovation would be the most financially rewarding whilst at the same time improving the energy efficiency, should be investigated. Furthermore, as renovations by affordable housing corporations may also encompass other targets such as urban livability or health through improving housing, it is useful to have an indicative cost of adding (partial) energy efficiency renovations to these projects quality (Groningen Energieneutraal, 2018; RVO, 2018).

Structure of the paper

The structure of this paper is as follows: firstly, this paper will introduce the findings of related literature on the topic. Second, the methodology and data of the research will be described. Third, the results of this research will be presented and discussed. Fourth, conclusions based on the research findings and existing literature will be presented in addition to implications of the findings and other remarks on the subject.

Related literature

Labels, certifications and rating systems for the energy efficiency of buildings have been available in the U.S. since the end of the last century and have been extensively used in Europe and Australia for longer (Chegut et al., 2016). There have been a multitude of studies examining real estates' value related to energy efficiency, but only a limited number of studies put their focus on the affordable housing sector (Chegut et al., 2016; Copiello, 2015). A summary of a selection of results from related literature is given below. The foremost findings are divided into the following categories: *residential real estate, commercial real estate and affordable housing.*

Residential real estate

1. Using a dataset of 177,000 transactions from the Dutch housing market, Brounen & Kok (2011) found that the price premium for homes with a "green label" (labels A, B, C) were on average 3,6% compared to non-green labelled homes (labelled D, E, F, G).
2. An empirical study of 192,000 transaction of residential properties in Wales by Fuerst, McAllister, Nanda & Wyatt (2016) found significant price premiums of 12,8% for A/B and 3,5% for C compared to D. Price discounts were seen for dwellings with lower energy performance certificates; E (-3,6%) and F (-6,5%).
3. Popescu, Bienert, Schutzenhofer & Boazu (2012) studied 19 apartment flats in the city of Lasi in Romania and found price premiums on energy efficient renovated flats ranging from -2,78% to + 6,25%, with an average premium of 2,68%.
4. Walls, Gerarden, Palmer & Bak (2017) examined price premiums of two different labelling schemes (LEED & Energy Star) in Portland, Oregon, Austin and Texas, U.S.A.. In their research they found price premiums in Austin of 8-9% whilst in Portland this premium was 4%. An analysis on the basis of energy costs showed that the premium corresponded with energy expected savings.
5. Cerin, Hassel & Semenova (2014) examined the Swedish housing market, and concluded that the premium for energy-performance was conditional on a benchmark (reference), age and sales-price class. Furthermore, high rate of adoption and high quality of the EPC's in Sweden stand in stark contrast to many other European examples.
6. In a study involving 1679 single family homes in Atlanta, U.S.A., the research of Zhang, Li, Stephenson & Ashuri (2018) found a 11,7% price premium on homes with energy certificates, translating to a $47,000 premium. The results were also influenced by external factors such as neighbourhood quality and the quality of schools in the area.
7. Deng, Li & Quigley (2012) analyzed the price effect of the "Green Mark" energy efficiency labels (Platinum, Gold Plus, Gold & Certified) on 37,000 transitions from the Singaporean housing market. They concluded that the Green Mark certification demands a premium of around 6% when compared to similar non-labelled dwellings, but also note that level of certification has a significant impact on the premium, with the highest labelled dwellings (Platinum) demanding a 14% premium.

Commercial real estate

1. A study of 10,000 commercial buildings by Eichholtz, Kok & Quigley (2010) found that a 10% decrease in energy consumption of a commercial building, leads to a 1% increase in value. Buildings with an Energy Star certification received a rent premium of 6% compared to similar non-certified buildings.
2. Carlson & Pressnail (2018) compared the net operating income (NOI) of four office properties before and after energy efficient renovations in Toronto, Canada. The NOI was based on occupancy x rental rate. They found that in two out of the four cases, NOI improved after renovation, in one it decreased, whilst in the last case the data was incorrect and therefore inconclusive. An additional

finding was the volatility of occupancy was reduced after renovation. Their conclusion was the energy efficient renovation of commercial office buildings can increase occupancy rates, but does not necessarily do so.

3. A study by Song, Ye, Li, Wang & Ma (2017) of office buildings in southern China found that energy efficiency renovations were cost effective. In their paper, they identified 27 different scenarios of energy efficiency measures/renovations. The placement of exterior walls, infiltration repairing and window replacement were found to be the three most significant parameters influencing energy use and value.

Affordable Housing

1. Chegut, Eichholtz & Holtermans (2016) analyzed 17,835 houses sold in the Dutch affordable housing sector and found a 6,3% premium for A-labelled dwellings compared to C-labelled dwellings. Price premiums varied between 2-6,3% (3,000-9,700 EUR). Homes with label D or G sell for a small price discount of 1%. Furthermore, the cost of energy-efficient renovation is identified at 190 EUR/M2, whilst the value for these renovated dwellings was raised by 330 EUR/M2, supporting the notion of renovate-to-sell, as a profitable activity.
2. Copiello (2015) studied the case of renovated residential apartment blocks in Turin, Italy. It finds renovation costs of the real estate to be 771EUR/M2, with a break-even point at 3 years post-renovation, assuming a market rate of return on equity, public non-payable grants and through sale of part of the estate. It concludes that energy efficiency capitalization in the rent alone is insufficient to fund energy efficiency renovations.

Methodology

The premise of energy performance disclosure (through EPC), is that increased transparency through reliable information on energy efficiency leads to the capitalization of energy labels in housing transaction price or value (Brounen & Kok, 2011, Zhang et al., 2018). This is due to the expected lower energy costs associated with the dwelling and the (perceived) higher quality of the property as it is made out of newer, more energy efficient, and thus better materials (Eichholtz et al., 2010). The expected savings are thereby expected to be capitalized into the value of the real estate or through the rental rates of a property, as illustrated by Copiello (2015) and Walls et al. (2017).

The amount and quality of data is a major challenge and of great importance to research in this area. It is of particular importance for three main areas: *market prices, environmental performance and building attributes*. Data oversights may mean that certain attributes are weighed unfairly and may cause a bias. For instance, if age of dwelling is omitted and the age and energy efficiency of a building are expected to be correlated, the negative price effect associated with age will be reflected in the energy efficiency coefficient. If relevant factors were to be left out of the model, price effects would be misattributed (Fuerst et al., 2016; Zhang et al., 2018).

A note on the European energy performance certificates (EPC)

EPC calculation is a standardized and holistic property-wide approach to calculate the EPC of a dwelling. No factors such as sustainability of the materials and such are taken into consideration as might be common for other energy certification programmes (RVO, 2018a; Walls et al., 2017). It encompasses only factors which can be directly linked to energy use (Bouw-Energie, 2018). This means, that the data in the dataset should be carefully selected, as not to measure one factor twice. Cerin et al. (2014) suggest that better relating EPC labels and expected costs of utility would improve their use and their power.

Hedonic pricing method is used to estimate the effects of EPC label from self-reported value estimates of four Groninger affordable housing corporations. The hedonic approach provides a statistical approach to determine housing prices based on a set of measured characteristics (Zhang et al., 2018). The hedonic model for this study will include the following explanatory variables as follows:

$$EUR/M2 = \beta 0 + \beta 1\gamma + \beta 2D + \beta 3x + \beta 4\partial + \beta 5\Omega + e$$

The dependent variable, price per square meter can be explained through the addition of the following coefficients:

$EUR/M2$	Dependent variable: Price divided by living area. Expressed in Euro value per square meter.
$\beta 0$	Constant
$\beta 1\gamma$	Coefficient energy label: This is the variable indicating the EPC energy label of the property and contains 7 categories [a]
$\beta 2D$	Coefficient building type: Consists of nine categories of different property types [a]
$\beta 3x$	Coefficient construction date: Categorized into 9 groups based on number of cases [a]
$\beta 4\partial$	Coefficient ownership status: Distinction is made between owner occupied and renter occupied dwellings [a]
$\beta 5\Omega$	Coefficient distance: Location aspect was included through calculating the distance of the "Postcode6" group to the city centre "De Grote Markt" of Groningen in meters.
e	Error term

[a] All non-interval data in the hedonic regression was inputted through the categorical selection of variables through binary selection of the applicable group. With 1 indicating the case fitting within the range of values associated with a group, and 0 indicating that the characteristics of the case did not. To see the full categories of groups for each coefficient, see figure 8.

Data & Descriptives

Area of study

As the EPC specifications are implemented EU-wide, and affordable housing corporations are mandated and operated along nationwide parameters, the sample in Groningen should be representative of E.U. affordable housing (Brounen & Kok, 2011). The varied stock of affordable housing properties and the size of the dataset should also ensure that the data is representative of the whole.

The relatively young population of Groningen compared to the rest of the country, largely due to the educational economy of Groningen should be of no significant importance to the data, as this population is excluded from access to affordable housing. Although this does affect the income, age, rental/owner etc. statistics significantly of the larger Groningen context compared to national average (CBS, 2018). As this issue exists, no comparisons will be made regarding these descriptive statistics.

The dataset was not limited to properties strictly within present-day municipality borders, with a number of properties outside of the 2018 municipality borders. In light of recent and future municipal restructuring *(gemeentelijke herindeling*) this research will not reject the observations outside of the currently identified municipal borders; as these are in a constant state of flux (Gemeente Groningen, 2018). The retention of these cases should add to the power of the models accuracy, or at least not reduce the predictive quality. An overview of the housing units analyzed can be found in figure 1 and 2. Each dot represents the first six postcode digits - the "*Postcode6*" (eg. 1234AB), indicating a street. The individual housing properties are identified by house number on that street, which are left out of the analysis of this paper.

