THE VALUE OF ACTUAL ENERGY PERFORMANCE IN THE DUTCH PRIVATE RESIDENTIAL SECTOR: A QUANTITATIVE APPROACH

COLOFON

Title	The value of actual energy performance in the Dutch private residential sector: A quantitative approach
Version	3.0 (Final)
Author	Niels Fine
Studentnumber	S3098028
E-mail	n.fine@student.rug.nl
	nielsfine@live.nl
Supervisor	Dr. Xiaolong Liu

Abstract.

A Dutch resident caused 30 percent more emissions than the average European. Only five EU countries are doing it worse than the Netherlands. Therefore, the Dutch residential sector is one of the key targets to reduce emissions. Policies, laws and regulations on both national and European scale try to encourage energy performance technologies in the building sector. This paper contributes to the literature by measuring actual energy performance instead of labels or certificates. Previous literature has showed the importance of increasing the energy performance of buildings by reducing energy use. However, there is not enough quantitative and reliable data available to base financial decisions on. Besides, The Dutch energy performance certificates (EPC) indicate the theoretical value of gas and electricity consumption and research have shown a disparity between theoretical and actual energy use. As a result, the EPC's are not representative for actual performance and can therefore influence clients in a wrong way. From 31 December 2020, all member states of the European Union, the Netherlands included, have to use the NZEB-tool to value energy performance. The concept of NZEB is based on Trias Energetica and the unit of measuring energy performance is kWh / m2 / year. This study uses a representative quantitative dataset of transactions in the Dutch owner-occupied residential sector with associated housing characteristics from 2013 to 2017. The average energy performance of the Dutch residential sector is between 150 and 175 kWh/m2/year. The results show a price premium for all transactions with higher energy performance. Transactions with the best energy performance (<25 kWh/m2/year) are transacted at an average price premium of 14.9% more than the base category.

Keyword: NZEB, EPC, energy performance, Dutch residential sector, Trias Energetica.

Master theses are preliminary materials to stimulate discussion and critical comment. The analysis and conclusion set forth are those of the author and do not indicate concurrence by the supervisor or research stuff.

CONTENT

1. INTRODUCTION

1.1 Motivation

The Netherlands uses a large amount of fossil fuel for both energy consumption as the generation of electricity. Only 5 percent of all energy comes from renewable sources, for example in Sweden it is 52 percent. The Netherlands is largely reliant on coal and natural gas, including the residential sector. A Dutch resident caused 30 percent more emissions than the average European. Only five EU countries are doing it worse than the Netherlands (CBS, 2016). Therefore, the Dutch residential sector is one of the key targets to reduce emissions. The energy performance of all houses in the Netherlands need to increase significantly by the end of 2050 (PBL, 2014). Energy performance is defined as:

'The amount of energy needed to meet the energy demand associated with a typical use of the building which includes inter alia, energy used for heating, cooling, ventilation, hot water and *lighting' (European Commission, 2016).*

Buildings are responsible for almost 40% of the European Union's (EU) energy consumption and accounted for 30% of EU's CO2 emissions in 2005 (SERPEC, 2009). Policies, laws and regulations on both national and European scale try to encourage energy performance technologies in the building sector (Cerin et al., 2014). In 2009, the average energy bill in the Netherlands ranged from €105, - to €231, -. For some households, energy costs represent almost half of the total monthly housing budget (Brounen & Kok, 2011). Moreover, energy costs will grow in the future. CBS predicts that a household will pay €334, - more for energy in 2019 compared to 2018 (Parool, 2019). The effectiveness of valuation is according to the European Union deeply reliant on the way they are carried out by the country in question (Mudgal, 2013). The regulation of building energy performance is in most EU member states based on building codes and the use of energy labels (European Union, 2010), both hypothetical calculation methods of energy performance. Also, the Dutch theoretical label calculation is a simplified static model.

Previous literature has showed the relevance of increasing the energy performance of the residential sector by reducing energy use (Cerin et al., 2014). However, Häkkinen and Belloni (2011) emphasize the fact that energy performance is not adequately valued by consumers due to the lack of information. As a result of difficulties in adopting energy performance attributes, there is not enough quantitative and reliable data available to base financial decisions on. Nonetheless, the valuation of energy performance of buildings has the possibility to become a crucial source of data within the residential sector (Lutzkendorf & Lorenz, 2011).

1.2 New energy performance policies

1.2.1 Dutch policy

In the Netherlands, laws and regulations are being made to increase the energy performance of the residential sector. Dutch natural gas (fossil energy) was for years in abundance and inexpensive thanks to the *Groninger* gasfield. Since 1959, 95% of the Dutch housing stock has been connected to gas. As a result of the gas extraction, major earthquake damage has occurred in the region of North-East Groningen. To stop the earthquake issues, Eric Wiebes (2018) - Minister for Economic Affairs and the Climate -, decided to break down gas winning in Groningen at the end of 2030. After the decision of breaking down the gas extraction in Groningen, the Dutch government approved at the 9th of April 2018 a change of the electricity and gas law 1998 (2018, April 26). The law now prescribes that new construction can no longer be connected to natural gas after the first of July 2018.

1.2.2 European policy

The building industry account for 40% of total energy consumption in the European Union. Therefore, the reduction of energy consumption and the increasing use of renewable energy are important EU goals to reduce fossil energy dependency and emissions (European Parliament, 2010). The European Union requires all new buildings to be nearly zero-energy by the end of 2020 (NZEB). A NZEB is defined in Article 2(2) of the Directive 2010/31/EU as:

'*A building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby'*.

The concept of NZEB provides synergy between renewable energy and energy performance in order to obtain the most cost-effective solution (European Commission, 2016).

1.2.3 NZEB

Newly built homes in The Netherlands have to change from their energy performance certification to the NZEB method. The concept of NZEB is based on Trias Energetica. The concept was introduced in 1996 by Dr. Lysen. As a strategy, this has been elaborated by Dr. Duijvestein, from the TU Delft, which emphasized the order of the successive steps (RVO, 2013). In the simplest form the Trias Energetica looks like this:

Step 1. Limit the energy demand
Step 2. Use energy from renewable sources
Step 3. Use finite (fossil) energy sources efficient

From January 1, 2020, the Netherlands included, have to use the NZEB-tool to value energy performance. The unit of energy will be kWh/m2 per year'. The NZEB-tool is structured as follows:

Step	**Indicator**	**Meaning**	**Requirement**
NZEB 1	Energy requirement	Need for energy for heating and cooling	Maximum 70 kWh/m2 per year thermal
NZEB 2	Primary fossil energy consumption	The amount of fossil fuel used for heating, cooling, hot water and Installations	Maximum 30 kWh/m2 per year primary fossil
NZEB 3	Share of renewable energy	The amount of renewable energy divided by the total primary energy use (fossil + renewable).	Minimum 50%

Table 1: The NZEB-tool (Aedes, 2018)

The advisory requirements for the average new home have been set at 70 kWh / m2 / year for NZEB 1 (energy requirement), 30 kWh / m2 / year for NZEB 2 (primary fossil energy consumption) and 50% for NZEB 3 (share of renewable energy). The Ministry of Foreign Affairs announced the intended requirements at the NEN conference at November 20, 2018. The NZEB-tool is developing and details are worked out (Aedes, 2018). NZEB causes the entire construction industry, from the process of developing, designing, building and sales, big challenges (RVO, 2017). Brounen and Kok (2011) have demonstrated that start-up problems cause negative effects on introducing and implementing energy labels. They infer that the Dutch government have to take lessons out of the way energy labels were implemented in the Netherlands. Together with providing housing without natural gas, it is essential that more experience is gained over the next years with building NZEB in the Netherlands (Blok, 2015).

1.3 Scientific relevance

Until now, the only comparable academic research focusing on the Dutch residential sector has been examined by Brounen & Kok (2011). However, the work of Brounen & Kok is not in line with future European calculation methods. Also, in recent years energy performance has gained a lot of importance and new insights. It's difficult to point out the actual market value of energy performance when missing crucial reliable quantitative and widely supported documentation and research (Häkkinen & Belloni, 2011). The purpose of this paper is to focus on recent methods using other valuation methods to value energy performance.

1.4 Central research question

This paper contributes to the literature by measuring actual energy performance, which is in line with future European calculation methods instead of labels or certificates. Therefore, the research aim of this study is to value actual energy performance in the Dutch private residential sector. The unit of measurement for energy performance is kWh/m2/year, where the value is measured in Euro's.

1.5 Conceptual model

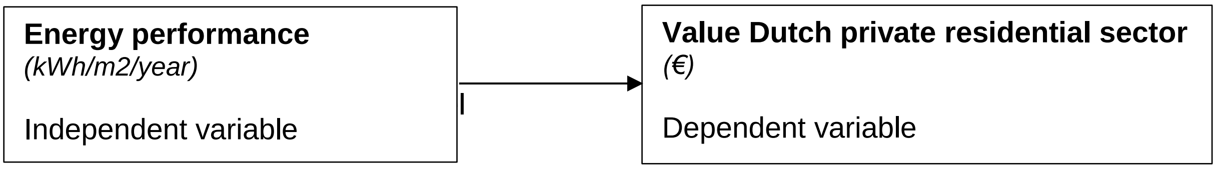


Fig 1. Conceptual model

The conceptual model shows the simplified representation of the research problem (figure 1). The model can be used as a basic guideline in order to give answer to the central research question.

1.6 Research design

This study uses a representative quantitative dataset of transactions in the owner-occupied residential sector with associated housing characteristics from 2013 to 2017. Second, this study makes use of detailed variables to measure energy performance. In order to investigate time variation, the analysis benefits from an annual measure of energy performance in order to estimate results from 2013 - 2017.

1.7 Stratified sampling

It was not possible to gather transactions for all provinces due to the limited data supply of the NVM. The NVM could only provide data with the needful variables for 4 provinces. In the Netherlands, there are regional differences in pressure on the housing market and population growth (PBL/CBS, 2016). For this reason and to reduce human bias, the NVM had to choose 2 provinces which are declining and growing in population. The sampling method can be called as stratified. Subsequently, the NVM took for both groups two random provinces: Groningen, Zeeland, Flevoland and Gelderland. Flevoland and Gelderland are increasing in population, Groningen and Zeeland are decreasing in population (Appendix K). As a result, the sample is representative of the population of interest.

Fig. 2. Four observed Dutch provinces

The remainder of this paper is organized as follows. Chapter 2 describes the theory behind valuing the housing market and energy performance both in a scientific and political way. Chapter 3 describes the methodology. Chapter 4 presents the data, where chapter 5 discusses the results. Chapter 6 concludes, followed by the references and appendix.

2. THEORY

In order to answer the research question, literature into this subject what already have been done in the Netherlands and abroad has been studied. The results of these studies were examined. In addition, the studies also helped to choose the right approach for this research.

2.1 Valuing the Dutch residential sector

2.1.1 Building characteristics

The residential sector is heterogeneous: houses differ in construction period, type, quality, location and living environment. The valuation process tries to include all characteristics that influence the market value. According to Cobb (1984), building characteristics have the most influence on the value and can be seen as the base of determining the value of a house. Also, Boelhouwer and De Vries (2000) came to this conclusion. Studies by Kain and Quinley (1970) and Witte et al. (1979) indicated size is the most important building characteristic. However, a larger number of rooms make a negative input to the house price. A more spacious looking house is priced more than a house with more, but smaller spaces (Visser & Van Dam, 2006). Not only the existence of characteristics is critical, also the quality of these characteristics is critical into the valuing process (Kain & Quigley, 1970). Follain and Jimenez (1985) searched for the willingness to pay for certain building characteristics. The results showed a minimal willingness to pay for extra living space. In other words, when the buyer's income increases, the willingness to pay for extra living space does not grow in the same line with it. On the other hand, quality variables seem to react different. An increase in income appears to have a major effect on the willingness to pay for quality variables (Follain and Jimenez, 1985). In the Netherlands, houses with more qualitative isolation and maintenance variables respond significant and positive with the transaction price (Brounen & Kok, 2011). Visser and Van Dam (2006) carried out a major research on the Dutch residential sector. They showed that the physical building characteristics have a major influence on house prices. Building characteristics in urban environments explain approximately 44 percent of the house price. This percentage is in a rural environment even higher, around 54 percent. The construction period and the type of house also have an influence on the house price. Newer homes are more expensive than older ones, and detached houses and semi-detached houses are much more expensive than terraced houses (Visser & Van Dam, 2006).

2.1.2 Location characteristics

In land-use theory is often appointed that value is determined by only one thing: location. As already mentioned by Cobb (1984), this not really the case. However, theories by Von Thünen (1826), Weber (1929) and Christaller (1966) analyzed the great importance of geographical location of specific activities in relation to the value of land. The bid-rent theory by Alonso (1964) can be seen as the base for economic analysis of land value. The theory focuses on the relationship between land use and the value of land. Individual households and businesses make trade-offs between land price, transport costs and the amount of land they need. This leads to a simple model, in which land prices decreases as you move further away from the center of the city. Mostly commercial activities are concentrated in the center of the city. Industrial and residential activities will choose a location further away from the city center. The American sociologist Florida states that a metropolitan center with many amenities attracts more consumers than a center with fewer facilities (Florida, 2002). Again, Visser and Van Dam (2006) concluded this in the Netherlands, where in (inner) cities the land price is higher, which means more often opted for high-rise buildings. The land price is lower in suburbs and around the cities where more single-family houses are built and the house price is lower (Visser & Van Dam, 2006).

