Do Residents Appreciate Green Labels? – A Quantitative Approach into the Relationship between Energy Labels and Residential Satisfaction in the Netherlands.

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Date: 31 January 2020

ABSTRACT. Residential satisfaction measures the difference between the actual (objective) and desired (subjective) dwelling, neighbourhood, personal and household characteristics (Galster & Hesser, 1981). In most studies, these are the characteristics that are used to examine residential satisfaction. Energy and sustainability attributes are in most cases included in the dwelling characteristic, or they are not even considered. In this study, energy labels are taken as the main explanatory variable to predict its impact on the residential satisfaction. The current literature examines the price premiums and other financial aspects, or the technical aspects of energy labels. Especially after the introduction of obligatory energy labels for sales and rental dwellings, the impact of energy labels on residential satisfaction will increase, as residents will become aware of the energy labels. Therefore, a study on the relation of these two phenomena is needed. The WoON2018 data provide the required information to conduct such research. An Ordered Logistic Regression pursuant to the assumptions of the Proportional Odds Model is performed to find which relations exist between energy labels and residential satisfaction. The results of this study show that homeowners, public tenants and low incomes are more likely to be satisfied with their dwellings at higher energy label rates. Private tenants, high incomes and middle incomes are less likely to be satisfied with their dwellings at higher energy label rates.

Keywords: Energy label, residential satisfaction, homeowner, private tenant, public tenant, Dutch housing market

university of groningen / faculty of spatial sciences

COLOPHON

Document	Master's Thesis
Title	Do Residents Appreciate Green Labels?
Subtitle	A Quantitative Approach into the Relationship between Energy Labels and Residential Satisfaction in the Netherlands.
Version	Final Version

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Date	31 January 2020

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1. INTRODUCTION

The climate problem is one of the main issues of the twenty-first century. Measures are taken at various levels to minimize the causes of the climate problem. The Paris Climate Change Agreement of 2016 is an example of global climate agreements. Such agreements lead to national policies to reduce the greenhouse gas emissions and boost sustainable energy usage. A significant part of the measures are about increasing the conscious consumption behaviour of the population, such as stimulation of public transport and circular economy. What many soon forget is that housing is also a form of consumption. It is therefore important to analyse the role of sustainability in housing consumption.

The construction and real estate sector takes globally 36% of final energy use and 39% of carbon dioxide (CO_2) emission for account in 2017 (International Energy Agency, 2018). 22% of the final energy use, which is about 92 exajoules (EJ) globally, belongs to the residential buildings sector. Only the transport sector (28%) has a more share in the global final energy use. Therefore, the residential sector has a significant contribution to the global climate problem. The energy consumption in residential buildings consist mainly of cooking, space heating and water heating (Global Status Report, 2018). For the European Union, only 17.5% of the energy consumption in households consists of renewable energy and 7.8% of derived heat sources (Eurostat, 2019). The remaining 74.7% of the energy consumption consists of non-renewable and polluting sources, such as fossil fuels.

To achieve consciousness about housing as energy consuming consumption good and reducing the final energy use, the European Union implemented in 2012 the new guidelines on energy labels (EUR-Lex, 2012). The Dutch government implemented on 1 January 2015 the more simplified and reliable version of the energy labels to residential buildings (Rijksoverheid, 2015). An energy label is mandatory for the sale and rental of a home. The energy labels serve as a benchmark to measure the energy performance of a dwelling. The labels vary between A and G, where A is the most energy efficient rate and G the least (*Appendix A*). The government encourages homeowners, private parties and housing associations to have the best possible energy rating for their homes and support them financially (Rijksoverheid, 2017). The German Renewable Energy Sources Act from 2000 guaranteed a grid connection for households if they invest in renewable energy sources and a 20-years government-set feed-in tariff for households, which made installing solar power beneficial and affordable for households (International Energy Agency, 2014). Germany has become the fourth most installed solar power capacity country in the world (IRENA, 2019). The Energy Star program is set up by the United States Environmental Protection Agency to promote energy efficiency in products and (residential) buildings (Energy Star, N.D.), which is similar to the European energy labels.

Residents can use such measures to save money through lower energy bills, reduce their energy usage and decrease the environmental impact of their homes. These measures may also increase the awareness of residential energy consumption and promote the energy transition to renewable energy sources by stimulating energy efficient and sustainable measures in dwellings. An

energy-efficient dwelling includes a proper floor, wall and roof insulation, an energy-efficient heating system, solar panels and double-pane windows. In addition to saving on energy costs, a well-insulated and energy-efficient home brings more comfortable and pleasant living to households. A higher energy rating means less greenhouse gas emissions, which is beneficial for the environment. Some residents consider sustainability important and feel satisfied when they do something positive for the environment. Consequently, a higher energy rating may result in higher residential satisfaction. On the other hand, residential buildings with high energy ratings often have higher selling and rent prices. The higher costs of housing may lead to dissatisfaction for some residents. Especially for residents who do not care about the environment and households with lower incomes.