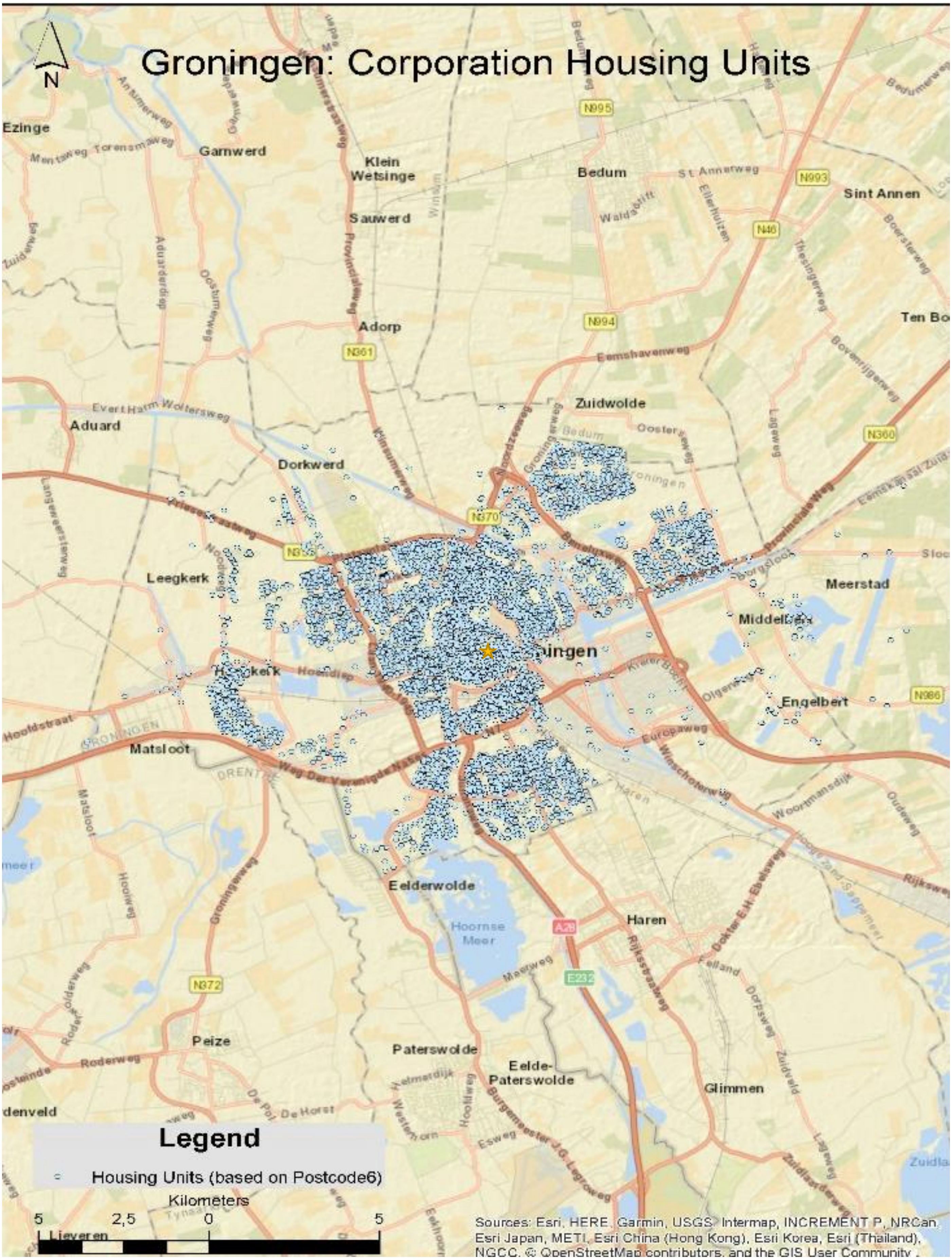


Figure 1 Affordable Housing Properties. "Zoomed-out". Star = City centre. Source: authors own work & ESRI basemap

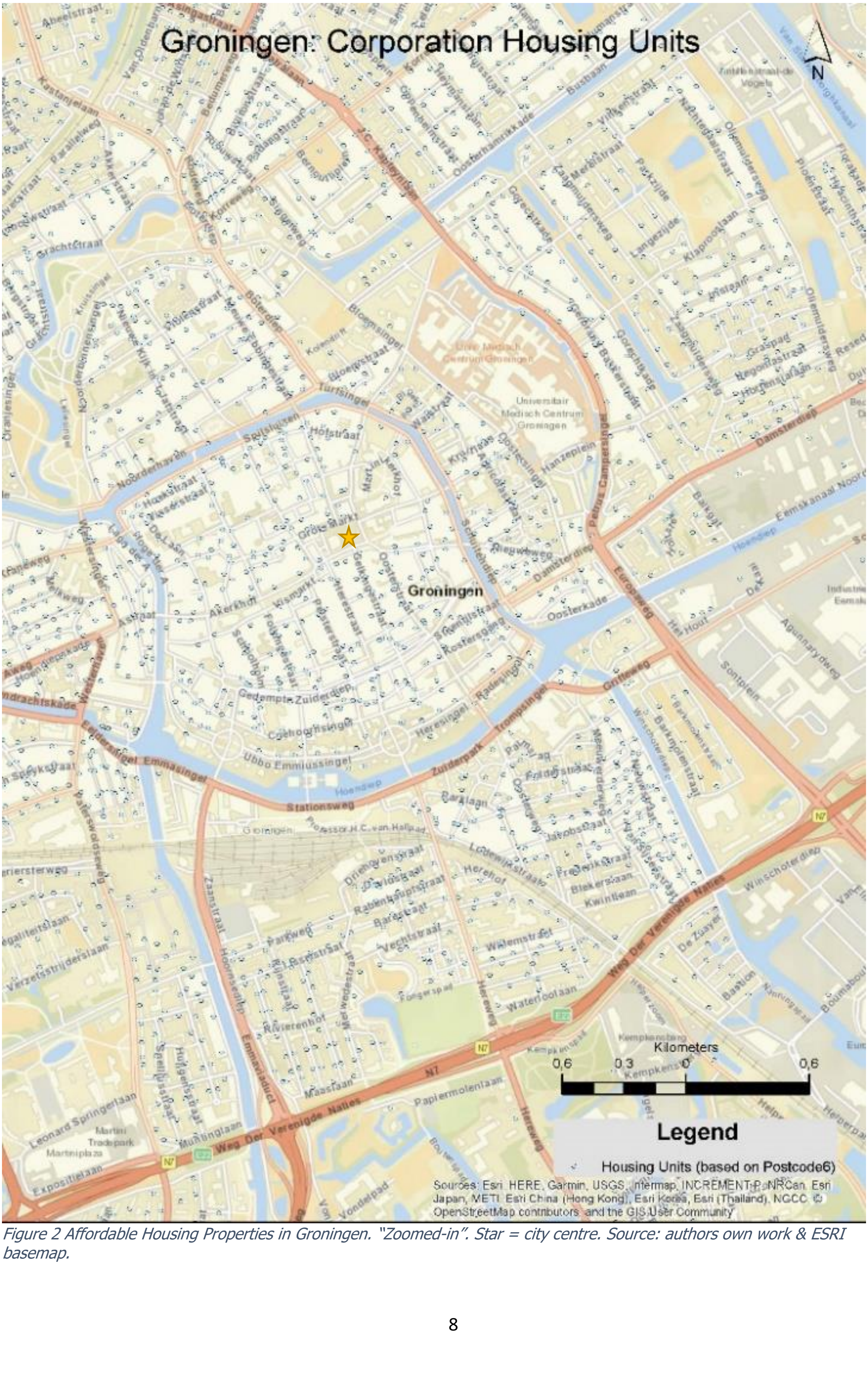


Figure 2 Affordable Housing Properties in Groningen. "Zoomed-in". Star = city centre. Source: authors own work & ESRI basemap.

Data and variables

The analysis of this research will be based on a dataset of approximately 37,000 valid self-reported cases from the five big affordable housing corporations (*sociale woningbouw corporaties*) active in Groningen, namely; *Huismeesters*, *Lefier*, *Nijestee*, *Wierden en Borgen* and *Patrimonium*. The dataset was obtained through the collective effort by the affordable housing corporations, the municipality and external advisory parties to find a solution for the 2035 CO2 goals of the municipality. For each real estate unit, a standardized set of variables was inputted by each corporation and Enexis (the utility provider) which provided the energy use for each property. For the context of this analysis, quantitative methods are preferred over qualitative analysis as the dataset is too large, the variable of interest is perfectly displayed as numeric continuous data and there would be no value added by making in depth analysis of hedonic choices as that would go beyond the scope of this paper.

In order to eliminate the effect of outliers, properties with extremely low and high values were omitted from the sample. This was done for price (WOZ – *Waarde Ontroerende Zaken*), construction date, location and size. Monumentally protected properties were also eliminated from the dataset, as these are subject to wholly different laws and perceptions of value and are thus not representative of the whole. Furthermore, cases with missing values were removed from the analysis. The data cleaning resulted in a valid dataset of 36,883 affordable housing properties.

The attribute data from the dataset comes in multiple forms: text, numerical, categorical (represented as dummy variables in the regression) and binary variables. Apart from distance to the city centre, based on GIS computation of the Postcode6 location, no further data sources were used to either cross-reference or supplement the dataset.

Ethical considerations

To safeguard the privacy of parties, household data has been aggregated into street-level (Postcode6) data points and the properties of affordable housing corporations are not isolated nor identified as such. This should satisfy any ethical issues relevant for this study.

Descriptive statistics

The case processing summary directly calculated from the SPSS dataset, showing a selection of variable descriptives, is seen below in figure 3. Further on in this section, more detailed summaries and remarks of the separate descriptive statistics will be given. Confidence intervals are added to give the construction date averages a more illustrative bandwidth.