Besides national location, also regional and local factors affect market values. The presence of open spaces, greenery and water have significant impact (Gulicher, 2008). Tyrväinen and Miettinen (2000) studied the impact of urban forests on house prices. Forest view and the nearness of a forest have both a positive effect on house prices. Every kilometer further away from the nearest forest, leads to a decrease in value up to 5,9%. In addition, Luttik (2000) researched the effect of greenery on housing prices in the Netherlands. The results show that the view on open space has a premium of 6% and 12%. Concluding, the valuation process is based on many variables of physical, social and spatial nature. The following question is, what part does energy performance has in the valuing process of the residential sector.

2.2 The barriers of improving energy performance

2.2.1 Additional building costs

Sustainability requires an investment, both from the perspective of the project developer as well as the consumer. The project developer will have to face additional building costs and

the risk to overprice the product in the market. Consumers on the other hand need a higher mortgage or make a higher investment in the property. Additional costs are the biggest barrier in adopting measures to increase energy performance (Hydes and Creech, 2000).
Shi et al. (2016) have researched the degree of conflict for stakeholders in the process of sustainable construction. They have seen a great conflict between the cost effectiveness and green buildings. In other words, higher building costs is the most likely reason to blow of sustainable construction.
In a study by Kim et al. (2014) the authors noted an increase of 10.77% in the construction cost due to the implementation of energy saving attributes for residential projects. In comparison with a traditional building, the 'green' building include a PV-system as alternative power supply, electrical vehicle charging system, high-efficiency cooling and heating system, energy efficient water heater and electrical device and energy efficient lighting fixtures.

2.2.2 Client demand

The social acceptance of green buildings is a known factor in the decision of investing in energy saving attributes. The value of a house corresponds with the amount of money buyers are willing to spend. Investments in energy efficiency attributes are still low despite less fixed- and maintenance costs and better building- and climate performance. More attention from multiple stakeholders has been asked to raise public awareness and know-how about the benefits. This should take effect by developing a method to enlarge the availability and quality of information to the public (Häkkinen and Belloni, 2011).
Dong-XueZhao et al. (2015) emphasize the social problems behind the lack of awareness of energy performance such as customer knowledge, investment intention, hierarchy of needs, behaviors and social acceptance. Although the intention of the majority of consumers is to pay more for energy efficiency over the standard building, actual investments are small.

2.2.3 Lack of transparency

Investments in energy performance is based on information and the understanding of the economic and social benefits (Wustenhagen et al., 2007). Yet, house buyers are generally not fully informed about energy performance of the house they want to buy and so not capable of making rational decisions. Palmquist (2005) argues that expectations value the house. When house buyers correct their expectations, also the value changes. The less information there is available, the smaller the premium, and vice versa. These expectations greatly depend on the awareness and information people have. This issue can be best explained by the theory of Akerlof's (1970) 'market for lemons'. Theoretically, when missing crucial reliable information about energy performance, house buyers will pay a lower amount for a better performing house than what it is worth. In order to create transparency among stakeholders, information and knowledge will have to be shared more efficiently in the future. The integration of energy performance into the property valuation process is just a particular illustration (Lutzkendorf & Lorenz, 2011).

2.2.4 Lack of standard measurement

The valuation process of energy efficiency is dependent on the way they are carried out by the EU member states (Mudgal, 2013). This indicates a lack of standard measurement throughout the EU, which ensures differences between the measurability of energy performance and to what extent it is realized (Allcott and Greenstone, 2012). Additionally, studies that have been written indicated a discrepancy between theoretical and actual energy use (Majcen, 2016; Laurent et al., 2013). In the Netherlands, Guerra Santin (2010) showed that actual energy use in strong performing dwellings was higher in reality than first had been theoretically calculated. Upgrading or buying a house to improve energy performance needs an investment in advance, and the uncertainty in relation to its return can be a reason for consumers not to undertake this investments in energy performance (Majcen, 2016).

2.2.5. Lack of responsibility

Shi et al. (2016) plead for more effort from developers, clients and the government during the green building developments. The stakeholders should not pay attention so much to costs, but to the gains in the mid- to long term. All stakeholders need to work together to minimize conflicts within sustainable construction. From the perspective of building's long-term performance, it will be important to reduce capital cost and incremental cost of green building developments.

2.3 The drivers of improving energy performance

2.3.1 Price premium

Banfi et al. (2008) found out there is a 13% premium for better energy performance. A lower price premium is found in Ireland, where the price of a dwelling increases by 2,3% per rising label (Mudgal et al., 2013). Cajias and Piazolo (2012) found in the German residential sector

a one percent increase in energy performance, increased rents by 0.08% and the market value of houses by 0.45%. In the Netherlands, Brounen and Kok (2011) found a positive relation between transaction price and energy labels during 2008 and 2009. Houses with the highest energy rating sold for 10.2% more relative to the average rating. Hyland et al. (2013) find a premium 9.3% for a label A compared to a label D. Conversely, an F or G label is worth 10,6% less. A more recent study by Van Hoek and Koning (2018) showed that the savings on energy costs in a ‘green’ building vary between €1100, - and €2100, - per year when compared to a label D.
Multiple studies, starting by Hausman (1979), show future energy savings exceeds the primary energy performance investments. Mandell & Wilhelmsson (2011) have showed the willingness to pay (WTP) for extra environmental characteristics. The outcomes demonstrate a positive WTP for climate attributes and it is even higher for households who are environmentally aware. Increasing the environmental awareness in a society leads to a larger market value for energy efficiency (Mandell & Wilhelmsson, 2011). Brounen et al. (2015) found out there is not a significant indication that certificating or labeling itself has an impact on the transaction price or the buyer’s valuation of a house. They propose that more research needs to be done in understanding investment choices of households.

2.3.2 Client demand

There has been recently more attention for improving the energy performance in the residential sector. House prices are mainly driven by location, size and dwelling type. However, the price is also influenced by attributes as triple glazing, isolation and improved energy systems. Especially due to certification in the EU there has been a change in consumer behavior by providing information on the energy performance. Growing concern about climate change there has been an increasing client concern and parallel to this a client demand for energy performance (Fuerst et al., 2015).

2.4 Valuing energy performance

2.4.1 Energy performance certification

Valuing energy performance demonstrate the added value generated by the good ‘energy performance’. Energy performance has become more important and should affect market value of a property, but is still not directly valued in the market price. In January 2008, energy performance certification (EPC) was introduced in the Netherlands by the European Union

Energy Performance Directive (EPBD). The certification is based on physical characteristics of a dwelling in order to predict the total energy consumption. Literature show a positive and significant relationship between EPC's and transaction prices (Brounen & Kok, 2011). Nevertheless, available data of EPC's do not match with recent building conditions. The EPC labels indicate the theoretical value of gas and electricity consumption. Within that value, a moderate score on one aspect can be compensated by an extra high score on another aspect. For example, a poorly insulated house can be compensated with a lot of solar panels. The unit of energy is measured in MJ/m2 per year. A house with an excellent EPC doesn't mean by definition a low amount of kWh/m2 a year. As a result, the labels are not representative for actual performance and can therefore influence clients in a wrong way (Majcen, 2016).

2.4.2 Discrepancy between theoretical and actual energy use

Multiple studies indicated a disparity between theoretical and actual energy use (Majcen 2016; Laurent et al, 2013). The gap between theoretical and actual energy use derive due to numerous uncertainties. Ramallo-González et al., (2013) labels these uncertainties into three groups: environmental, workmanship and behavioral. Environmental describes the energy performance which is different from what is primarily assumed. The workmanship factor indicates the discrepancy between documentation and actual performance. For instance, the underperformance of certain installation systems. Another example is the quality of the surveillance, calculation and documentation of the labelling process of energy performance. Behavioral involves client behavior and attitude what has an effect on indoor temperature- and ventilation settings or showering. Guerra Santin (2010) also indicate that the degree of comfort a household wants has impact on the energy performance. The labelling process is a theoretical model, which does not take into account the above-mentioned subjective acts.

2.4.3 Performance gap

Another problem which has been recognized is the energy efficiency gap. This performance gap states the contrast between the assumed level of energy performance investments and the level actually achieved (Allcott and Greenstone, 2012). This gap often shows the financial downside of investing in energy efficiency measures. Uncertainties about financial returns may be a reason for clients not to improve its energy performance. For example, Majcen (2016) observed upgraded building in the Netherlands from label G towards label A. These buildings performed significantly less than in the first place was expected. When results structurally lead to a negative performance gap, payback times could be inaccurate as well as achieving targets that have been set for increasing energy performance.

2.4.4 (Breaking) The vicious circle of blame

Cadman (2000) defined the concept of 'the vicious circle of blame' among the stakeholders which are involved in the energy performance process. The concept states that developers, investors, constructors and owners blame each other for not adapting energy efficient attributes. The valuation process of energy performance doesn't change if the attitude towards energy performance also not change (Cadman, 2000). As a response, Lorenz and Hartenberger (2008) created the concept 'breaking the vicious circle of blame', where all above mentioned stakeholders add value to this process (figure 3). In fact, it can be seen as a potential vicious circle since responsibilities are often still missing.

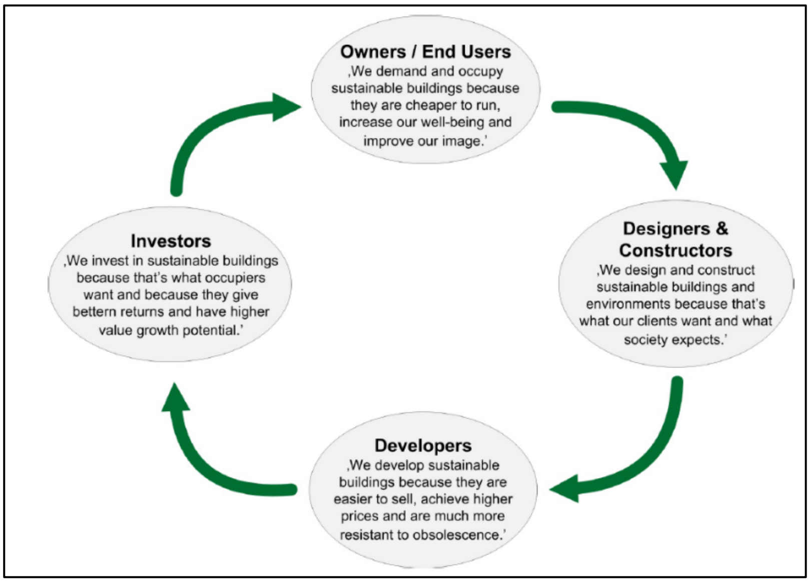


Fig. 3. Breaking the vicious circle of blame (Lorenz & Hartenberger, 2008)

The question of interest is: how much is a consumer willing to pay for energy performance in the Dutch residential sector? Therefore, the research hypothesis will be write down as follows:

'In the Dutch residential sector, higher energy performance sells at a price premium relatively to similar properties, and lower energy performance sell at a price discount'.

3. METHODOLOGY

This chapter explains the choice for the basic model. Why is this model the most suitable instrument to determine the value? Second, the regression model used for calculating the effect of energy performance on housing values is presented and explained. Then it is indicated how the results of the regression must be interpreted. Last, some limitations to the model are discussed.

3.1 Hedonic regression model

A regression analysis describes the relationship between a given variable and one or more other variables. The model operates from the notion that the economic value of a product is the result of measurable qualities and properties (Rosen, 1974). The model is used for the valuation of real estate based on their properties. According to Rosen, the hedonic pricing model is based on the assumption that a house can be as a sum of characteristics. The housing market is heterogeneous and not a uniform entity. It is therefore not possible to simply compare houses by its price. The price of a dwelling is determined by the price of his characteristics. In the model, it is possible to divide the characteristics into subgroups: Energy performance (P) transaction (T), building (B), location, (L), and time (Y). The basic hedonic regression model can be write down in mathematical terms as follows:

$$y(V) = x(P, T, B, L, Y)$$

The left form is the value of the house and is the sum of the right form, i.e. the characteristics. The OLS- assumptions have been checked for and no problems have come to light in advance (Appendix F/G/H). The variables will be discussed in greater detail.

3.2 Aggregated variables

In this study, the master dataset from the NVM first consisted of individual house transactions. The other datasets existed of zip code P6 observations due to privacy reasons (Appendix J). By reason of potential inaccurate results, all observations need to be aggregated at a zip code P6 level. Therefore, the individual transactions were aggregated into an average transaction price of a zip code P6, together with other NVM variables. Consequently, all observations with underlying variables are measured at the same level.