Brounen & Kok (2011) find the first evidence of the market adaptation and economic implications of the old energy rating implementation in the Netherlands, which has been updated in 2015. They show that higher energy label values increase the price value of owner-occupied homes. Chegut et al. (2016) show that A-labeled dwellings are 6.3 percent more valuable than C-labeled ones in the Netherlands. The positive relation between better energy ratings and higher sales premiums is also found for the Italian[1], Spanish[2] and British[3] owner-occupied dwellings ([1]Fregonara et al., 2014; [2]Ayala et al., 2016; [3]Fuerst et al., 2015). Owner-occupied homes without energy labels are sold for less than homes with labels in California (Kahn & Kok, 2014). Fregonara et al. (2017) show that energy labels explain six to eight percent of the price differences for single-family homes. However, for apartments it has no effect at all. In general, apartments are inhabited by households with lower income, which means that they benefit less from value premiums than higher incomes.

Various studies have been conducted into the relationship between energy ratings and rental prices. Feige et al. (2013) examined 2,500 rental properties in Switzerland. Overall, they find a positive relationship between the environmental characteristics of residential buildings and their rental levels. Surprisingly, the energy rating of dwellings have a negative impact on the rental levels. Dwellings with worse energy ratings have higher rent prices, due to the rental structure in Switzerland. Im et al. (2017) find that energy efficient features increase the rent prices in the United States and Cajias & Piazolo (2013) find the same results for the German rental dwellings. Hyland et al. (2013, p.943) show that "energy efficiency has a positive effect on both the sales and rental prices of properties, and that the effect is significantly stronger in the sales segment of the property market".

In countries with a green subsidy, the market is shifting capital from polluting to clean sectors (Eichner & Runkel, 2014). The market is prepared to switch to cleaner energy sources, but this does not imply a higher residential satisfaction. Brounen & Kok (2011) study the market adoption of energy performance benchmarks, in which they conclude that information is the key in encouraging the housing market into energy conservation. Michelsen & Madlener (2017) find that information and campaign on clean energy may have a positive impact on residential satisfaction. However, information is not always complete and according to Marmolejo-Duarte & Bravi (2017), this could lead to incorrect cost-benefit perception for the residents. An incorrect cost-benefit perception may

lead to dissatisfaction among residents. In the United States, lower incomes are less aware of energy labels and they place little value on it (Murray & Mills, 2011). Energy savings, environmental benefits and comfort benefits, such as thermal comfort, air quality and noise protection, are significantly valued by homeowners and renters (Banfi et al., 2008). Tan (2014) analyses the residential satisfaction of homeowners in Malaysia by using similar attributes as in the Dutch housing energy labels. Solar panel systems and double-pane doors and windows provide the most residential satisfaction.

Research on energy ratings often focusses on the financial aspect of residential buildings, such as sales and rent premiums of owner-occupied and rental homes. This is due to the interest of investors and homeowners in the price premiums of dwellings. In general, there is a positive relation between energy ratings and selling and rent prices of dwellings, as the literature shows. The introduction of the current energy labels in the Netherlands could have increased the awareness of green living among residents. However, since the introduction of the housing energy labels, no research has been conducted on the effects of energy labels on residential satisfaction. There is a clear gap in the literature on the relation between these two phenomena. Residential satisfaction is often analysed with only classic attributes such as dwelling characteristics, neighbourhood characteristics and the socio-economic status of residents. The introduction of mandatory energy labels in the Dutch housing market makes it necessary to analyse the effects of energy labels on residential satisfaction. Energy labels may affect the awareness and importance of energy ratings, housing sustainability and energy transition among residents, and this could affect their residential satisfaction.

This study aims to analyse whether energy labels of homes do affect the residential satisfaction of residents and will give an insight in the effects of energy labels on residential satisfaction. The energy labels for homes are a relatively new phenomenon. If the impact of energy labels on residential satisfaction is known, the residential sector can increase residents' satisfaction by taking measures in homes. Homeowners of homes with high energy ratings get a price premium on top of the home value. If it also appears that energy labels contribute to higher residential satisfaction, then there is more reason for homeowners to upgrade their homes. Private landlords and public housing corporations can adapt and improve their policies on sustainability more efficiently and find a balance between sustainability and additional costs for tenants. The efficient and balanced policies could help increasing the residential satisfaction further.

The remainder of this paper is organised as follow. Section 2 will describe the theory that is needed to understand the conceptual model, which will be the guide for the methodology, quantitative analysis and interpreting the results. The theory also determines the dependent, main independent and control variables. Section 3 introduces the conceptual model, main question, sub-questions and hypothesis in a research problem statement. Section 4 will describe the used data, variables and methods. Section 5 presents the results of the quantitative analysis. The results are explained and interpreted. Section 6 will end the paper with a conclusion, recommendations and a self-reflection.