							Construction Date: 95% Confidence Intervals	
EPC Label	**N**	**WOZ (€)**	**Distance (meter)**	**Size (M2)**	**Price/M2 (€/M2)**	**Construction Date**	**Lower**	**Upper**
A	2383	158434,75	3947,55	98,269	1612,249	1993,74	1992,55	1994,94
A+	62	155241,94	4150,74	97,81	1587,236	2002,29	1998,36	2006,22
A++	112	138616,07	5422,23	116,38	1191,024	1989,73	1986,38	1993,08
B	5911	125228,39	3912,99	85,70	1461,235	1971,79	1971,79	1973,04
C	11399	115157,03	3744,99	85,63	1344,753	1965,8	1965,34	1966,26
D	10119	109842,87	3888,85	86,24	1273,632	1963,25	1971,10	1972,49
E	4550	106346,15	3713,41	81,77	1300,585	1960,26	1965,34	1966,26
F	1697	110665,88	3540,00	82,96	1333,958	1957,49	1956,65	1958,32
G	650	112423,08	3625,63	80,45	1397,495	1958,06	1956,49	1959,62
Total/ Average	**36883**	**125773**	**3994**	**91**	**1389,13**	**1974**	**1974**	**1977**

Figure 3 Descriptive statistics Summary.

According to a simple descriptive analysis (figure 3), it is clear to see that A, A+ and A++ constitute a relatively small proportion of total observations, a mere 7% in total. To bring this into perspective (figure 4), dwellings with labels C, D and E combined attribute 70% of the total. For this reason, labels A and above are combined into the new group "*A>*" for use in the hedonic regression. The choice of using energy label C as the holdout is due it being the most numerous of the observed cases as well as it being the choice in related literature (Chegut et al., 2016).

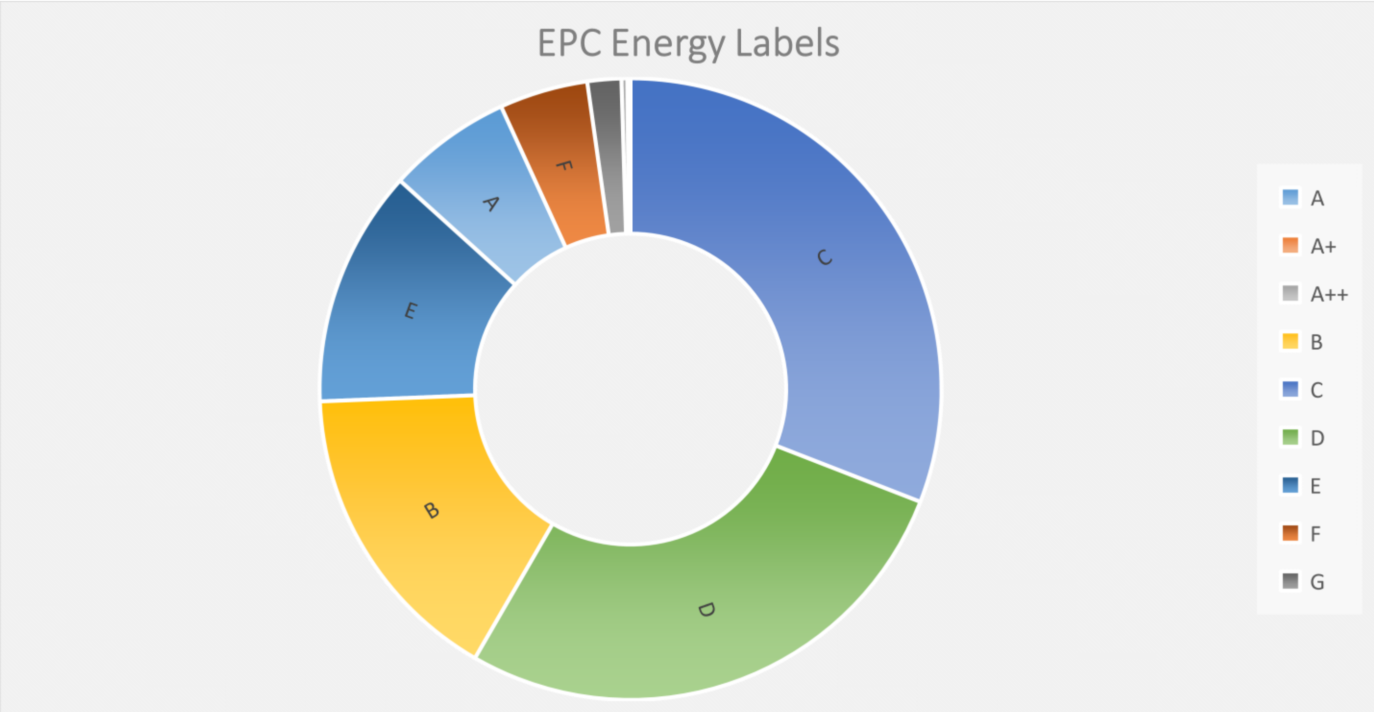


Figure 4 Descriptive: EPC energy label & relative composition

Looking at the boxplots of the variables price/M2 and energy label (figure 5), it is apparent that there seems to be a non-linear price increase with EPC certification. On average, price/M2 is 1389 EUR. In line with related literature, the descriptives illustrate that price/M2 is different amongst the energy labels; with the lower labels having a value of closer to 1000 EUR/M2 and the highest valued group, A and A+ having a value closer to 2000/M2. Label B appears to be in the middle. What does stand out, is that A++ is an obvious outlier in the trend, observing values closer to 1000 EUR/M2. A reason for this may be found in the construction dates of the properties, where label A++ dwellings have an average construction date of 1989, whilst A+ and A have average construction dates of 1993 and 2002 respectively (figure 3); indicating that A++ dwellings are older dwellings, and it is likely that they have had energy efficiency renovations recently (NOM - Energy Neutral) leading to the high EPC label.

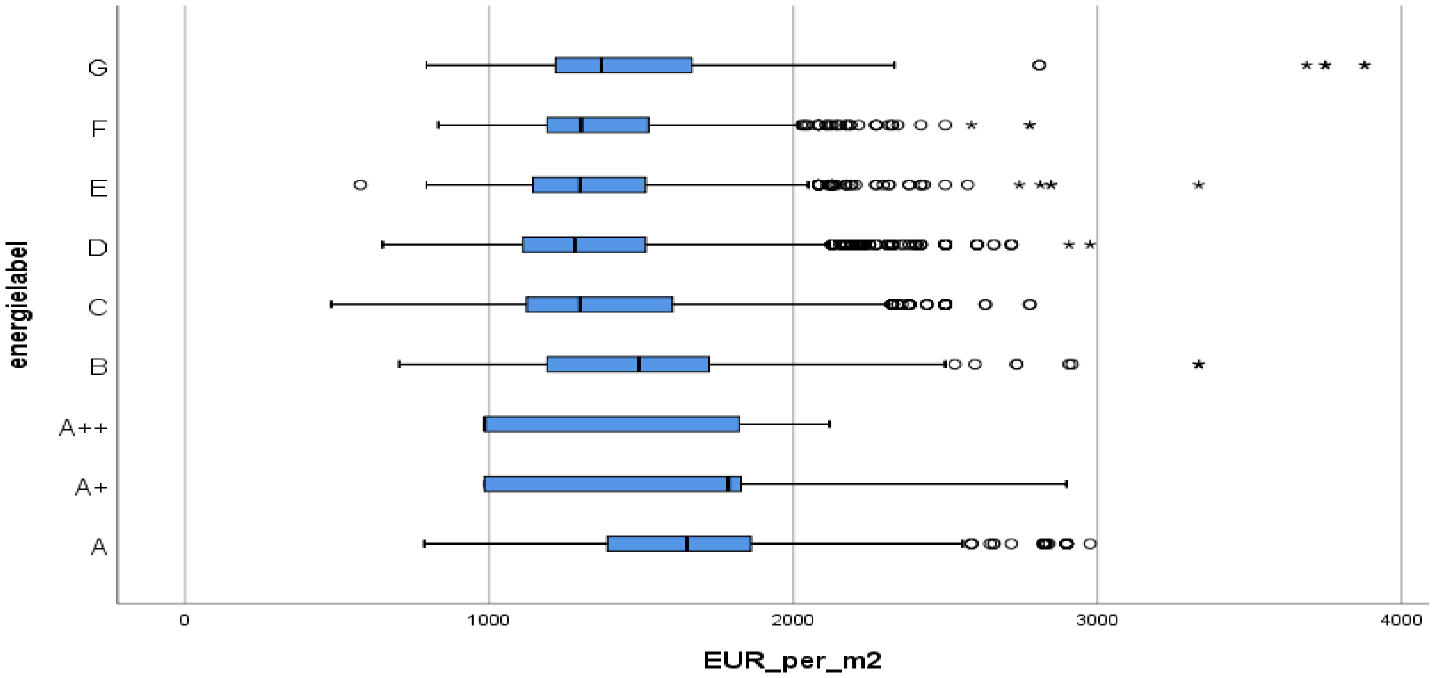


Figure 5 Energy Label & Price/M2

Looking at construction dates alone in figure 6, it is clear that there is not an equal distribution of housing built in the allotted groups of years. 1961-1970 has the highest proportion of real estate still in operation, with 7549 units. The three construction periods of 1961-1990 constitute a combined number of 19502 out of the total 36883 dwellings. This is over 52% of the total housing stock. What can definitely be said is that at this current time, older housing dating from around 1960-1980 constitutes a large portion of the portfolio of the Groninger affordable housing corporations. And this will be a colossal challenge in the CO2 ambitions of the future.