3.3 The regression model

The hedonic regression model is used to estimate the effect of energy ratings (as a proxy for energy performance) on average transaction prices (as a proxy for the value) through OLS. The regression model of this research can be write down as follows:

$$\ln(V) = \alpha + \beta_P P + \beta_t T + \beta_b B + \beta_l L + \beta_y Y + u$$

Where,

α = Constant
V= Transaction price
P= Energy Performance variables
T= Transaction variables
B= Building variables
L= Location variables
Y= Year variables
u = Error term

For the display of all variables in the subgroups of the model you are referred to appendix C. The characteristics used during this research are logical with the variables that are commonly used for these kinds of regressions. The dependent variable is the transaction price ($\ln(V)$), which is the natural logarithm of the average transaction price of a neighborhood. The observations are normally distributed due to a limited number of extreme observations (Appendix H). These extreme values have, despite only a small number observations, a major influence on the outcomes in a regression in absolute terms. Therefore, this study transformed the dependent variable into a logarithm. Another reason is to create a linear relationship and to seek a constant rate of change. The interpretation of the estimated coefficient β is that a one unit increase in X will produce an expected increase in log Y of β units.

The independent variable is energy performance ($\beta_P P$). The coefficient $\beta_P P$ measures the effect of energy performance on the average transaction price of the neighborhood. The variable ‘energy performance’ is a categorical variable, therefore the premium is measures per category and results must be interpreted in percentages. Another energy performance variable is ‘the average electricity and gas consumptions per year’ of the neighborhoods measured in euro’s. To control for transaction data ($\beta_t T$), I include the duration of the sale in days to control. Brounen and Kok (2011) argue ‘days of sale’ implies the pressure of the local housing market and consequently prices. Also, I include a dummy variable ‘Free by name’, which I expect effects the price.

The building characteristics ($\beta_b B$) starts with the type of house. A categorical variable which include apartment, terraced house, switched house, corner house, semi-detached house and a detached house. Followed by the size of the house measured in square meters. Next, this model includes the number of rooms. The same applies to the number of floors, toilets and balconies. The model adds many dummy variables into the model, like whether the neighborhood has on average a garage, basement, fireplace, own parking spot, loft or attic or not. Additionally, I include the dummy whether a dwelling is a monument or not. Monuments might have positive effect on price, but a negative effect on energy performance due to certain building restrictions (Brounen & Kok, 2011). The construction period will be included as a categorical variable to control for the age of the building since different types of building period influence prices and energy performance. I control for maintenance by assigning variables for both isolation, interior as exterior quality. Also, these variables are categorical ranging from poorly to well-conditioned. These quality variables are of substantial effect (Brounen & Kok, 2011).

This research includes locational variables ($\beta_l L$). To start with the dummy variable whether a neighborhood is situated in a center or not. Also, the model takes into account if a neighborhood is situated next to quality place like a forest, park or next to water.
Finally, the regression controls multiple years. By including a categorical variable ‘year’ ($\beta_y Y$) ranging from 2013 till 2017, the model controls for unexpected variation or special events in time which other control variables cannot capture.

3.4 Limitation to the model

However, when estimating the value of energy performance, the model can run into some limitations like omitted variable bias and self-selection into the sample. Even though the selection process is stratified, results will be not easily comparable to each other due to the diversity of effects among regions (Eichholtz et al., 2010). They find a smaller premium for buildings situated in more expensive and bigger regions. By controlling for both location factors as well as sale duration, the model controls for regional differences in pressure on the housing market.

This study uses kWh/m2/year as a proxy for energy performance. However, where labels are meant to make house buyers aware of the house's energy performance and not house sellers (who already are aware), it is possible that this influence the results. Since, this study focusses on future calculation methods, it's not in the first place the aim to measure clients' behavior. Nonetheless, a next study can take this type of awareness into account.

Another limitation is the 'human touch' where no useful variables are included. The model does not control for the number of people in a certain residential property or neighborhood. The number of persons is on the other hand an important variable in measuring energy costs. None of these data is available due to privacy reasons. Therefore, the variables number of rooms and size of the house will control for this problem.

4. DATA

In this chapter, the data will be introduced. It indicates how the data were obtained and how it was edited to a workable dataset. Last, a descriptive statistic is shown, where subsequently is zoomed in on eye-catching output.

4.1 Data sources

The Netherlands does not have one dataset including energy performance data as well as all necessary housing variables. Therefore, this study makes use of four different data sources. The transaction data with corresponding variables is used from the NVM. The energy grid operators are the other sources. Dutch grid operators have to share their information by law. The datasets contain the aggregated consumption data for all Small Consumption Connections (KV) in the service area of the Grid operator. In total 16 files are used distributed over four sources.

The NVM data consisted of individual private residential transactions. The Dutch grid operators have to ensure the anonymity of their clients, therefore these data are aggregated. A minimum of 10 connections are merged per line, what lead to observations at a zip code P6 level.

4.2 Matching procedure

Working with multiple datasets from different sources ask for equal treatment. First, all files of Enexis, Enduris and Liander needed to be combined to one dataset. The variables in these files were being renamed equally, and also translated to English. Second, variables which were no longer needed were removed. Next, the 'year' variable has been added to all energy consumption datasets. Finally, the energy consumption variables for both electricity and gas were changed into monetary values. Now, all files from the different grid operators of different years could be combined into one energy consumption dataset. This dataset consisted of 910,133 observations aggregated at zip code P6 level from the period 2013 to 2017 in the provinces Groningen, Zeeland, Flevoland and Gelderland.
Subsequently, the NVM file, consisted of 151,024 observations, needed to merge with the energy consumption dataset. After the renaming process and the removal of variables in the NVM file, the two datasets could merge, resulting in 100,043 observations. This new dataset

now consisted of individual private residential transactions with aggregated energy consumption data. Therefore, the individual observations of the NVM were collapsed to P6 zip codes. The removal of extreme values, dropping of variables and creation of dummies can be found in the appendix. After the cleaning process, the dataset consisted of 57,112 useful observations.

4.3 Creating energy performance variables

This paper builds on the results of Brounen and Kok (2011), where houses in the Netherlands with a high energy performance sell at a price premium relatively to similar properties, and low energy performance houses sell at a price discount. Besides, Cerin et al. (2014) indicates that energy performance itself, on average, are not related to the selling prices of residential properties. Therefore, energy performance need to be divided into classes for better results. The energy performance variable is divided into classes based on the Building Energy Rating (BER) method used by Irish government and European Union (SEAI, 2018) (Appendix A).

In the raw dataset, the energy performance was calculated as the average standard annual usage (SAU) and measured in kWh for electricity and in m3 (cubic meters) for gas. The standard annual usage is the expected annual consumption from a customer on a grid connection at standardized conditions and on the basis of a normalized year. It is becoming increasingly common for private individuals to induce their own energy, so the delivered energy is deducted from the SAU.

First, the monetary variable was created by multiplying the SAU with electricity- and gas prices from the relevant year (See appendix I). After this, total cost of energy was divided by the gross internal area (GIA) in m2, resulting in the variable '€/m2/year'.

Second, the NZEB variable (kWh/m2/year) was created by first transforming m3 (cubic meters) for gas into kWh. 1 m3 of gas has an upper value of 35.17 MJ. 1 kWh has an energy content of 3.6 MJ. 1 m3 of gas corresponds to 35.17 MJ divided by 3.6 MJ is 9.769 kWh. Multiplying the variable gas in m3 with 9.769 resulted in the variable gas per kWh. Now, both the electricity as the gas variable were calculated as kWh/year. The sum of both variables divided by the gross internal area (GIA) in m2, resulted in the NZEB variable 'kWh/m2 per year'. Energy performance leads to direct and indirect, monetary and non-monetary benefits. Therefore, the new NZEB energy performance variable (kWh/m2/year) and a monetary variable were created (€/m2/year).

4.4 Descriptive statistics

All data used in the model have the same frequency of observation. This study makes use of time series data. Data which have been collected over the period 2013 until 2017 on multiple variables. The variables are both continuous as discrete data. The most useful and important characteristics are described below in the descriptive statistics table (table 2).
In the context of this study, the findings were dependent upon the availability of data in three main categories; (1) transaction characteristics, (2) building and location characteristics and (3) energy performance characteristics. The collection and assembly of data from these three areas is described below.

Table 2 Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Transaction characteristics					
Transaction price (€)	57,112	219406.8	86011.28	50000	500000
duration sale (days)	57,112	256.9795	374.1279	0	3889
Building characteristics					
Type of house					
Apartment	57,112	.144453	.3515516	0	1
Terraced house	57,112	.2849139	.4513774	0	1
Switched house	57,112	.0589368	.2355085	0	1
Corner house	57,112	.1365562	.3433813	0	1
Semi-detached house	57,112	.1961234	.3970665	0	1
Detached house	57,112	.1790167	.3833696	0	1
Building period					
1500 – 1944	57,112	.1595111	.3661553	0	1
1945 – 1970	57,112	.2525914	.4345023	0	1
1971 – 2000	57,112	.4751541	.4993867	0	1
2001 >	57,112	.1127434	.3162816	0	1
House size (m2)	57,112	117.4857	33.57734	40	450
Number of rooms	57,112	4.707291	1.213542	1	20
Leasehold ('1'= Yes)	57,112	.0062684	.0789253	0	1
Free by name ('1'= Yes)	57,112	.0060233	.0773762	0	1
Monumental ('1'= Yes)	57,112	.0063734	.0795797	0	1
isolation					
Poorly isolated	57,112	.3617979	.4805249	0	1
Moderately isolated	57,112	.323995	.4680022	0	1
Sufficiently isolated	57,112	.1423344	.3493958	0	1
Good isolated	57,112	.1718728	.3772732	0	1
Interior condition					
Poorly int. condition	57,112	.0172643	.1302558	0	1
Moderately int. condition	57,112	.0799832	.2712695	0	1
Sufficiently int. condition	57,112	.7784704	.4152797	0	1
Good int. condition	57,112	.1242821	.329906	0	1
Exterior condition					
Poorly ext. condition	57,112	.0141301	.1180284	0	1
Moderately ext. condition	57,112	.0622461	.2416041	0	1
Sufficiently ext. condition	57,112	.8086567	.3933621	0	1
Good ext. condition	57,112	.1149671	.318985	0	1
Location characteristics					
Location in centre ('1'= Yes)	57,112	.0722615	.2589227	0	1
Quality location					
No extra quality	57,112	.7060513	.4555727	0	1
Next to forest	57,112	.0359469	.1861594	0	1
Next to water	57,112	.0753432	.2639466	0	1
Next to park	57,112	.0366998	.1880254	0	1
Clear sight	57,112	.1459588	.353068	0	1
Year					
2013	57,112	.1388675	.3458112	0	1
2014	57,112	.175865	.3807086	0	1
2015	57,112	.2011486	.4008624	0	1
2016	57,112	.2373757	.4254781	0	1
2017	57,112	.2467432	.4311198	0	1

4.4.1 Transaction characteristics

As discussed in the methodology, all data are aggregated at a zip code P6 level. The aggregated transaction price of a zip code ‘neighbourhood’, is the dependent variable of this study. The mean of these transactions is €219.407, -. To control for outliers, this dataset only consists of transaction prices between the €50.000, - and €500.000, -. A second transaction variable is called the duration of sale in days. As a proxy for local housing market conditions I use the variable ‘the duration days of sale’. There are transactions which are being sold at the starting day of the sale, other transactions take more than ten years.

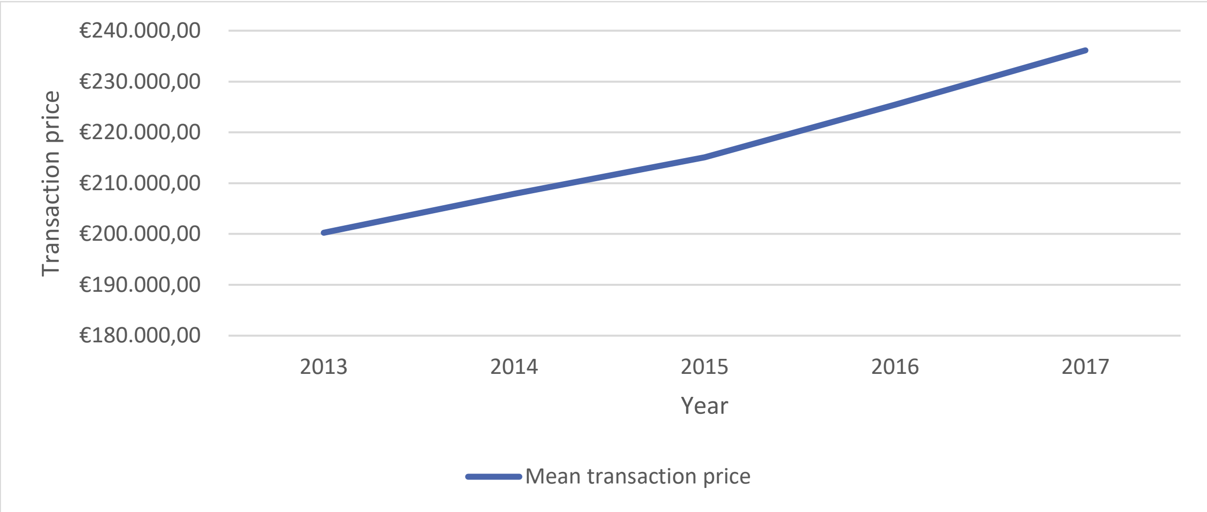


Fig. 4 Mean transaction price from 2013 until 2017

The dataset consists of transactions between 2013 and 2017 (figure 4). Moreover, it makes it possible to see the development of the transaction prices throughout the years. According to Eichholtz et al. (2013) energy performance becomes less important during less economic times because good energy performance is not a basic requirement in buying a house. Therefore, value can be affected by time. Even though we see an increase in transaction prices, the observation period of this study can be seen as moderate without any extreme economic values.