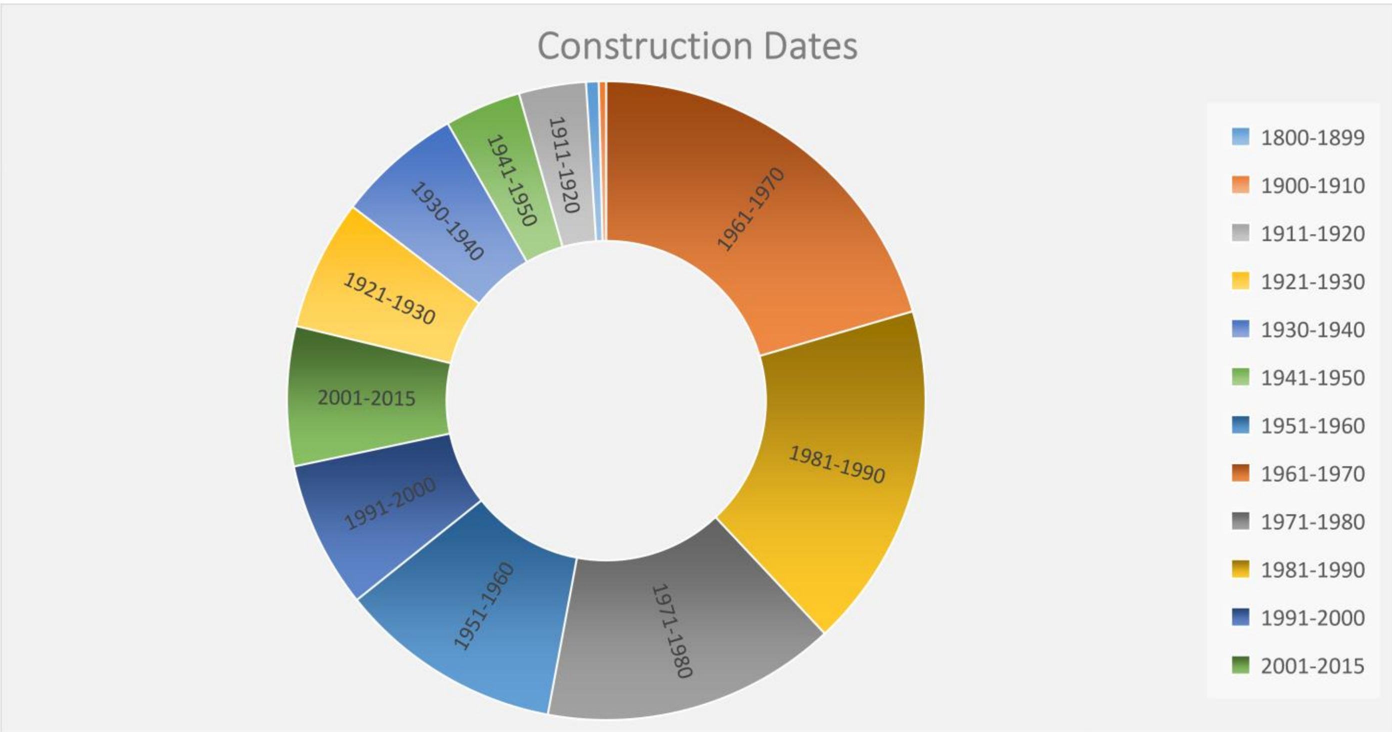


Figure 6 Construction dates of housing

When looking at the different types of real estate housing properties, nine different categories are identified. These types can be seen in figure 7. Again, as with construction dates, it is immediately visible that the distribution amongst the types is not equal; with "*Portiekwoning*" contributing approximately one third of the total amount of properties. "*Meergezinswoning*" and "*Tussen|Rijwoning*" are also overrepresented. This phenomenon can be explained by the characteristics of these buildings. Housing in the categories of Portiek- and Meergezinswoning are multistoried apartment type of flats. These are quick and cheap to construct and lead to concentration and high densities of inhabitants. Tussen/rijwoning are single family dwellings, but the buildings are stuck together in a row. Simplifying construction, due to scalar and production-line type of advantages. With the limited space available, higher density housing types are prolific forms of housing in The Netherlands for affordable housing corporations.

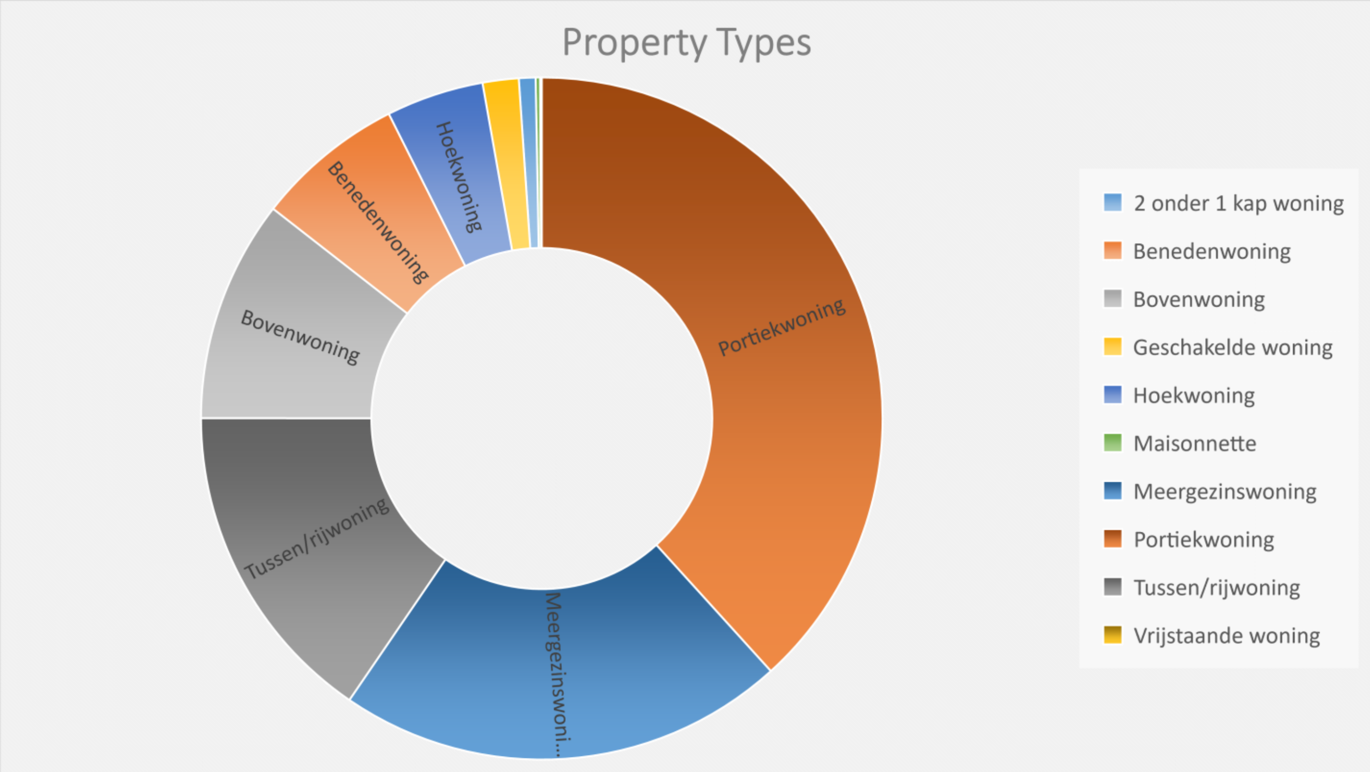


Figure 7 Property types & relative proportion

Results and Discussion

The hedonic regression was performed with 5 different "*blocks*" in the model by using the "*Enter*" method, using a significance level of 0,05 as is a standard requirement. Block 5 was used in the results, as this contained all variables compared simultaneously and was significant. Table 2 and 5 in the appendix show the ANOVA and full output of the blocks in the regression.

The Pearson Correlations (figure 9) are largely in line with expectation of the characteristic's influence on the EUR/M2 of real estate; with an increase in value associated with a higher energy label in line with existing literature proposing that energy efficiency is indeed capitalized in the value of property (Brounen & Kok, 2011; Cerin et al., 2014; Chegut et al., 2016). However, looking at the coefficients of the regression in figure 8, apart from being non-linear, this trend is not exactly the same for the regression coefficients. Here 26 out of the 28 variables used in the hedonic regression were statistically significant, with "*Woningtype_2-onder-1*" and "*Energylabel D*" the only ones with a significance higher than 0,05, exceeding the 5% limit and thus non-significant.

With an adjusted R-square of just over 40% (table 2), it can be said that the explanatory power of this regression is lower than related literature such as Chegut et al. (2016) and Zhang et al. (2018) with R-squares of circa 80% and 90% respectively. However, as the model summary shows the regression to be significant, and improving as variables were added, we can assume that the overall observations are valid indicative, and thus will move ahead with the discussion as is.

Coefficients[a]										
Block No		*Unstandardized Coefficients*		*Standardized Coefficients*			*95,0% Confidence Interval for B*		*Collinearity Statistics*	
		B	*Std. Error*	*Beta*	*t*	*Sig.*	*Lower Bound*	*Upper Bound*	*Tolerance*	*VIF*
0	(Constant)	1526,534	5,135		297,263	0,000	1516,468	1536,59		
1 Energy Label	A>	71,001	7,329	0,055	9,688	0,000	56,637	85,36	0,500	1,999
	B	53,748	4,152	0,060	12,945	0,000	45,610	61,88	0,751	1,332
	D	4,469	3,559	0,006	1,256	0,209	-2,506	11,44	0,688	1,454
	E	26,354	4,678	0,026	5,634	0,000	17,186	35,52	0,733	1,365
	F	19,031	6,865	0,012	2,772	0,006	5,576	32,48	0,838	1,193
	G	74,651	10,454	0,030	7,141	0,000	54,161	95,14	0,917	1,090
2 Property Type	Woningsoort_2_onder_1	1,542	15,439	0,000	0,100	0,920	-28,718	31,80	0,929	1,076
	Woningsoort_Benedenwoning	-51,448	6,627	-0,040	-7,764	0,000	-64,437	-38,46	0,603	1,659
	Woningsoort_Bovenwoning	-295,526	5,980	-0,274	-49,418	0,000	-307,247	-283,80	0,515	1,942
	Woningsoort_Geschakelde_Woning	-83,424	10,654	-0,033	-7,830	0,000	-104,306	-62,54	0,910	1,099
	Woningsoort_Hoekwoning	-101,128	6,709	-0,064	-15,073	0,000	-114,278	-87,97	0,873	1,145
	Woningsoort_Maisonnette	-106,654	29,291	-0,015	-3,641	0,000	-164,066	-49,24	0,982	1,018
	Woningsoort_Meergezinswoning	-27,142	3,845	-0,034	-7,060	0,000	-34,678	-19,60	0,700	1,428
	Woningsoort_Tussen_rijwoning	-115,245	4,328	-0,126	-26,626	0,000	-123,729	-106,76	0,711	1,406
	Woningsoort_Vrijstaande_woning	223,279	45,758	0,020	4,880	0,000	133,592	312,96	0,986	1,015
3 Construction Date	Bouwjaar1800_1899	391,087	17,206	0,094	22,730	0,000	357,363	424,81	0,925	1,081
	Bouwjaar1900_1910	363,485	22,121	0,067	16,432	0,000	320,127	406,84	0,943	1,060
	Bouwjaar1911_1920	303,057	48,424	0,166	35,975	0,000	286,545	319,56	0,745	1,342
	Bouwjaar1921_1930	332,956	7,268	0,250	45,809	0,000	318,710	347,20	0,531	1,884
	Bouwjaar1931_1940	227,838	7,385	0,168	30,851	0,000	213,363	242,31	0,535	1,868
	Bouwjaar1941_1950	120,528	7,883	0,070	15,289	0,000	105,076	135,97	0,752	1,330
	Bouwjaar1951_1960	81,683	5,031	0,078	16,236	0,000	71,822	91,54	0,682	1,467
	Bouwjaar1971_1980	115,812	4,691	0,125	24,687	0,000	106,617	125,00	0,621	1,611
	Bouwjaar1981_1990	248,136	4,461	0,285	55,630	0,000	239,394	256,87	0,604	1,657
	Bouwjaar1991_2000	393,927	5,930	0,312	66,430	0,000	382,304	405,54	0,718	1,392
	Bouwjaar2001_2015	474,982	7,706	0,368	61,639	0,000	459,878	490,08	0,445	2,247
4	Eigendom	74,912	4,859	0,063	15,419	0,000	65,390	84,43	0,946	1,057
5	DISTANCE METERS	-0,072	0,001	-0,398	-83,316	0,000	-0,074	-0,07	0,695	1,440
a. Dependent Variable: EUR_per_M2										

Figure 8 Regression Coefficients.

Note:
The constant of 1526 from the unstandardized coefficient is reliant on the holdouts used for each of the blocks in the hedonic regression model (table 2). These are Energy Label C, Property Type Portiekwoning, Construction Date 1961-1970 and Rental users.

Pearson Correlations

	EUR_per_m2
EUR_per_m2	1
A>	0,198
B	0,122
D	-0,131
E	-0,061
F	-0,024
G	0,012
Woningsoort_2_onder_1	-0,013
Woningsoort_Benedenwoning	0,137
Woningsoort_Bovenwoning	-0,082
Woningsoort_Geschakelde_Woning	-0,052
Woningsoort_Hoekwoning	-0,105
Woningsoort_Maisonnette	-0,004
Woningsoort_Meergezinswoning	0,082
Woningsoort_Tussen_rijwoning	-0,105
Woningsoort_Vrijstaande_woning	0,017
Bouwjaar1800_1899	0,075
Bouwjaar1900_1910	0,045
Bouwjaar1911_1920	0,071
Bouwjaar1921_1930	0,13
Bouwjaar1931_1940	0,012
Bouwjaar1941_1950	-0,014
Bouwjaar1951_1960	-0,02
Bouwjaar1971_1980	-0,204
Bouwjaar1981_1990	0,05
Bouwjaar1991_2000	0,181
Bouwjaar2001_2015	0,276
Eigendom	0,046
DISTANCE METERS	-0,402

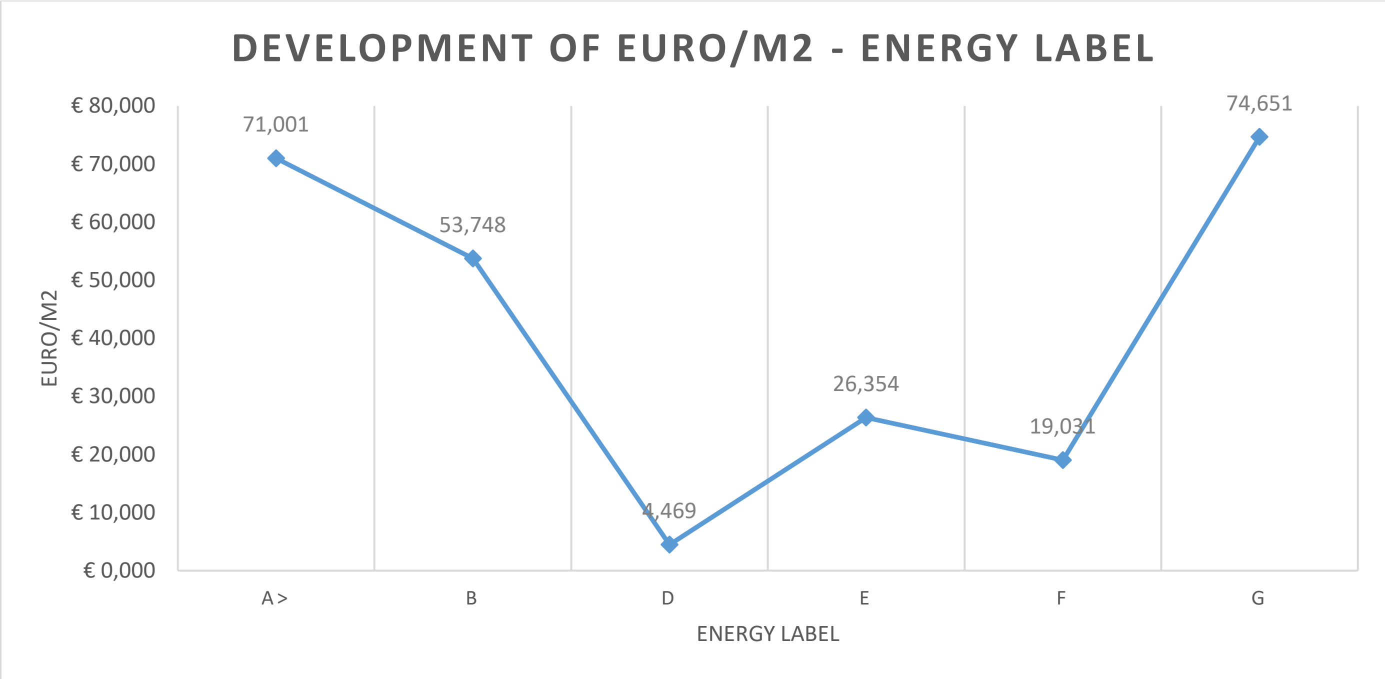
Figure 9 Pearson Correlation of variables & price/M2

In figure 10, the expected EUR/M2 of dwellings from the regression is visualized based on energy labels. What is striking is that all the energy labels are valued higher than label C, with G being the highest with 74,65 EUR (+4,9%) and A> second with 71 EUR (+4,65%) more than the constant, bringing total value up to 1601 and 1597 EUR/M2 respectively. This goes against energy efficiency logic and most related literature, although from Popescu et al. (2012) also find discounts in some renovated properties which isn't logical per se. The effect may be explained through the layout of the property, maintenance, neighbourhood characteristics or the fact that they are of significant age and therefore "*characteristic*" properties, which command a premium. Construction date also has a strong effect on value, as seen in figure 11 which visualizes the average calculated from the dataset and the R-Square change in table 2 in the appendix. These results correspond to Carlson & Pressnail's (2018) conclusions that energy efficient renovation can but doesn't necessarily improve financial performance of real estate.

On the one hand, the findings show value changes differing than found in related literature, namely Chegut et al. (2016) which finds a premium for label A dwellings of 6,3% compared to the 4,65% found in this research for label C affordable housing renovated to label A. On the other hand, results are higher than findings of Walls et al. (2016) and Popescu et al. (2018) who found premiums of 4% and 2,68% respectively. However, results are even more out of touch when compared to private real estate properties as studied by Zhang et al. (2018), Deng et al. (2012) and Fuerst et al. (2016) who found premiums of 11,7%, 14% and 12,8% respectively.

Although the results of this research are lower than most of the related literature, it should be said that no real estate market is the same and that the collective effort on this topic will give insights into regional variations. Furthermore, the temporal aspect is of great significance to valuation of real estate, as economic cycles significantly impact transaction prices (Brounen & Kok, 2011). All in all, these findings (C relative to A) are not extremely far away from related literature, though the linear nature is missing entirely.

Looking at these results, one can only assume energy efficient renovations cannot be profitable. When the value increases of only 70 EUR (4,65%) are compared to the cost estimates of renovation of between 161-771EUR/M2 (Chegut et al., 2016; Copiello, 2015). These estimates are closer to 10-50% of the constant for this case, nowhere near the highest increases observed for this paper. These results indicate that energy efficiency capitalization in the value alone is insufficient to fund energy efficiency renovations in a renovate-to-sell approach. This conclusion is in line with the conclusions of Copiello (2015) who indicates supplementary aims and financing should be combined with energy efficiency renovations to achieve profitability/break-even.