4.4.2 Building and location characteristics

The NVM data provides variables about the transacted objects. Once again, these data are aggregated at a neighborhood level. Terraced houses account for more than quarter of the sample. Subsequently, the group ‘semi-detached’ account for almost 20%. The group which have the least observations ‘Switched house’, accounts for only 6%.

There are some notable points when we tabulate type of house with the energy ratings (table 3). Most observations are in the categories 125 - 150 and 150 – 175. Again, the Energy Ratings are based on the BER method used by Irish government and European Union (see appendix A). The average energy performance of the Dutch residential sector is between 150 and 175 kWh / m2 / year, so this is in line with the sample. Apartments have substantial more observations with better energy ratings, but also substantial more observation with poor ratings. Also detached houses have more poor energy ratings. Also, semi-detached observation has relatively less low energy ratings (table 3).

Most observations are built between 1971 and 2000. The average size of observations is 117 square meters and the average number of rooms is 4,7. Also, the model contains some binary variables. Both leasehold as free by name accounts for 6% for the observed transactions. Also, the dataset consists of the binary variable ‘monuments’, 6% of the observations are monuments.

To control for maintenance and quality of the observation, the dataset uses variables to measure insolation, interior and exterior condition. Most observations are sufficiently in good condition, both inside and outside. On the contrary, 36% of the observations are poor isolated. The model uses a lot more building characteristics, which can be seen in appendix B.

To control for location, the observations include information about whether it is located in a city center. Also, whether the location of the observations have extra quality. Only 7% of all observations are located in the city center. 71% have no extra quality, but 29% do have and the most common extra quality is to have a clear view (15%).

Table 3 Cross tabulation between energyrating and type of house

Energyrating *(kWh/m2/year)*	**Apartment**	**Terraced house**	**Switched house**	**Corner-house**	**Semi-detached**	**Detached house**	**Total**
<25	28	0	0	0	0	0	28
=>25 & < 50	226	14	0	5	0	6	251
=>50 & < 75	266	41	5	24	26	65	427
=>75 & < 100	352	370	77	223	306	391	1,719
=>100 & < 125	819	2,190	497	1,003	1,255	1,016	6,780
=>125 & < 150	1,225	4,667	960	1,927	2,372	1,552	12,703
=>150 & < 175	1,377	3,903	778	1,834	2,324	1,520	11,736
=>175 & < 200	1,108	2,371	450	1,157	1,556	1,421	8,063
=>200 & < 225	738	1,191	246	689	1,072	1,135	5,071
=>225 & < 260	689	769	181	503	1,005	1,160	4,307
=>260 & < 300	471	385	84	218	599	823	2,580
=>300 & < 340	313	166	40	89	314	477	1,399
=>340 & < 380	182	91	18	62	163	269	785
=>380 & < 450	209	73	21	45	117	242	707
=>450	247	41	9	20	92	147	556
Total	8,250	16,272	3,366	7,799	11,201	10,224	57,112

4.4.3 Energy performance characteristics

The consumption of gas and electricity by households in 2016 was 9.2 percent lower than in 2012 (CBS, 2018). In line with research from CBS (2018), the consumption of gas and electricity in the dataset was 9.1% lower in 2017 than in 2013 (figure 5).

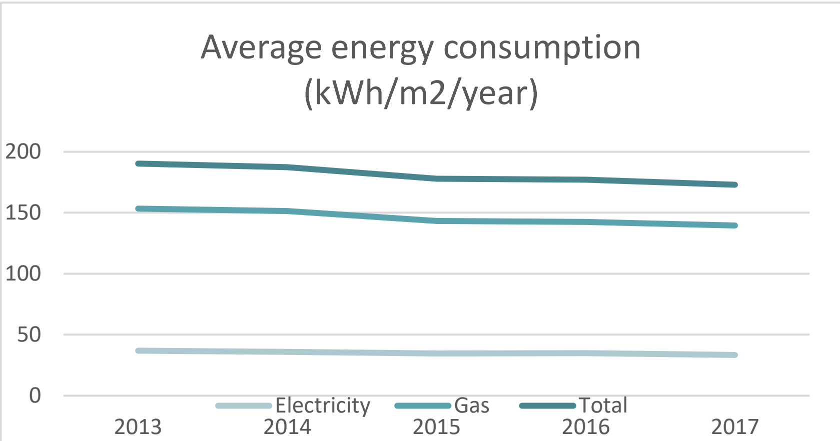


Fig. 5 Average energy consumption 2013-2017

The Energy Ratings have been plotted in table 3 and are of great importance in the model. Furthermore, the binary variable 'NZEB' is added to the model. When an observation uses less than 70 kWh / m2 / year for electricity and less than 30 kWh / m2 / year for gas, the observation meets future regulations.

Table 4. Tabulation of NZEB

NZEB	Apartment	Terraced	Switched	Corner	Semi-detached	Detached	Total
NO	7,804	16,258	3,366	7,793	11,200	10,223	56,644
YES	446	14	0	6	1	1	468
Total	8,250	16,272	3,366	7,799	11,201	10,224	57,112

Only 468 observations meet future NZEB regulation, of which 446 are apartments (table 4). The Netherlands uses a large amount of gas. On the other hand, electricity will be the main energy driver. Having a good energy rating will not say you will met future regulation. Therefore, also the variable NZEB is added to the model.

5. RESULTS

In the regression model (table 4) the results are shown. Our variable of interest is the independent variable 'Energy rating'. The outcomes of the regression give a price effect in percentages. In model 1 all variables are included and can be seen as the base model. The model explains almost 70% of the natural logarithm of the average sales price based on 57,112 observations. Most of the energy rating variables are significant at a 1% level, except for the variable 'Energyrating =>50 | <75 kWh/m2/year', which is not significant.
I hypothesized that higher energy performance sells at a price premium relatively to similar properties, and lower energy performance sell at a price discount'. The average energy performance of the Dutch residential sector is between 150 and 175 kWh/m2/year, and is therefore used as the base category. The results show a price premium for all categories performing better than the base category and Dutch average. On the other hand, transactions which do perform worse have a price discount. The results are in line with previous literature, including Banfi et al. (2008) and Brounen and Kok (2011). Therefore, the alleged hypothesis is not rejected.
Transactions with the best energy performance (<25 kWh/m2/year) are transacted at an average price premium of 14.9% more than the base category. Considering that the average transaction price of a dwelling in the sample equals €219.407, - the euro value of energy performance premium amounts to €32.692, -. Also, the category '=>50 | <75 kWh/m2/year' shows a premium of 6,5%. The transactions with the worse energy performance transacted at a 27,6% discount relatively to the base category, which equals a price discount of €60.556, -.
Also, the maintenance variables are significant at a 1% level. Holding out the 'poor isolated and condition', the model shows big differences in value throughout these variables. 'Good isolated' observations are 13% more worth compared to poor isolation observations. Further, both interior as well as exterior condition has a positive influence at the transaction price which is line with the research of Brounen and Kok (2011). There are also big differences between the types of house. A detached house transacts at 29,7% more than a terraced house. The difference is even greater compared with the research of Visser and Van Dam (2006). The location variable 'location in center' is not significant. The variable 'quality of location' is significant, the value of the observation is worth 9% more when located near a forest, even greater than first was analyzed by Luttik (2000).

Table 4: Regression results. Energyrating and transaction prices (dependent variable: natural logarithm of transaction price)

	(1)	(2)	(3)
Energy characteristics			
NZEB			-0.059*** [0.011]
Energyrating ('*150 – 175'* hold out)			
< 25	0.139*** [0.041]	0.098** [0.043]	
25 - 50	0.031** [0.015]	0.002 [0,016]	
50 - 75	-0.006 [0.012]	-0.019 [0.012]	
75 - 100	0.065*** [0.007]	0.072*** [0.008]	
100 - 125	0.039*** [0.004]	0.051*** [0.004]	
125 - 150	0.008*** [0.003]	0.012*** [0.003]	
175 - 200	-0.019*** [0.003]	-0.022*** [0.003]	
200 - 225	-0.030*** [0.004]	-0.040*** [0.004]	
225 - 260	-0.051*** [0.005]	-0.065*** [0.005]	
260 - 300	-0.077*** [0.007]	-0.100*** [0.007]	
300 - 340	-0.118*** [0.009]	-0.142*** [0.009]	
340 - 380	-0.151*** [0.011]	-0.179*** [0.011]	
380 - 450	-0.199*** [0.012]	-0.236*** [0.013]	
450 >	-0.323*** [0.015]	-0.357*** [0.016]	
Building characteristics			
Isolation ('*poorly isolated'* hold out)			
Moderately isolated	0.052*** [0.002]		0.052*** [0.002]
Sufficiently isolated	0.108*** [0.003]		0.108*** [0.003]
Good isolated	0.122*** [0.003]		0.122*** [0.003]
Interior condition ('*poorly condition*' hold out)			
Moderately int. condition	0.078*** [0.011]		0.079*** [0.011]
Sufficiently int. condition	0.185*** [0.011]		0.188*** [0.011]
Good int. condition	0.239*** [0.012]		0.242*** [0.012]
Exterior condition ('*poorly condition*' hold out)			
Moderately ext. condition	0.057*** [0.012]		0.059*** [0.012]
Sufficiently ext. condition	0.137*** [0.012]		0.140*** [0.012]
Good ext. condition	0.141*** [0.013]		0.143*** [0.013]
Type of house ('*Detached house*' hold out)			
Apartment	-0.245*** [0.005]	-0.224*** [0.005]	-0.252*** [0.005]
Terraced house	-0.260*** [0.004]	-0.274*** [0.004]	-0.260*** [0.004]
Switched house	-0.197*** [0.005]	-0.206*** [0.005]	-0.197*** [0.005]
Corner house	-0.198*** [0.004]	-0.210*** [0.004]	-0.199*** [0.004]
Semi-detached house	-0.129*** [0.003]	-0.125*** [0.003]	-0.129*** [0.003]
House size (m2)	0.002*** [0.000]	0.003*** [0.000]	0.003*** [0.000]
Number of rooms	0.001 [0.001]	-0.003*** [0.001]	0.002 [0.001]
Monumental	0.057*** [0.011]	0.054*** [0.012]	0.054*** [0.011]
Location characteristics			
Location in center	-0.002 [0.004]	-0.000 [0.004]	-0.008** [0.004]
Quality of location ('*No extra quality'* hold out)			
Next to forest	0.090*** [0.005]	0.097*** [0.005]	0.092*** [0.005]
Next to water	0.039*** [0.003]	0.047*** [0.004]	0.040*** [0.003]
Next to park	0.026*** [0.005]	0.036*** [0.005]	0.028*** [0.005]
Clear sight	0.006** [0.003]	0.014*** [0.003]	0.007*** [0.003]
Constant	11.233*** [0.011]	11.485*** [0.009]	11.233*** [0.011]
Obs.	57112	57112	57112
R-squared	0.696	0.655	0.693
Energy costs	YES	YES	YES
Construction period	YES	YES	YES
Years	YES	YES	YES

Standard errors are in parenthesis, *** p<0.01, ** p<0.05, * p<0.1, Models also include many more characteristics (see appendix B)

In column (2), I exclude the maintenance variables to measure if the existence of maintenance characteristics is critical in the valuation of energy performance. According to Kain and Quigley (1970) the quality of maintenance plays an important role in valuing houses.
Not controlling for maintenance leads to a decreasing premium and increasing discounts to the value. The results are less significant and also the R-squared decreases to 65,5%. Therefore, I conclude that maintenance variables take an important role in the model and should be included into the model.
In column (3), I use the NZEB variable as the independent variable and include the maintenance variables again. Where good energy ratings in column (1) and (2) have mainly significant positive influence at transaction prices, the NZEB variable in model (3) has negative influence at the transaction price. The model checked for correlation between NZEB and other housing characteristics, and there was no correlation, even not with the type of house. ‘NZEB’ observations transact at 5,9% less than observations without NZEB. Compared to model (1), the control variables have not changed much. There could be various reasons why this negative effect has been demonstrated. For example, apartments transact in general for less compared to other types of houses (Visser & Van Dam, 2006). Second, the question is whether the observations have been applied in accordance with the standards as stated by Ramallo-González (2013). Finally, the question rises if there was enough information available at the moment of transaction.
Summarizing, the results demonstrate energy performance does generate added value to transaction price in the Dutch private residential sector. Energy performance is an important indicator in the valuing process. Meanwhile, the concept of NZEB is not positively valued in the transaction price.