Energy Label	A>	B	Constant (C)	D	E	F	G
EUR/M2 Change	71,001	53,748	1526,534	4,469	26,354	19,031	74,651
% Change	4,651	3,521	0	0,293	1,726	1,247	4,89

Figure 10 Price development based on EPC energy labels. Relative to constant. Holdouts (Label C, Portiekwoning, 1970, Rent)

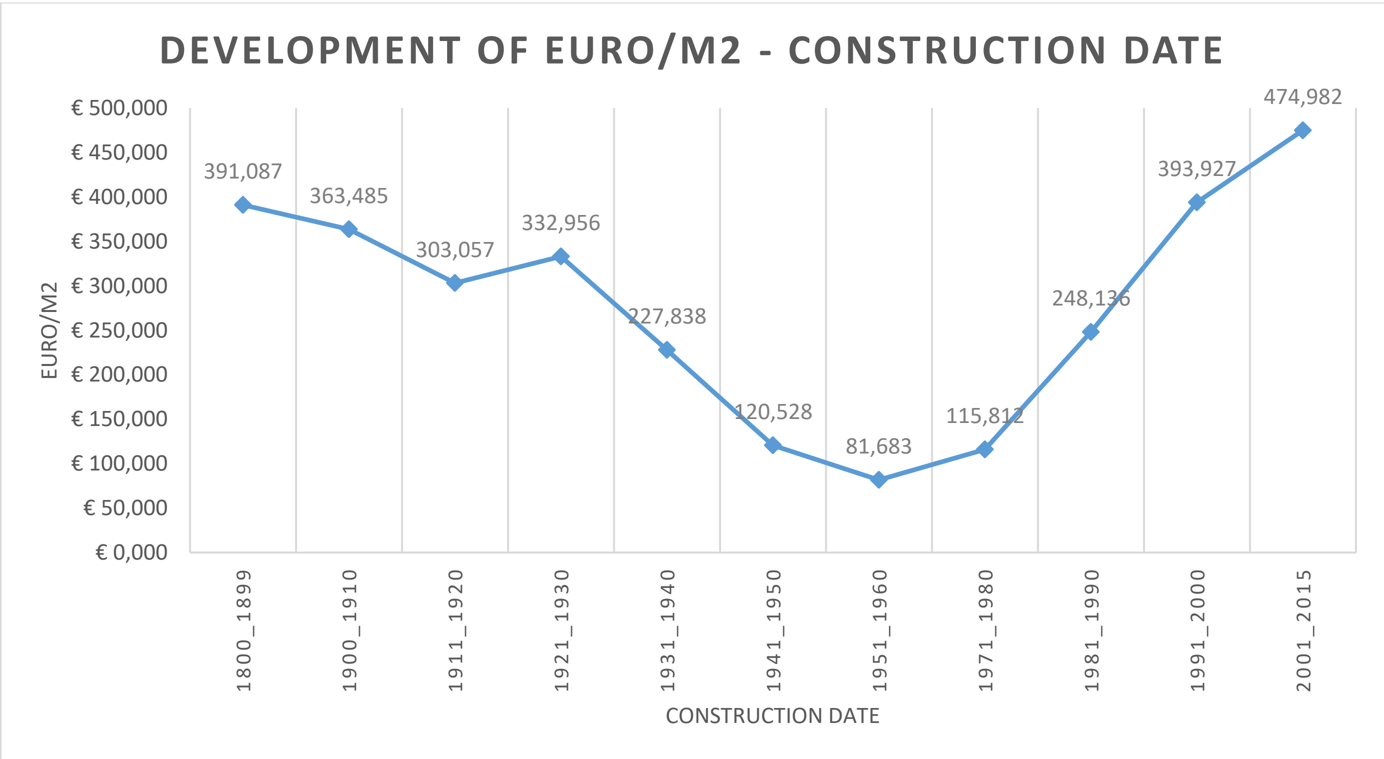


Figure 11 Price/M2 development based on construction date. Relative to constant. Holdouts (Label C, Portiekwoning, 1970, Rent)

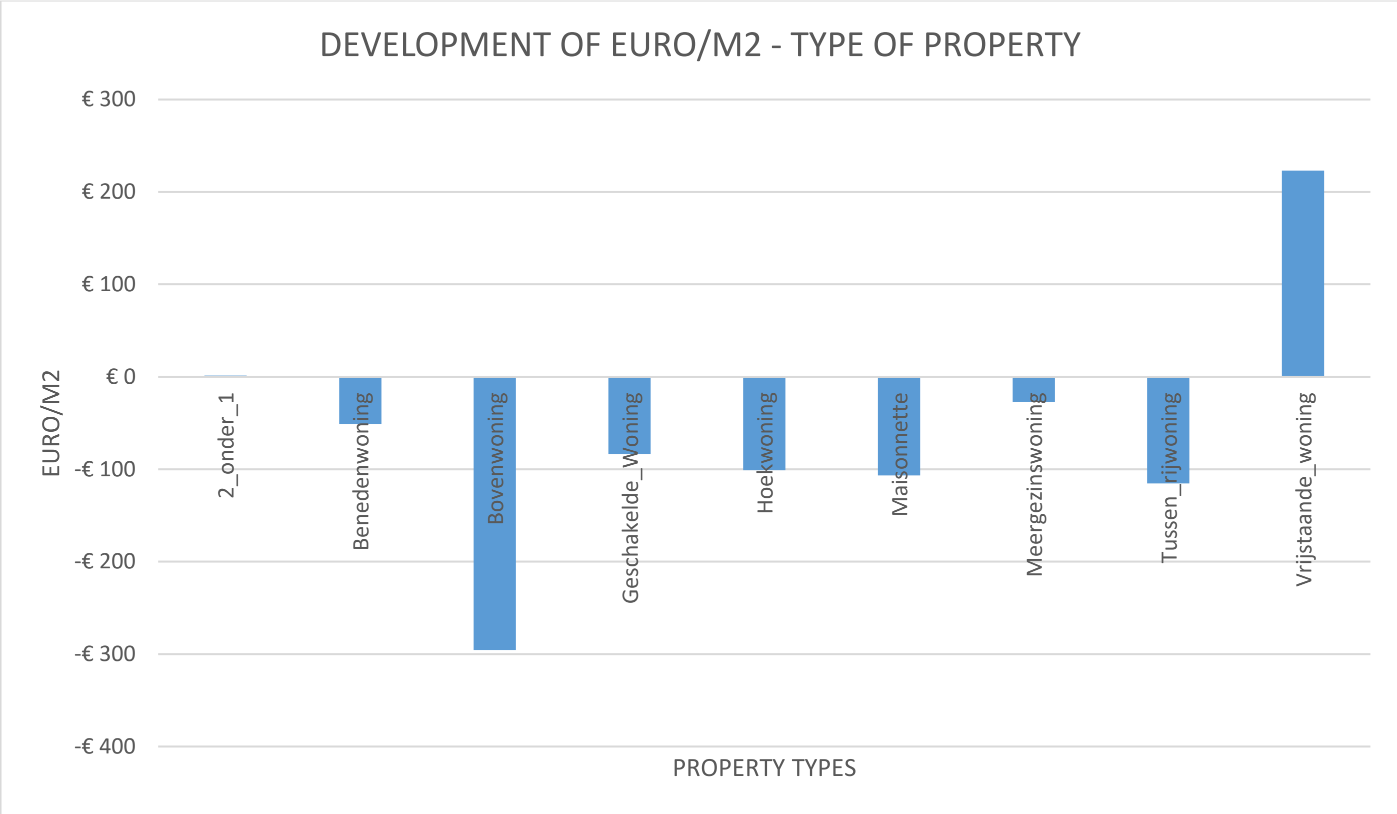


Figure 12 Price development based on type of building. Relative to constant. Holdouts (label C, Portiekwoning, 1970, Rent)

The coefficient, property type, is displayed in figure 12. Based on the holdout "*portiekwoningen*", it is seen that all other properties, apart from "*vrijstaande woning*" (single family home) and "*2-onder-1*" (two family homes) receive a discount, though the latter was found to be non-significant. This indicates that the single family home is an outlier amongst its peers, as a significant and large premium is observed for this type of property.

The discounts are not unexpected when looking at the average value/M2 calculated from the dataset, figure 13, where its shows that "*portiekwoningen*" are indeed valued above many property types. Something that isn't directly clear when not correcting for size, and merely looking at total average property value (figure 14). Making a case for property-type specific research in the future. Interpreting the R-square changes in the model summary (table 2) shows that the addition of building type has around the same predictive quality on the model as energy labels do.