6. DISCUSSION & CONCLUSION

Energy performance can play an important role in the reduction of emissions. The traditional policies regarding energy measurement make place for new policies, measurements and instruments, mostly driven by the European Union. One example is the introduction of the NZEB-tool. Previous literature has showed the importance of increasing the energy performance of buildings by reducing energy use. From January 1, 2020, the Netherlands included, have to use the NZEB-tool to value energy performance. This paper reports the first evidence of actual energy performance on market value in the Netherlands by using future calculation methods.
The results of this research are affirmative and are in line with previous research. The research aim of this study is to value actual energy performance in the Dutch private residential sector. Results shows us that less energy consumption and higher energy performance is valued positively. The market value of actual energy performance in the Dutch residential sector has great potential. The best performing observations are 14,9% more worth compared to the Dutch average household. On the other side, weak performing observations show negative results. The results show us almost a perfect gradual positive development in added value when energy performance is increasing. These findings can of great importance for investors, developers and households' investment decisions.

Inexplicably, the concept of NZEB shows a negative value. The results are difficult to generalize due to an excess of apartments into the variable of interest. Nevertheless, the results show no significant positive signal. Brounen and Kok (2011) have demonstrated that start-up problems cause negative effects on introducing and implementing energy labels. They infer that the Dutch government have to take lessons out of the way energy labels were implemented in the Netherlands. It can be concluded that the role of the government in implementing the NZEB-tool becomes important. Together with providing housing without natural gas, it is essential that more experience is gained over the next years with building NZEB in the Netherlands. Therefore, it will be crucial to reveal reliable quantitative, widely supported documentation and research according the NZEB-tool. The effectiveness of valuation is according to the European Union deeply reliant on the way they are carried out by the country in question (Mudgal, 2013). Theoretically, when missing crucial reliable information about energy performance, house buyers will pay a lower amount for a better performing house than what it is worth. Of course, the research is exploratory and the NZEB regulations have not yet been implemented in practice. However, uncertainties about financial returns may be a reason for clients not to improve its energy performance (Majcen, 2016). Therefore, it will be essential to clarify forthcoming calculation methods in order to break the vicious circle of blame. Consequently, investments in energy performance are based on information and the understanding of the economic and social benefits (Wustenhagen et al., 2007). information and knowledge will have to be shared more efficiently in the future in order to fully integrate energy performance, like the NZEB-tool, into the property valuation process.

REFERENCES

Aedes (2018). *Wet- en Regelgeving: Aedes onderzoekt gevolgen voorgenomen nieuwe BENG-eisen*. Available at: https://www.aedes.nl/artikelen/aedes-onderzoekt-gevolgen-voorgenomen-nieuwe-beng-eisen.html Accessed 05-01-2019.

Akerlof, G. A., (1970). The market for “lemons”: Qualitative uncertainty and the market mechanism. *The Quarterly Journal of Economics*, 84 (3), 488–500.

Allcott, H., & Greenstone, M (2012). Is There an Energy Efficiency Gap? Journal of Economic Perspectives. *American Economic Association,* 26 (1), 3-28

Alonso, W., (1964). Location and Land Use: Toward a General Theory of Land Rent. Cambridge, Massachusetts, *Harvard University Press*.

Banfi, S., Farsi, M., Filippini, M. & Jacob, M., (2008). Willingness to pay for energy saving measures in residential buildings. *Energy Economics.* 30 (2), 503–516.

Blok, S. A., (2016). *Voortgang energiebesparing gebouwde omgeving.* The Hague [letter of government]. https://www.rijksoverheid.nl/documenten/kamerstukken/2016/11/28/kamerbrief-over-energiebesparing-gebouwde-omgeving [Accessed 06-07-2017]

Boelhouwer, P.J. & Vries, de P., (2000). *Prijsontwikkeling van bestaande en nieuwe koopwoningen*, Delft: Technische Universiteit Delft.

Brounen, D. & Kok, N., (2011). On the economics of energy labels in the housing market. *Journal of Environmental Economics and Management*, 62 (2), 166–179.

Cadman, D., (2000). ‘The vicious circle of blame’. [Online] Available from: https://www.researchgate.net/figure/The-vicious-circle-of-blame-Cadman-2000_fig1_265725887 [Accessed 18-04-2019]

Cajias, M. & Piazolo, D., (2012). Green performs better: Energy efficiency and financial return on buildings. *Journal of Corporate Real Estate*, 15 (1), 53–72.

CBS (2016). *Nederland langs de Europese meetlat 2016*. [Online] Available from: https://download.cbs.nl/pdf/2016-nederland-langs-de-europese-meetlat-2016.pdf [Accessed 20-03-2019]

CBS (2018). *Energie verbruik van particuliere huishoudens*. [Online] Available from: https://www.cbs.nl/nl-nl/achtergrond/2018/14/energieverbruik-van-particuliere-huishoudens [Accessed 20-03-2019]

Cerin, P., Hassel, L. G., & Semenova, N., (2014). Energy performance and housing prices. *Sustainable Development,* 22 (6), 404–419.

Cobb, S., (1984). The Impact of Site Characteristics on Housing Cost Estimates. *Journal of Urban economics*, 26-45.

Dong-Xue., Z., Bao-Jie, H., Johnson, C. & Mou, B., (2015). Social problems of green buildings: From the humanistic needs to social acceptance, Renewable and Sustainable Energy Reviews, *Elsevier*, vol. 51(C), pages 1594-1609.

Eichholtz, P., Kok, N. & Quigley, J. M., (2010). Doing well by doing good? Green office buildings. *The American Economic Review*, 100 (5), 2492-2509.

Eichholtz, P., Kok, N. & Quigley, J. M., (2013). The economics of green building. *Review of Economics and Statistics*, 95 (1), 50-63.

European Commission (2016). On guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings. *Official Journal of the European Union.* [Online] Available from: http://data.europa.eu/eli/reco/2016/1318/oj [Accessed 14-10-2018]

European Parliament, Council of the European Union (2010). *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings*. [Online] Available from:

http://www.buildup.eu/sites/default/files/content/EPBD2010_31_EN.pdf [Accessed 14-10-2018]

Florida, R., (2002). *The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life*. New York: Basic Books, 404p.

Follain, J. R., & Jimenez, E., (1985). The Demand for Housing Characteristics in Developing Countries, *Urban Studies*, 421-432.

Fuerst, F., McAllister, P., Nanda, A. & Wyatt, P., (2015). Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England. *Energy Economics*, 48, 145–156.

Guerra Santin, O., (2010). Actual energy consumption in dwellings; The effect of energy performance regulations and occupant behavior. PhD thesis.

Gulicher, T., (2008). De invloed van groene open ruimte in de omgeving op de waarde van woningen. Amsterdam, ASRE, PhD thesis.

Häkkinen, T., & Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information*, 39(3), pp.239-255.

Hartenberger, U., & Lorenz, D., (2008). Breaking the Vicious Circle of Blame – Making the Business Case for Sustainable Buildings. [Online] Retrieved from: https://www.researchgate.net/publication/263782010_Breaking_the_Vicious_Circle_of_Blame_-_Making_the_Business_Case_for_Sustainable_Buildings [Accessed 12-04-2019]

Hausman, J. A., (1979). Individual discount rates and the purchase and utilization of energy-using durables. *The Bell Journal of Economics*, 33–54.

Hoek, van T. & Koning, M., (2018). Klimaatbeleid en de gebouwde omgeving. *Economisch Instituut voor de Bouw*.

Hyland, M., Lyons, R. C., & Lyons, S., (2013). The value of domestic building energy efficiency – evidence from the Netherlands. *Energy economics*, 40 (0), 943-952
Kain, J. F., & Quigley, J. M., (1970). Measuring the Value of Housing Quality. *Journal of the American*, Statistical Association, 532-548.

Kim, J. Greene, M. & Kim, S., (2014) Cost comparative analysis of a new green building code for residential project development, *Journal of construction and engineering management*, 14. 1–10.

Hydes, N. & Clark, J., (2000). Incremental costs within the design process for energy efficient buildings. *Building Research and Information*, 28(5/6), 413–418.

Laurent, M., Allibe, B., Oreszczyn, T., Hamilton, I., Tigchelaar, C. & Galvin, R., (2013). Back to reality: How domestic energy efficiency policies in four European countries can be improved by using empirical data instead of normative calculation, *Proceedings of the European Council for an Energy Efficient Economy (ECEEE) Summer School*, 3–8

Larsson, N. & Clark, J., (2000). Reducing mechanical equipment cost: the economics of green design. *Building Research and Information*, 28(5/6), 403–407.

Lorenz, D., Lützkendorf, T., (2011). Sustainability and property valuation: Systematisation of existing approaches and recommendations for future action. *Journal of Property Investment & Finance,* Vol. 29 Issue: 6, pp.644-676.

Luttik, J., (2000). The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and Urban Planning*, 161-167.

Majcen, D., (2016). Predicting energy consumption and savings in the housing stock: A performance gap analysis in the Netherlands. Delft University of Technology, Faculty of Architecture and the Built Environment, OTB, *Research for the Built Environment*

Mandell, S., & Wilhelmsson, M., (2011) Willingness to Pay for Sustainable Housing. *Journal of Housing Research*. American Real Estate Society.

Mudgal, S., Lyons, L., Cohen, F., Lyons, R. & Fedrigo-Fazio, D., (2013). Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries. Paris: European Commission (DG Energy).

Palmquist, R. B., (2005). *Property value models*. Handbook of Environmental Economics, 2, 763–819.

Parool (2019). *CBS: energierekening wél honderden euro's omhoog.* [Online] Available from: https://www.parool.nl/nederland/cbs-energierekening-wel-honderden-euro-s-hoger~b2ba74a8/?referer=https%3A%2F%2Fwww.google.com%2F [Accessed 12-03-2019]

PBL (2014). Op weg naar een klimaat neutrale woningvoorraad in 2050. [Online] Available from: http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2014-op-weg-naar-een-klimaatneutrale-woningvoorraad-in-2050-achtergrond_1333.pdf [Accessed 03-05-2017]

PBL/CBS (2016). *Regionale bevolkings- en huishoudensprognose 2016–2040: sterke regionale verschillen. Bevolkingstrends.* [Online] Available from: https://www.pbl.nl/publicaties/pbl-cbs-regionale-bevolkings-en-huishoudensprognose-2016-2040-woningbouwveronderstellingen [Accessed 12-04-2019]

SEAI (2018). Energy in the Residential sector. 2018 report. [Online] Available from: https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf [Accessed 10-11-2018]

SERPEC (2009). Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC). Summary report

Ramallo-Gonzalez, A., Eames, M. E., & Coley, D. A., (2013). Lumped parameter models for building thermal modelling: An analytic approach to simplifying complex multi-layered constructions. Energy and Buildings, 60, 174-184

Rosen, S., (1974). Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy*, 82 (1), 34–55.

RVO (2017). Woningbouw volgens BENG: Do's en don'ts voor bijna energieneutraal bouwen. [Online] Available from: https://www.lente-akkoord.nl/wp-content/uploads/2017/02/Lente-akkoord-Woningbouw-volgens-BENG.pdf [Accessed 01-05-2018]

Shi, Q., Yan, Y., Zuo, J. & Yu, T., (2016). Objective conflicts in green buildings projects: A critical analysis, *Building and Environment*, Vol. 96, 107-117.

Tyrvainen , L., & Miettinen, A., (2000). Property Prices and Urban Forest Amenities. *Journal of Environmental Economics and Management*, 205-223.