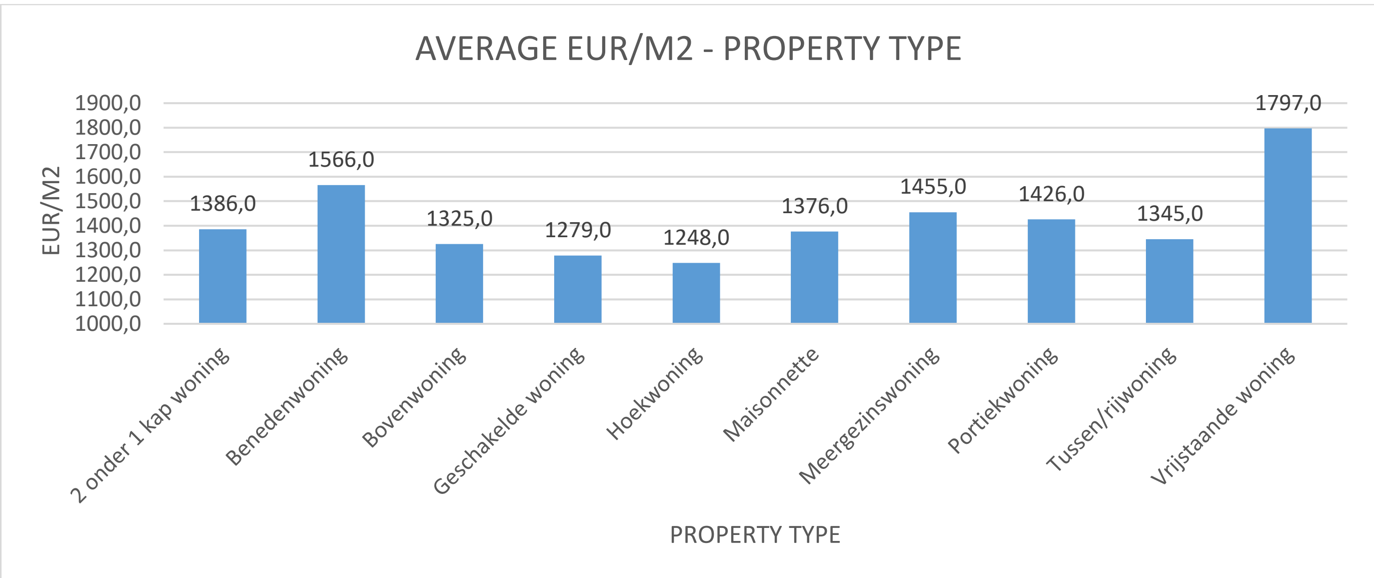


Figure 13 Average EURr/M2 based on property type

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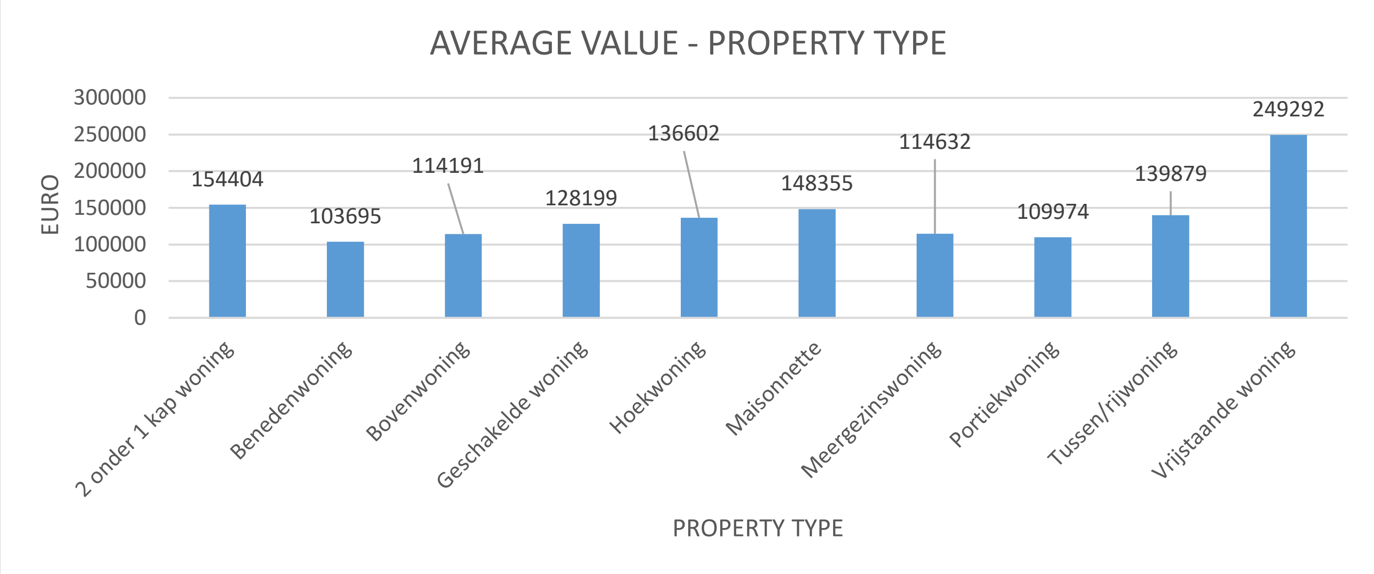

Figure 14 Average value (WOZ) in EUR based on property type

Another similarity between Chegut et al (2016) and the findings of this paper is that the value of owner-occupied dwellings are higher than rental-occupied properties. Although Chegut et al. (2016) encompasses properties across the whole Dutch market and finds a 3,6% premium, this analysis shows a 74,9EUR or 4,9% premium in relation to the constant of rental-occupied affordable housing properties. One noteworthy variation in this research is that the expected value is used, and not the transaction price. Additionally the difference between the two studies can be attributed to temporal aspect. One last observation is that the coefficient distance does seem to be following logic, with a discount of around 0,07 EUR for every meter a property is removed from the city centre. However, neighbourhood characteristics may have a larger influence than distance alone (Zhang et al., 2018)

The results from the hedonic regression indicate a price premium of 4,65% when label C properties are renovated to label A, translating to a value premium of 71 EUR/M2. The effect of EPC labels are not completely clear, nor are they in line with results from most related literature, which finds price discounts for lower labelled real estate, and premiums for higher labelled properties. Results of this analysis are more in line with Carlson & Pressnails conclusion that energy efficient renovations can, but do not automatically mean better financial performance/value. A renovate-to-sell approach would be possible based on the regression outcome, conditional on certain parameters. Such as renovation from C to A, as a value increase of 4,65% is observed with this jump. The highest premium for a – specifically – jump in energy label found in this analysis. Assuming renovation costs of between 161-771 EUR/M2, investment possibilities will be very limited when energy efficient renovations alone are performed. It would be wise to not extensively use this method to improve cash flows, they should only be considered in cases where state financial support is present, and in combination with other objectives such as health or livability, in line with Copiello's (2015) conclusions. To understand the effect of energy label on property values, it would be interesting to repeat the regression using different holdouts.

Multicollinearity test

Variance Inflation Factor (VIF) was calculated for the explanatory variables to order to test for Multicollinearity concerns in the hedonic regression. Multicollinearity can result in misleading and false interpretation of the regression model. If the value of VIF is greater than 10 for an explanatory variable, severe Multicollinearity exists in the regression model and therefore, the variable needs to be removed from further consideration (Zhang et al., 2018). The calculated VIF's in table 1 and figure 8 show no evidence of multicollinearity in the current model.

Residuals test

Once a regression model is developed, regression assumption should be checked. The following assumptions need to be examined: Independent errors where the scatterplot of the standardized residuals against predicted values in used to detect whether the residual terms are independent. Homoscedasticity where the scatterplot of standardized residuals against predicted values is used to detect whether the variance of the residual terms is evenly dispersed. Normal Probability-Probability (P-P) plot of regression standardized residuals can be used to assess whether the residuals are normally distributed variables with a mean of 0 zero (Zhang et al., 2018).

Table 3 and 4 shows the various residual plots to evaluate the quality of the regression. The histogram of the residuals seems bell shaped with a distribution uniformly around zero, indicating normality of the sample. The P-P plot residuals are roughly linear, and similar to the P-P plots of related literature, signifying that the error-terms are normally distributed. The scatterplot of standardized residuals and predicted values does show some problems with a number of outliers on the X-axis severely above or below the three standard deviations associated with 95% significance. However, as the P-P plot and histogram seem normal enough and as the shape of the scatterplot is fairly rectangular, clustered and the outliers are not heavily skewed, we can assume independence and normality of the data in the regression used for this research.

Conclusion

In this paper, the relationship between the value of real estate and its EPC energy label was analyzed. The dataset was compiled by affordable housing corporations after which hedonic regression was performed with control variables: construction date, distance from city centre, property type and ownership type.

This study finds non-linear increases in the value of a property based on energy labels, for all labels. With Label A showing a premium of 4,65% and label G showing a 4,89% premium. The conclusion of this paper should be a modest suggestion that energy efficiency is not sufficiently capitalized into the value of affordable housing properties, and that energy efficiency renovations are not profitable in the renovate-sell approach as a way to offload troublesome properties responsibly and improve cash flows.

Although the hedonic model included age and type of dwelling, other unaccounted factors are likely to have also played a role. These findings show that energy efficiency is capitalized into the value of real estate, but it seems to play a small role when as compared other coefficients tested. To improve this research, property values should be cross-checked through multiple sources, and perhaps incorporate transaction prices to control for non-rational factors. Although transaction prices would likely lead to more volatile results over time, it would reflect the market trends more accurately. The incorporation of information about the maintenance level and overall dwelling and neighbourhood quality and property layout should also increase the power of the hedonic regression. Probably it would also add to the accuracy of the regression when individual affordable housing corporations would be tested next to each other. Lastly, research into property-type and age specific real estate will most likely substantially improve the quality of further research into the matter.

Overall, there is a small pool of literature concerning specifically real estate properties owned and managed by affordable housing corporations. With the largest number of studies and qualitative observations from the Dutch context, likely due to the high proportion and quality of affordable housing in the Netherlands, it is difficult to compare findings to international contexts. It would greatly add to the interpretability of the results if there were similar quantitative studies from a more diverse range of countries. This paper has added a small piece to the puzzle of international literature regarding energy labels and their effects on affordable housing.

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Table 1 Regression Collinearity Diagnostics

Collinearity Diagnostics[a]				
	Tolerance	VIF	Eigenvalue	Condition Index
Woningsoort_2_onder_1	0,998	1,002	4,246	1,000
Woningsoort_Benedenwoning	0,995	1,005	1,821	1,527
Woningsoort_Bovenwoning	0,995	1,005	1,563	1,648
Woningsoort_Geschakelde_Woning	0,996	1,004	1,338	1,781
Woningsoort_Hoekwoning	0,999	1,001	1,233	1,856
Woningsoort_Maisonnette	0,993	1,007	1,166	1,908
Woningsoort_Meergezinswoning	0,965	1,037	1,128	1,941
Woningsoort_Tussen_rijwoning	0,986	1,015	1,078	1,984
Woningsoort_Vrijstaande_woning	0,999	1,001	1,058	2,003
Bouwjaar1800_1899	1,000	1,000	1,049	2,012
Bouwjaar1900_1910	1,000	1,000	1,031	2,030
Bouwjaar1911_1920	0,996	1,004	1,012	2,049
Bouwjaar1921_1930	0,988	1,012	1,004	2,056
Bouwjaar1931_1940	0,999	1,001	0,999	2,062
Bouwjaar1941_1950	0,978	1,023	0,980	2,081
Bouwjaar1951_1960	0,938	1,066	0,954	2,109
Bouwjaar1971_1980	0,972	1,029	0,943	2,122
Bouwjaar1981_1990	0,950	1,053	0,932	2,135
Bouwjaar1991_2000	0,953	1,050	0,894	2,179
Bouwjaar2001_2015	0,547	1,827	0,860	2,222
Eigendom	0,983	1,018	0,824	2,270
DISTANCE METERS	0,996	1,004	0,792	2,316

a. Dependent Variable: EUR_per_M2

Table 2 Model Summary & ANOVA

Model Summaryf									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,257a	0,066	0,066	319,603	0,066	433,422	6	36837	0,000
2	,352b	0,124	0,124	309,549	0,058	271,175	9	36828	0,000
3	,550c	0,302	0,302	276,274	0,178	856,048	11	36817	0,000
4	,553d	0,306	0,305	275,639	0,003	171,027	1	36816	0,000
5	,645e	0,416	0,415	252,835	0,110	6941,600	1	36815	0,000