Visser, P. & Van Dam, F., (2006). *De prijs van de plek, woonomgeving en woningprijs*. Ruimtelijke Planbureau, Rotterdam: NAi uitgevers

Wet van 9 april 2018 tot wijziging van de Elektriciteitswet 1998 en van de Gaswet. (2018, April 26). [Online] Retrieved from: https://zoek.officielebekendmakingen.nl/stb-2018-129.html [Accessed 05-07-2018]

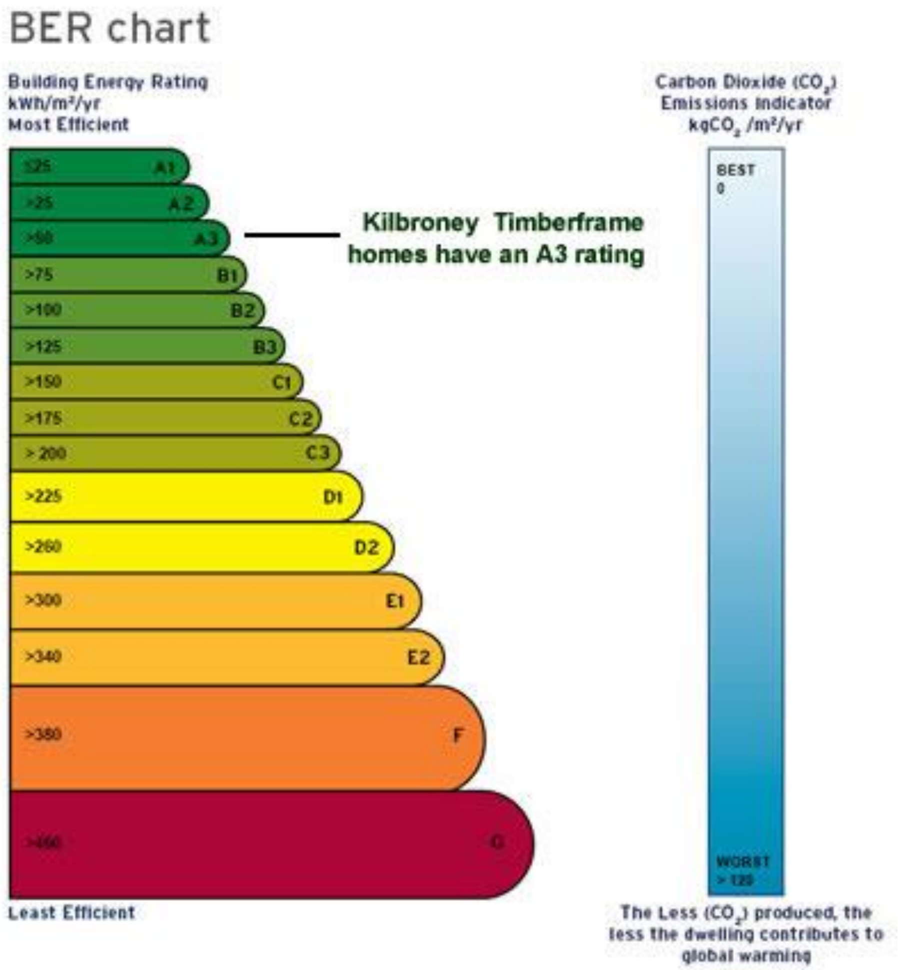
Wiebes, E., (2018). Gaswinning Groningen [letter of government]. Available from https://www.rijksoverheid.nl/documenten/kamerstukken/2018/03/29/kamerbrief-over-gaswinning-groningen [Accessed 05-07-2018]

Witte, A. D., Sumka, H. J., & Erekson, H., (1979). An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets. *The econometric society*, 1151-1173.

Wüstenhagen, R., Wolsink, M., & Bürer, MJ., (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35, 2683–2691.

APPENDICES

A. B.E.R. chart



B. Full regression model (1)

logtransactionprice	Coef.	St.Err	t-value	p-value	Sig.
0.energyrating	0.139	0.041	3.43	0.001	***
1.energyrating	0.031	0.015	2.14	0.032	**
2.energyrating	-0.006	0.012	-0.52	0.605	
3.energyrating	0.065	0.007	9.07	0.000	***
4.energyrating	0.039	0.004	9.28	0.000	***
5.energyrating	0.008	0.003	2.60	0.009	***
6b.energyrating	0.000	.	.	.	
7.energyrating	-0.019	0.003	-5.68	0.000	***
8.energyrating	-0.030	0.004	-7.25	0.000	***

9.energyrating	-0.051	0.005	-10.16	0.000	***
10.energyrating	-0.077	0.007	-11.62	0.000	***
11.energyrating	-0.118	0.009	-13.60	0.000	***
12.energyrating	-0.151	0.011	-13.94	0.000	***
13.energyrating	-0.199	0.012	-16.35	0.000	***
14.energyrating	-0.323	0.015	-21.75	0.000	***
0b.isolation	0.000	.	.	.	
1.isolation	0.052	0.002	23.00	0.000	***
2.isolation	0.108	0.003	34.91	0.000	***
3.isolation	0.122	0.003	38.43	0.000	***
0b.interior_condit~n	0.000	.	.	.	
1.interior_condition	0.078	0.011	7.26	0.000	***
2.interior_condition	0.185	0.011	16.87	0.000	***
3.interior_condition	0.239	0.012	19.92	0.000	***
0b.exterior_condit~n	0.000	.	.	.	
2.exterior_condition	0.057	0.012	4.87	0.000	***
3.exterior_condition	0.137	0.012	11.45	0.000	***
4.exterior_condition	0.141	0.013	10.82	0.000	***
energyconsumptionELK	0.000	0.000	13.06	0.000	***
energyconsumptionGAS	0.000	0.000	32.58	0.000	***
0.type_house	-0.245	0.005	-47.72	0.000	***
1.type_house	-0.260	0.004	-67.06	0.000	***
2.type_house	-0.197	0.005	-41.57	0.000	***
3.type_house	-0.198	0.004	-50.38	0.000	***
4.type_house	-0.129	0.003	-38.14	0.000	***
5b.type_house	0.000	.	.	.	
0b.building_period	0.000	.	.	.	
1.building_period	-0.075	0.003	-24.73	0.000	***
2.building_period	-0.053	0.003	-17.30	0.000	***
3.building_period	0.043	0.004	9.77	0.000	***
size_GIA_m2	0.002	0.000	28.17	0.000	***
number_rooms	0.001	0.001	0.90	0.366	
monumental	0.057	0.011	4.98	0.000	***
size_volume_m3	0.000	0.000	20.13	0.000	***
size_plot_m2	0.000	0.000	22.57	0.000	***
number_toilets	0.004	0.001	6.85	0.000	***
number_floors	0.026	0.002	12.38	0.000	***
number_balcons	0.021	0.003	7.46	0.000	***
basement	0.110	0.005	23.65	0.000	***
garage	0.032	0.003	10.86	0.000	***
stand	-0.006	0.002	-2.67	0.008	***
elevator	0.068	0.005	13.18	0.000	***
fireplace	0.049	0.004	11.40	0.000	***
parking	0.072	0.003	24.99	0.000	***
loft	0.004	0.005	0.93	0.351	
attic	-0.053	0.003	-18.93	0.000	***
leasehold	-0.169	0.011	-15.01	0.000	***
free_by_name	0.006	0.012	0.56	0.579	
0b.location_garden	0.000	.	.	.	
1.location_garden	-0.010	0.004	-2.35	0.019	**
2.location_garden	-0.016	0.003	-4.91	0.000	***
3.location_garden	-0.013	0.003	-4.27	0.000	***
4.location_garden	-0.018	0.003	-5.78	0.000	***
duration_sale	0.000	0.000	-31.33	0.000	***
location_in_centre	-0.002	0.004	-0.66	0.507	

0b.quality_location	0.000	.	.	.	
1.quality_location	0.090	0.005	18.50	0.000	***
2.quality_location	0.039	0.003	11.27	0.000	***
3.quality_location	0.026	0.005	5.38	0.000	***
4.quality_location	0.006	0.003	2.43	0.015	**
2013b.year	0.000	.	.	.	
2014.year	0.044	0.003	13.35	0.000	***
2015.year	0.068	0.003	21.04	0.000	***
2016.year	0.114	0.003	35.01	0.000	***
2017.year	0.145	0.003	47.30	0.000	***
_cons	11.233	0.011	1011.42	0.000	***

Mean dependent var	12.226	SD dependent var	0.383
R-squared	0.696	Number of obs	57112.000
F-test	2007.068	Prob > F	0.000
Akaike crit. (AIC)	-15375.165	Bayesian crit. (BIC)	-14784.282

*** p<0.01, ** p<0.05, * p<0.1

C. Variables of the model

	Variablename	Value	Description
1	zipcodeP6	#	The zipcodeP6 of the aggregated observations
2	City	Name	The city of the aggregated observations
3	Streetname	Name	The streetname of the aggregated observations
4	year	#	Year of transaction
5	house	0	No house
		1	House
6	Apartment	0	No apartment
		1	Apartment
7	sort_house	0	No house
		1	single-family
		2	mansion
		3	Farm
		4	Villa
8	type_house	0	apartment
		1	terraced house
		2	semi-detached house (switched)
		3	corner house
		4	semi-detached house
		5	detached house
9	building_period	0	1500-1944
		1	1945-1970
		2	1971-2000
		3	2001>

10	size_GIA_m2	#		Gross internal area of the dwelling in square meters
11	size_volume_m3	#		Volume of the dwelling kubic meters
12	size_plot_m2	#		Size of the plot in square meters
13	Interior _condition		0	Poorly condition
			1	Moderately condition
			2	Sufficiently condition
			3	Good condition
14	exterior_condition		0	Poorly condition
			1	Moderately condition
			2	Sufficiently condition
			3	Good condition
15	number_balcons	#		
16	number_floors	#		
17	number_toilets	#		
18	number_rooms	#		
19	basement		0	No basement
			1	Basement
20	garage		0	No garage
			1	garage
21	stand		0	no stand
			1	stand
22	elevator		0	no elevator
			1	elevator
23	fireplace		0	no fireplace
			1	fireplace
24	parking		0	No parkingspot
			1	parkingspot
25	loft		0	no loft
			1	loft
26	attic		0	no attic
			1	attic
27	Leasehold		-1	No leasehold
			0	Leasehold
28	free_by_name		0	costs buyer
			1	free by name
29	monumental		0	no monument
			1	monument
30	location_garden		0	no garden
			1	North
			2	East
			3	South

			4	West
31	location_in_centre		0	no
			1	yes
32	qualtity_location		0	no extra quality
			1	Next to forest
			2	Next to water
			3	Next to parc
			4	Clear sight
33	transactionprice	#		Transactionprice in Euro's
34	transactionprice_m2	#		Transactionprice in Euro's divided by the GIA of the dwelling
35	pricedifference_perc	#		The price difference between the price of asking and actual transactionprice
36	duration_sale	#		The duration of the sale in days
37	isolation		0	Poorly isolated
			1	Moderately isolated
			2	Sufficiently isolated
			3	Well isolated
38	connections	#		Number of energy connections measured in the zipcodeP6 area
39	sau_averageELK	#		Aggregated elektricity consumption in kWh per year
40	sau_averageGAS	#		Aggregated gas consumption in m3 per year
41	energyconsumptionELK	#		Aggregated elektricity consumption in € per year
42	energyconsumptionGAS	#		Aggregated gas consumption in € per year
43	energyconsumption_tot	#		Aggregated total energyconsumption in € per year
44	energyrating		0	<25 kWh/m2/year
			1	>25 & <50 kWh/m2/year
			2	>50 & <75 kWh/m2/year
			3	>75 & <100 kWh/m2/year
			4	>100 & <125 kWh/m2/year
			5	>125 & <150 kWh/m2/year
			6	>150 & <175 kWh/m2/year
			7	> 175 & <200 kWh/m2/year
			8	>200 & <225 kWh/m2/year
			9	>225 & <260 kWh/m2/year
			10	>260 & <300 kWh/m2/year
			11	300 & <340 kWh/m2/year
			12	>340 & <380 kWh/m2/year
			13	380 & <450 kWh/m2/year
			14	>450 kWh/m2/year
45	NZEB		0	No NZEB
			1	yes NZEB