ANOVAa						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	265633702,285	6	44272283,714	433,422	,000b
	Residual	3762747840,734	36837	102145,882		
	Total	4028381543,019	36843			
2	Regression	499491311,425	15	33299420,762	347,517	,000c
	Residual	3528890231,594	36828	95820,849		
	Total	4028381543,019	36843			
3	Regression	1218231383,415	26	46855053,208	613,868	,000d
	Residual	2810150159,604	36817	76327,516		
	Total	4028381543,019	36843			
4	Regression	1231225459,031	27	45600942,927	600,197	,000e
	Residual	2797156083,987	36816	75976,643		
	Total	4028381543,019	36843			
5	Regression	1674969698,661	28	59820346,381	935,784	,000f
	Residual	2353411844,358	36815	63925,352		
	Total	4028381543,019	36843			

Block 1: Energy Label
Block 2: Residential Type
Block 3: Construction Date
Block 4: Ownership Status
Block 5: Distance From City Centre → **this is the block used in the hedonic regression**

Table 3 Residual Statistics

Residuals Statistics[a]					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	814,88	2109,35	1402,34	213,219	36844
Residual	-1184,098	2164,131	0,000	252,739	36844
Std. Predicted Value	-2,755	3,316	0,000	1,000	36844
Std. Residual	-4,683	8,559	0,000	1,000	36844
a. Dependent Variable: EUR_per_M2					

Table 4 Residuals: Histogram, P-P Plot and Scatterplot

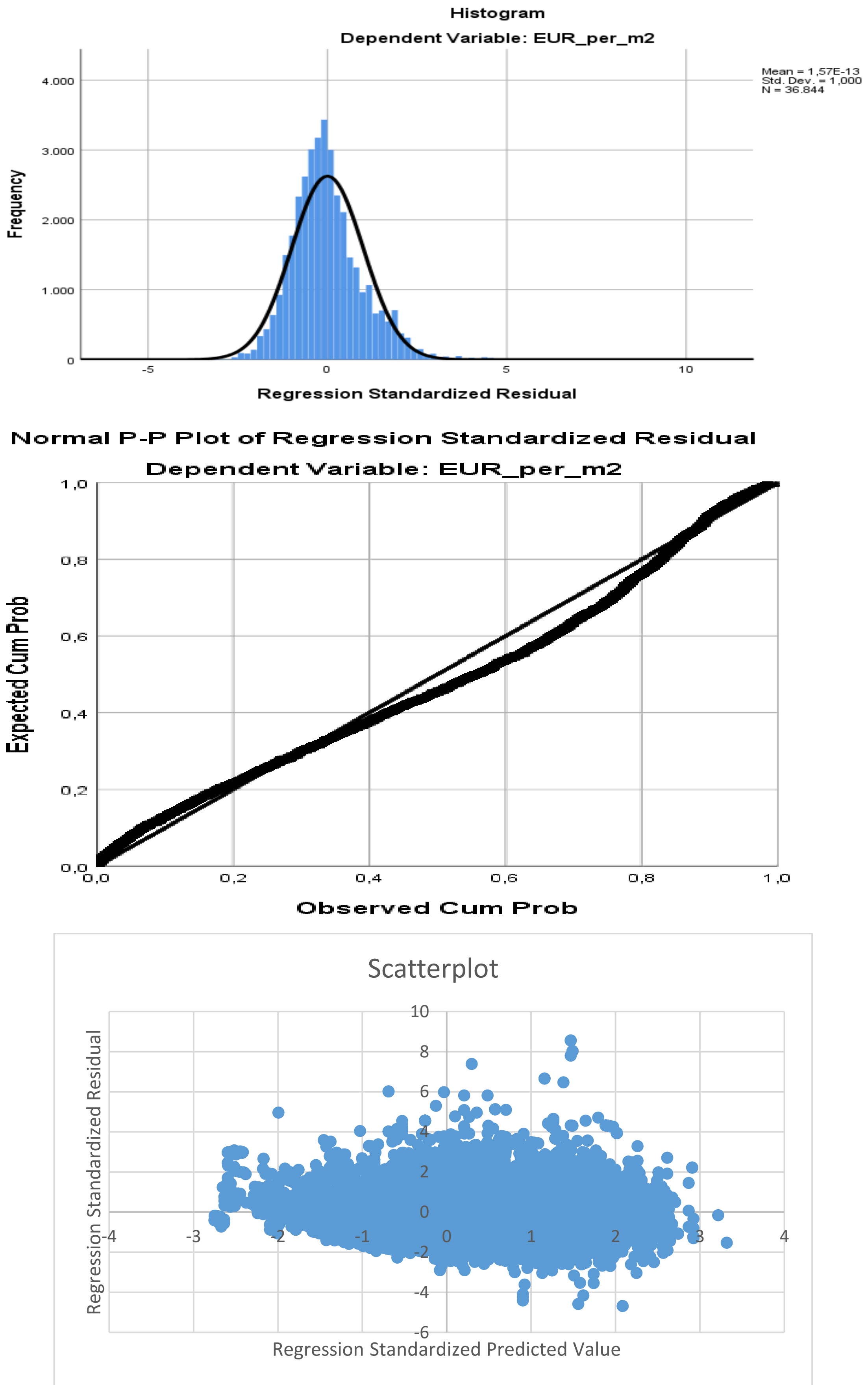

Table 5 Regression results of different hedonic models where different explainabble variables are considered

Regression results of different Hedonic models where explainable variables are considered in the model	Model 1			Model 2			Model 3			Model 4			Model 5		
	Unstand. Coe.	Std. Error	Std. Coe.	Unstand. Coe.	Std. Error	Std. Coe.	Unstand. Coe.	Std. Error	Std. Coe.	Unstand. Coe.	Std. Error	Std. Coe.	Unstand. Coe.	Std. Error	Std. Coe.
(Constant)	1388,433	2,994		1427,382	3,706		1264,458	4,403		1261,743	4,398		1526,534	5,135	
A>	253,565	6,994	0,195	279,258	6,882	0,215	38,325	7,997	0,029	38,842	7,979	0,030	71,001	7,329	0,055
B	106,572	5,132	0,118	107,654	4,981	0,119	42,891	4,534	0,048	43,830	4,525	0,049	53,748	4,152	0,060
D	-56,439	4,366	-0,076	-49,856	4,255	-0,067	4,343	3,886	0,006	2,691	3,880	0,004	4,469	3,559	0,006
E	-40,092	5,605	-0,040	-50,806	5,486	-0,051	33,582	5,096	0,033	28,375	5,099	0,028	26,354	4,678	0,026
F	-22,085	8,318	-0,014	-33,531	8,134	-0,021	23,736	7,460	0,015	13,604	7,483	0,009	19,031	6,865	0,012
G	43,401	12,898	0,017	30,814	12,587	0,012	71,210	11,382	0,028	58,956	11,395	0,023	74,651	10,454	0,030
2_onder_1				-100,567	18,355	-0,027	-200,434	16,611	-0,054	-212,171	16,597	-0,057	1,542	15,439	0,000
Benedenwoning				130,969	6,654	0,101	-66,671	7,238	-0,052	-66,517	7,222	-0,052	-51,448	6,627	-0,040
Bovenwoning				-116,649	5,662	-0,108	-302,742	6,533	-0,281	-301,617	6,519	-0,280	-295,526	5,980	-0,274
Geschakelde_Woning				-153,555	12,643	-0,060	-186,982	11,541	-0,073	-193,502	11,525	-0,076	-83,424	10,654	-0,033
Hoekwoning				-205,847	7,970	-0,131	-193,837	7,210	-0,123	-198,586	7,202	-0,126	-101,128	6,709	-0,064
Maisonnette				-56,356	35,723	-0,008	-156,737	31,995	-0,022	-162,919	31,925	-0,022	-106,654	29,291	-0,015
Meergezinswoning				-16,543	4,498	-0,020	-38,092	4,196	-0,047	-35,979	4,190	-0,045	-27,142	3,845	-0,034
Tussen_rijwoning				-137,368	4,961	-0,150	-175,803	4,644	-0,192	-179,654	4,643	-0,196	-115,245	4,328	-0,126
Vrijstaande_woning				160,642	55,680	0,014	29,053	49,745	0,003	-21,764	49,782	-0,002	223,279	45,758	0,020
1800_1899							602,951	18,596	0,145	591,607	18,573	0,142	391,087	17,206	0,094
1900_1910							554,360	24,035	0,103	539,956	24,005	0,100	363,485	22,121	0,067
1911_1920							412,997	9,093	0,226	407,632	9,081	0,223	303,057	8,424	0,166
1921_1930							472,028	7,735	0,355	466,547	7,729	0,351	332,956	7,268	0,250
1931_1940							344,927	7,922	0,254	344,926	7,904	0,254	227,838	7,385	0,168
1941_1950							211,386	8,525	0,123	213,888	8,507	0,125	120,528	7,883	0,070
1951_1960							115,741	5,476	0,111	117,330	5,465	0,113	81,683	5,031	0,078
1971_1980							44,765	5,034	0,048	42,902	5,025	0,046	115,812	4,691	0,125
1981_1990							236,957	4,871	0,272	235,798	4,860	0,271	248,136	4,461	0,285
1991_2000							373,854	6,474	0,296	373,357	6,459	0,296	393,927	5,930	0,312
2001_2015							511,760	8,406	0,397	509,402	8,389	0,395	474,982	7,706	0,368
Eigendom										69,263	5,296	0,058	74,912	4,859	0,063
DISTANCE METERS													-0,072	0,001	-0,398
Holdouts: Block 1 (Energylabel C); Block 2 (Portiekwoning); Block 3 (1961_1970); Block 4 (Rental)															

Block 1: Energy Label
Block 2: Residential Type
Block 3: Construction Date
Block 4: Ownership Status
Block 5: Distance From City Centre