D: Do file dataset 'energy'

```
rename (obj_hid_GARAGE) (garage)
rename (obj_hid_GEMEUBILEERD) (furnished)
rename (obj_hid_HUISNUMMER) (housenumber)
rename (obj_hid_INHOUD) (size_volume_m3)
rename (obj_hid_ISNIEUWBOUW) (newconstruction)
rename (obj_hid_ISOL) (isolation)
rename (obj_hid_KELDER) (basement)
rename (obj_hid_KOOPCOND) (sale_condition)
rename (obj_hid_KWALITEIT) (quality)
rename (obj_hid_LIFT) (elevator)
rename (obj_hid_LIGCENTR) (central_location)
rename (obj_hid_LIGMOOI) (quality_location)
rename (obj_hid_BWPER) (building_period)
rename (obj_hid_CATEGORIE) (housing_type)
rename (obj_hid_DATUM_AFMELDING) (date_sale)
rename (obj_hid_ERFPACHT_TONEN) (leasehold)
rename (obj_hid_LIGDRUKW) (location)
rename (obj_hid_LOOPT) (duration_sale)
rename (obj_hid_M2) (size_livingspace_m2)
rename (obj_hid_MONUMENT) (monument)
rename (obj_hid_MONUMENTAAL) (monumental)
rename (obj_hid_NBALKON) (numer_balcons)
rename (obj_hid_NKAMERS) (number_rooms)
rename (obj_hid_NVERDIEP) (number_floors)
rename (obj_hid_NWC) (number_toilets)
rename (obj_hid_ONBI) (interior_condition)
rename (obj_hid_ONBU) (exterior_condition)
rename (obj_hid_OORSPRVRKOOPPR) (original_price)
rename (obj_hid_OORSPRVRKOOPPRM2) (original_price_m2)
rename (obj_hid_OPENH) (fireplace)
```

```
rename (obj_hid_PARKEER) (parking)
rename (obj_hid_PERCEEL) (size_plot_m2)
rename (obj_hid_PROCVERSCHIL) (pricedifference_perc)
rename (obj_hid_SCHUUR) (stand)
rename (obj_hid_SOORTAPP) (sort_apartment)
rename (obj_hid_SOORTHUIS) (sort_house)
rename (obj_hid_SOORTWONING) (sort_dwelling)
rename (obj_hid_SOORTDAK) (sort_roof)
rename (obj_hid_STRAATNAAM) (streetname)
rename (obj_hid_TRANSACTIEPRIJS) (transactionprice)
rename (obj_hid_TRANSACTIEPRIJSM2) (transactionprice_m2)
rename (obj_hid_TUIN_OPP) (size_garden_m2)
rename (obj_hid_TUINLIG) (location_garden)
rename (obj_hid_TYPE) (type_house)
rename (obj_hid_VERKOOPCOND) (building_condition)
rename (obj_hid_VERW) (sort_heating)
rename (obj_hid_VLIER) (loft)
rename (obj_hid_WOONKA) (sort_livingroom)
rename (obj_hid_WOONOPP) (size_GIA_m2)
rename (obj_hid_WOONPLAATS) (city)
rename (obj_hid_ZOLDER) (attic)
rename (obj_hid_ISBELEGGING) (investment)
rename (obj_hid_GED_VERHUURD) (part_rented)

merge m:1 zipcodeP6 year using "/Volumes/THESIS/DATA/ENERGIE/DATA_ENERGIE.dta"

    Result                           # of obs.
    -----------------------------------------
    not matched                        890,131
        from master                     50,981  (_merge==1)
        from using                     839,150  (_merge==2)

    matched                            100,043  (_merge==3)
    -----------------------------------------
```

```
drop if energyconsumption_tot==.
(254,302 observations deleted)
drop if transactionprice==.
(650,311 observations deleted)
drop obj_buurt_ID obj_hid_DATUM_AANMELDING obj_hid_LAATSTVRKOOPPR
obj_hid_HUISNUMMERTOEVOEGING obj_hid_INPANDIG
obj_hid_LAATSTVRHUURPR obj_hid_LAATSTVRKOOPPR1 obj_
hid_LAATSTVRKOOPPRM2 obj_hid_NVMCIJFERS obj_wijk_ID
smartmeter_perc delivery_directionELK _merge obj_pc4_ID obj_pc6_ID obj_hid_STATUS
drop if sort_dwelling==4
(1,037 observations deleted)
drop if housing_type==3
(339 observations deleted)
drop if housing_type==4
(326 observations deleted)
drop if sort_dwelling==1
(3 observations deleted)
drop if sort_dwelling==3
(6 observations deleted)
drop date_sale
drop if transactionprice<50000
(200 observations deleted)
drop if transactionprice>1000000
(122 observations deleted)
drop original_price original_price_m2
```

E: Do file dataset ‘NVM’

```
rename (obj_hid_GARAGE) (garage)
rename (obj_hid_GEMEUBILEERD) (furnished)
rename (obj_hid_HUISNUMMER) (housenumber)
rename (obj_hid_INHOUD) (size_volume_m3)
rename (obj_hid_ISNIEUWBOUW) (newconstruction)
```

rename (obj_hid_ISOL) (isolation)
rename (obj_hid_KELDER) (basement)
rename (obj_hid_KOOPCOND) (sale_condition)
rename (obj_hid_KWALITEIT) (quality)
rename (obj_hid_LIFT) (elevator)
rename (obj_hid_LIGCENTR) (central_location)
rename (obj_hid_LIGMOOI) (quality_location)
rename (obj_hid_BWPER) (building_period)
rename (obj_hid_CATEGORIE) (housing_type)
rename (obj_hid_DATUM_AFMELDING) (date_sale)
rename (obj_hid_ERFPACHT_TONEN) (leasehold)
rename (obj_hid_LIGDRUKW) (location)
rename (obj_hid_LOOPT) (duration_sale)
rename (obj_hid_M2) (size_livingspace_m2)
rename (obj_hid_MONUMENT) (monument)
rename (obj_hid_MONUMENTAAL) (monumental)
rename (obj_hid_NBALKON) (numer_balcons)
rename (obj_hid_NKAMERS) (number_rooms)
rename (obj_hid_NVERDIEP) (number_floors)
rename (obj_hid_NWC) (number_toilets)
rename (obj_hid_ONBI) (interior_condition)
rename (obj_hid_ONBU) (exterior_condition)
rename (obj_hid_OORSPRVRKOOPPR) (original_price)
rename (obj_hid_OORSPRVRKOOPPRM2) (original_price_m2)
rename (obj_hid_OPENH) (fireplace)
rename (obj_hid_PARKEER) (parking)
rename (obj_hid_PERCEEL) (size_plot_m2)
rename (obj_hid_PROCVERSCHIL) (pricedifference_perc)
rename (obj_hid_SCHUUR) (stand)
rename (obj_hid_SOORTAPP) (sort_apartment)
rename (obj_hid_SOORTHUIS) (sort_house)
rename (obj_hid_SOORTWONING) (sort_dwelling)
rename (obj_hid_SOORTDAK) (sort_roof)
rename (obj_hid_STRAATNAAM) (streetname)

```
rename (obj_hid_TRANSACTIEPRIJS) (transactionprice)
rename (obj_hid_TRANSACTIEPRIJSM2) (transactionprice_m2)
rename (obj_hid_TUIN_OPP) (size_garden_m2)
rename (obj_hid_TUINLIG) (location_garden)
rename (obj_hid_TYPE) (type_house)
rename (obj_hid_VERKOOPCOND) (building_condition)
rename (obj_hid_VERW) (sort_heating)
rename (obj_hid_VLIER) (loft)
rename (obj_hid_WOONKA) (sort_livingroom)
rename (obj_hid_WOONOPP) (size_GIA_m2)
rename (obj_hid_WOONPLAATS) (city)
rename (obj_hid_ZOLDER) (attic)
rename (obj_hid_ISBELEGGING) (investment)
rename (obj_hid_GED_VERHUURD) (part_rented)

merge m:1 zipcodeP6 year using "/Volumes/THESIS/DATA/ENERGIE/DATA_ENERGIE.dta"

    Result                           # of obs.
    -----------------------------------------
    not matched                        890,131
        from master                     50,981  (_merge==1)
        from using                     839,150  (_merge==2)

    matched                            100,043  (_merge==3)
    -----------------------------------------

drop if energyconsumption_tot==.
(254,302 observations deleted)
drop if transactionprice==.
(650,311 observations deleted)
drop obj_buurt_ID obj_hid_DATUM_AANMELDING obj_hid_LAATSTVRKOOPPR
obj_hid_HUISNUMMERTOEVOEGING obj_hid_INPANDIG
obj_hid_LAATSTVRHUURPR obj_hid_LAATSTVRKOOPPR1 obj_
hid_LAATSTVRKOOPPRM2 obj_hid_NVMCIJFERS obj_wijk_ID
```

smartmeter_perc delivery_directionELK _merge obj_pc4_ID obj_pc6_ID obj_hid_STATUS

drop if sort_dwelling==4

(1,037 observations deleted)

drop if housing_type==3

(339 observations deleted)

drop if housing_type==4

(326 observations deleted)

drop if sort_dwelling==1

(3 observations deleted)

drop if sort_dwelling==3

(6 observations deleted)

drop date_sale

drop if transactionprice<50000

(200 observations deleted)

drop if transactionprice>1000000

(122 observations deleted)

drop original_price original_price_m2

drop if size_livingspace_m2<50

(1,743 observations deleted)

drop size_garden_m2 smartmeter_perc delivery_directionELK

drop if energyconsumption_tot>10000

(13 observations deleted)

drop if energyconsumption_tot > 5000

(636 observations deleted)

drop if sauTOT_kWh_m2 > 1000

(8 observations deleted)

drop if number_rooms> 20

(2 observations deleted)

drop if number_toilets >10

(32 observations deleted)

drop if size_plot_m2 > 20000

(91 observations deleted)

drop if transactionprice_m2 > 6000

(8 observations deleted)

```
drop if transactionprice_m2 > 5000
(21 observations deleted)
drop if transactionprice_m2 > 4000
(156 observations deleted)
drop if transactionprice > 500000
(1,745 observations deleted)


cor
(Only livingspace and GIA and monument and monumental really correlated)
drop investment size_livingspace_m2 monument

drop newconstruction part_rented furnished province quality sort_roof building_condition
drop if building_period==0
collapse (firstnm)city streetname (mean)leasehold garage size_volume_m3 investment
isolation basement
sale_condition elevator duration_sale size_livingspace_m2 monument monumental
number_balcons number_rooms
number_floors number_toilets interior_condition exterior_condition fireplace parking
size_plot_m2 pricedifference_perc
stand transactionprice transactionprice_m2 building_condition sort_heating loft
sort_livingroom
size_GIA_m2 attic sau_averageGAS sau_averageELK connections energyconsumptionELK
energyconsumptionGAS
energyconsumption_tot (median) building_period housing_type sort_apartment sort_house
sort_dwelling
location_garden central_location type_house quality_location location, by (zipcodeP6 year)

replace isolation = 0 if isolation <1.51
replace isolation = 2 if isolation >1.51 & isolation <3.51
replace isolation = 3 if isolation >3.51 & isolation <4.51
replace isolation = 4 if isolation >4.51
replace building_period = 0 if building_period  <3.51
replace building_period = 2 if building_period >3.51 & building_period <5.51
```

```
replace building_period = 3 if building_period >5.51 & building_period <8.51
replace building_period = 4 if building_period >8.51
gen house = 0
replace house = 1 if housing_type<1.6
(51,434 real changes made)
gen apartment = 0
replace apartment = 1 if housing_type>1.6
(8,192 real changes made)
replace leasehold = 0 if leasehold<0.5
(2,226 real changes made)
replace leasehold = 1 if leasehold>=0.5
(82 real changes made)
replace garage = 0 if garage<0.5
(311 real changes made)
replace garage = 1 if garage>=0.5
(14,429 real changes made)
replace basement = 0 if basement<0.5
(52,950 real changes made)
replace basement = 1 if basement>=0.5
(818 real changes made)
rename (sale_condition) (costs_buyer)
replace elevator = 0 if elevator <0.5
(269 real changes made)
replace elevator = 1 if elevator >=0.5
(914 real changes made)
replace monumental = 0 if monumental <0.5
(38 real changes made)
replace monumental = 1 if monumental >=0.5
(112 real changes made)
replace interior_condition = 0 if interior_condition  <4
(1,028 real changes made)
replace interior_condition = 1 if interior_condition >=4 & interior_condition <6
(4,726 real changes made)
replace interior_condition = 2 if interior_condition >=6 & interior_condition <8
```

(46,172 real changes made)
replace interior_condition = 3 if interior_condition >=8
(7,700 real changes made)
replace exterior_condition = 0 if exterior_condition <4
(848 real changes made)
replace exterior_condition = 2 if exterior_condition >=4 & exterior_condition <6
(3,685 real changes made)
replace exterior_condition = 3 if exterior_condition >=6 & exterior_condition <8
(47,942 real changes made)
replace exterior_condition = 4 if exterior_condition >=8
(7,151 real changes made)
replace fireplace = 0 if fireplace<1.5
(2,081 real changes made)
replace fireplace = 1 if fireplace>=1.5
(3,175 real changes made)
replace stand = 0 if stand<0.5
(70 real changes made)
replace stand = 1 if stand >=0.5
(39,465 real changes made)
replace parking = 0 if parking<0.5
(24 real changes made)
replace parking = 1 if parking>=0.5
(31,891 real changes made)
drop sort_heating
replace loft = 0 if parking<0.5
(2,427 real changes made)
drop sort_livingroom
replace attic = 0 if parking<0.5
replace sort_house = 0 if sort_house<0.5
(8,192 real changes made)
replace sort_house = 1 if sort_house >=0.5 & sort_house <5.5
(43,029 real changes made)
replace sort_house = 2 if sort_house >=5.5 & sort_house <7.5
(2,644 real changes made)

```
replace sort_house = 3 if sort_house >=7.5 & sort_house <9.5
(3,708 real changes made)
replace sort_house = 4 if sort_house >=9.5
(2,053 real changes made)
drop sort_apartment
replace type_house = 0 if type_house<0.5
(8,192 real changes made)
replace type_house = 1 if type_house >=0.5 & type_house <1.5
(15 real changes made)
replace type_house = 2 if type_house >=1.5 & type_house <2.5
(220 real changes made)
replace type_house = 3 if type_house >=2.5 & type_house <3.5
(481 real changes made)
replace type_house = 4 if type_house >=3.5 & type_house <4.5
(361 real changes made)
replace type_house = 5 if type_house >=4.5
(800 real changes made)
drop sort_dwelling
replace location_garden = 0 if location_garden <0.5
(0 real changes made)
replace location_garden = 1 if location_garden >=0.5 & location_garden <2
(741 real changes made)
replace location_garden = 2 if location_garden >=2 & location_garden <4
(6,631 real changes made)
replace location_garden = 3 if location_garden >=4 & location_garden <6
(13,604 real changes made)
replace location_garden = 4 if location_garden >=6
(14,871 real changes made)
replace quality_location = 0 if quality_location<0.5
(0 real changes made)
replace quality_location = 1 if quality_location>=0.5 & quality_location <1.5
(325 real changes made)
replace quality_location = 2 if quality_location>=1.5 & quality_location <2.5
(431 real changes made)
```

```
replace quality_location = 3 if quality_location>=2.5 & quality_location <3.5
(137 real changes made)
replace quality_location = 4 if quality_location>=3.5
(208 real changes made)
replace central_location = 0 if central_location<2.5
(53,817 real changes made)
replace central_location = 1 if central_location>=2.5
(4,337 real changes made)
rename (central_location) (location_in_centre)
drop location
drop housing_type
replace attic = 0 if attic<0.5
(675 real changes made)
replace attic = 1 if attic>=0.5
(2,590 real changes made)
rename (costs_buyer) (free_by_name)

order zipcodeP6 city streetname year house apartment sort_house type_house
building_period size_GIA_m2 si
> ze_volume_m3 size_plot_m2 interior_condition exterior_condition number_rooms
number_floors number_toilets
>  number_balcons basement garage stand elevator fireplace parking loft attic leasehold
free_by_name monume
> ntal location_garden location_in_centre quality_location transactionprice
transactionprice_m2 pricediffer
> ence_perc duration_sale isolation connections sau_averageELK sau_averageGAS
energyconsumptionELK energyco
> nsumptionGAS energyconsumption_tot
gen logtransactionprice =log(transactionprice)
generate energyconsumption_m2 = energyconsumption_tot / size_GIA_m2,
before(logtransactionprice)
generate sau_averageGAS_kWh = sau_averageGAS*9.76944444, after(sau_averageGAS)
generate sau_averageTOT_kWh = sau_averageELK+sau_averageGAS_kWh,
after(sau_averageGAS_kWh)
```

```
generate sauELK_kWh_m2 = sau_averageELK/size_GIA_m2
generate sauGAS_kWh_m2 = sau_averageGAS_kWh/size_GIA_m2
generate sauTOT_kWh_m2 = sauELK_kWh_m2 + sauGAS_kWh_m2
drop if sauTOT_kWh_m2 > 1000
(8 observations deleted)

generate energyrating = 0
replace energyrating = 1 if sauTOT_kWh_m2 > 25 & sauTOT_kWh_m2 < 50
(257 real changes made)
replace energyrating = 2 if sauTOT_kWh_m2 >= 50 & sauTOT_kWh_m2 < 75
(485 real changes made)
replace energyrating = 3 if sauTOT_kWh_m2 >= 75 & sauTOT_kWh_m2 < 100
(1,879 real changes made)
replace energyrating = 4 if sauTOT_kWh_m2 >= 100 & sauTOT_kWh_m2 < 125
(7,069 real changes made)
replace energyrating = 5 if sauTOT_kWh_m2 >= 125 & sauTOT_kWh_m2 < 150
(13,049 real changes made)
replace energyrating = 6 if sauTOT_kWh_m2 >= 150 & sauTOT_kWh_m2 < 175
(12,038 real changes made)
replace energyrating = 7 if sauTOT_kWh_m2 >= 175 & sauTOT_kWh_m2 < 200
(8,313 real changes made)
replace energyrating = 8 if sauTOT_kWh_m2 >= 200 & sauTOT_kWh_m2 < 225
(5,235 real changes made)
replace energyrating = 9 if sauTOT_kWh_m2 >= 225 & sauTOT_kWh_m2 < 260
(4,445 real changes made)
replace energyrating = 10 if sauTOT_kWh_m2 >= 260 & sauTOT_kWh_m2 < 300
(2,663 real changes made)
replace energyrating = 11 if sauTOT_kWh_m2 >= 300 & sauTOT_kWh_m2 < 340
(1,438 real changes made)
replace energyrating = 12 if sauTOT_kWh_m2 >= 340 & sauTOT_kWh_m2 < 380
(804 real changes made)
replace energyrating = 13 if sauTOT_kWh_m2 >= 380 & sauTOT_kWh_m2 < 450
(718 real changes made)
replace energyrating = 14 if sauTOT_kWh_m2 >= 450
```

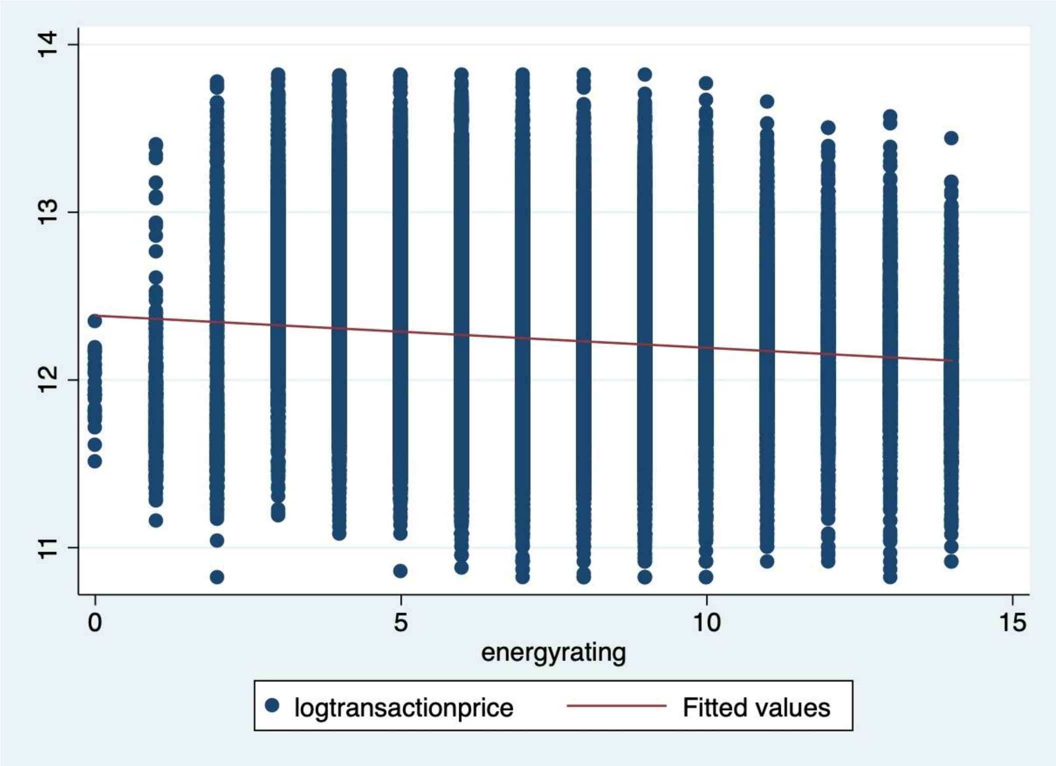
(561 real changes made)

gen NZEB = 0

replace NZEB = 1 if sauELK_kWh_m2 <= 70 & sauGAS_kWh_m2 <= 30

(470 real changes made)

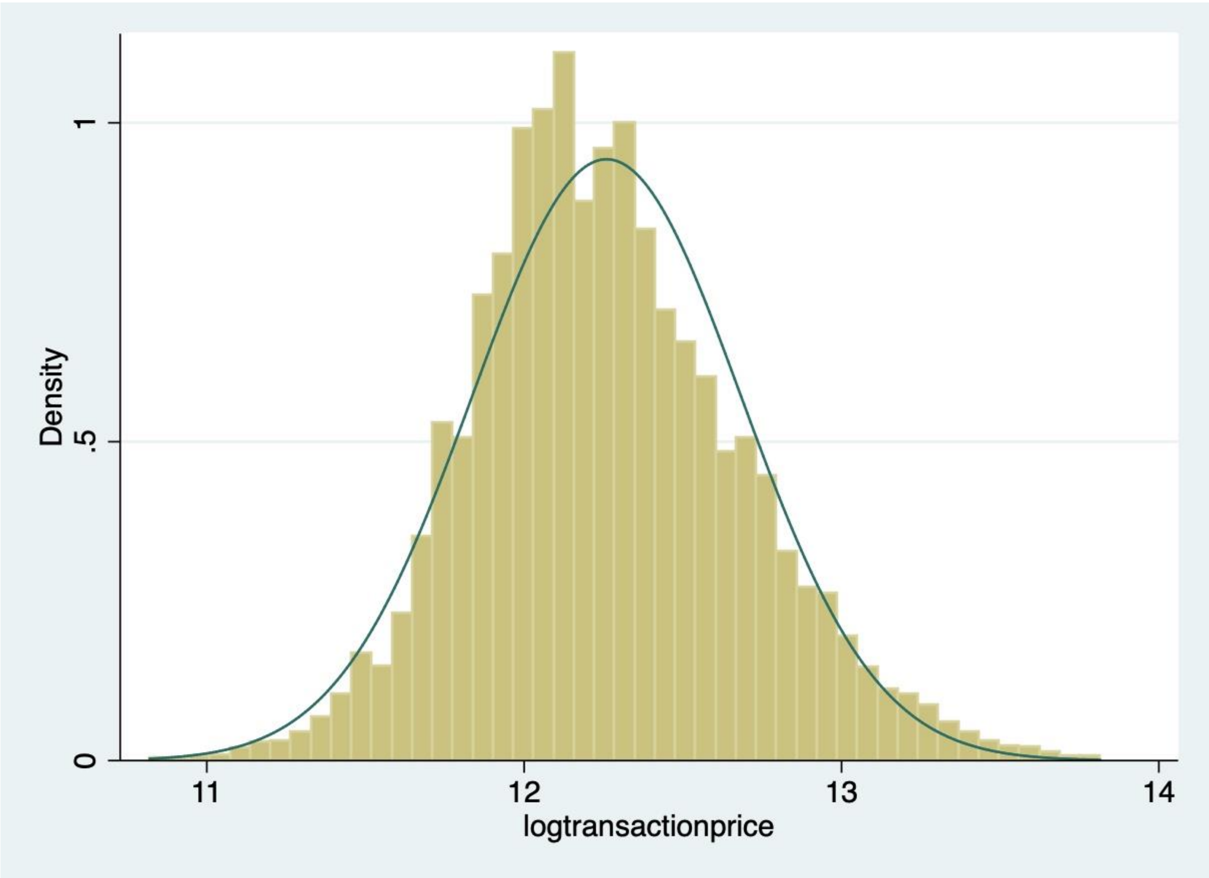
F: Linearity



G. Homoscedasticity of Residuals

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: energyrating energyconsumptionELK energyconsumptionGAS isolation interior_condition exterior_condition type_house building_period monumental size_GIA_m2 size_volume_m3 size_plot_m2 number_rooms number_toilets number_floors number_balcons basement garage stand elevator fireplace parking loft attic leasehold free_by_name location_garden location_in_centre quality_location duration_sale year chi2(31) = 8493.92 Prob > chi2 = 0.0000

H. Normality of Residuals



I: Energy prices 2013-2017

Gas and electricity, average prices of consumers	**Price gas** *(Euro per M3)*	**Price electricity** *(Euro per kWh)*
1e kwartaal 2013	0,66	0,205
2e kwartaal 2013	0,65	0,202
3e kwartaal 2013	0,64	0,202
4e kwartaal 2013	0,66	0,207
2013	**0,65**	**0,204**
1e kwartaal 2014	0,61	0,204
2e kwartaal 2014	0,52	0,199
3e kwartaal 2014	0,60	0,198
4e kwartaal 2014	0,60	0,200
2014	**0,58**	**0,200**
1e kwartaal 2015	0,61	0,209
2e kwartaal 2015	0,59	0,209
3e kwartaal 2015	0,55	0,195
4e kwartaal 2015	0,56	0,203
2015	**0,58**	**0,204**
1e kwartaal 2016	0,55	0,178

2e kwartaal 2016	0,55	0,173
3e kwartaal 2016	0,55	0,178
4e kwartaal 2016	0,58	0,178
2016	**0,56**	**0,177**
1e kwartaal 2017	0,64	0,195
2e kwartaal 2017	0,61	0,188
3e kwartaal 2017	0,60	0,188
4e kwartaal 2017	0,64	0,195
2017	**0,62**	**0,192**

J: Used datasets

Source	**Level**	**Subject**	**Area (s)**	**Year (s)**	**Number of files**
NVM	Individual	Private residential transactions with corresponding characteristics	The province of Groningen, Zeeland, Flevoland and Gelderland	2013-2017	1
Enexis	Zip code P6	Aggregated energy consumption data	The province of Groningen	2013 2014 2015 2016 2017	5
Enduris	Zip code P6	Aggregated energy consumption data	The province of Zeeland	2013 2014 2015 2016 2017	5
Liander	Zip code P6	Aggregated energy consumption data	The provinces of Flevoland and Gelderland	2013 2014 2015 2016 2017	5

K: Stratified selection process