2. THEORETICAL FRAMEWORK

This chapter will discuss the effect of energy labels and other attributes on residential satisfaction. First, residential satisfaction is described and discussed in general. Dwellings are heterogeneous goods composed of different components. Components that influence residential satisfaction can be divided in two sets of objective factors: contextual characteristics and compositional characteristics (Galster & Hesser, 1981). Secondly, these contextual and compositional characteristics will be discussed. The aim of this is to determine the main determinants of residential satisfaction by using the literature. Subsequently, literature and theory on energy labels are discussed and it will be explained how energy labels could affect residential satisfaction.

2.1 Residential Satisfaction

Theories on residential satisfaction are based on the idea that residential satisfaction measures the difference between the actual (objective) and desired (subjective) dwelling, neighbourhood, personal and household characteristics (Galster & Hesser, 1981). Dwelling and neighbourhood characteristics can be seen as external influences on residential satisfaction, while personal and household characteristics as internal influences. Weidemann & Anderson (1985) state that residential satisfaction is the result of the objective dwelling characteristics, the objective resident characteristics and the subjective norms and values, perception and aspiration of these residents. Households are inclined to make judgments based on their norms and values, perception and aspiration. Residential satisfaction indicates the absence of complaints and an agreement between the actual and the desired situation (Weidemann & Anderson, 1985; Lu, 1999). In other words, the residential satisfaction increases when the gap between actual and desired situation decreases. Galster (1987) calls this the 'aspiration-gap approach'. As we consider households and residents as rational beings, in first instance they will settle in homes that suit their desires the best to achieve the highest utility (Coolen & Hoekstra, 2001). Once they have moved into a home, changes can take place in their neighbourhood or personal characteristics. As a result, the actual situation changes, and this may affect the residential satisfaction. Dwelling characteristics however only change when renovation takes place. Homeowners, especially those who live in single family homes, are mostly more satisfied with their dwellings and neighbourhoods than renters (Elsinga & Hoekstra, 2005; Lu, 1999; Rohe & Basolo, 1997).

Rossi (1955) shows in his life-cycle theory that a mismatch in the actual situation and the desired aspirations result in dissatisfaction. This has three possible outcomes (Weidemann & Anderson, 1985). The first outcome is that residents can re-evaluate and reduce their housing aspirations. The second outcome is that residents can make adjustments to their homes (e.g. renovation), so their homes meet their needs. The third outcome is to move to another home unit. Lu (1998) also concludes that residential dissatisfaction has significant impact on residents' mobility behaviour. Households are moving because they expect that this will reduce the gap between the actual and aspired situation, and will therefore be satisfied with their new homes (Rossi, 1955).

2.2 Contextual Characteristics

Dwelling characteristics. The first contextual characteristics are the dwelling characteristics. These characteristics consist of the physical dwelling features and the qualitative state of these features and the dwelling as a whole (Galster & Hesser, 1981). The features consist of quantitative structural attributes of dwellings, such as the number of rooms and the total surface area. In addition, Galster & Hesser (1981) use other attributes, such as construction year, housing type, heating, interior and exterior condition, layout of the home and the presence of balcony and garden, to determine residential satisfaction. As expected, they find that there is a positive correlation between negative dwelling characteristics and higher residential dissatisfaction, regardless the residents' personal characteristics.

Various dwelling characteristics are used in studies into residential satisfaction, depending on the available variables in data-sets. Amerigo & Aragones (1997) mainly look at the appearance and the materials used in homes. The layout and internal structure of homes is used by Mohit et al. (2010). Elsinga & Hoekstra (2005) use the number of rooms, housing type, presence of bath or shower, adequate heating, presence of garden and balcony, damp and humidity problems and condition of the roof. Boumeester et al. (2011) approaches the various home attributes in a structured way. Homes are heterogeneous and consist of various attributes. Households value these attributes differently, which are the "part values". All these part values together form the "total value", which is the total attribute package of a dwelling. Boumeester et al. (2011) state that the number of attributes can be infinite in theory, but there are main attributes that appears in the chief part of studies (*Table 1*). Dwelling characteristics and neighbourhood characteristics are often used interchangeably in the literature. In this study they are taken separately.

Dwelling Characteristics		
Type of dwelling	Total usable surface area of dwelling	Architecture
Number of rooms	Presence of balcony	Storage space
Size of living room	Size of balcony	Quality/Level of maintenance
Tenure	Presence of backyard	Year/Period built
Price	Size of backyard	Private parking space

Table 1: The most used dwelling characteristics. Source: Boumeester et al. (2011). Edited by author.

Locational Characteristics. The second contextual characteristics are the neighbourhood characteristics (Galster & Hesser, 1981). However, the neighbourhood characteristics only fall short. 'Locational characteristics' is preferred in this study, because factors such as region, municipality, city and distance to the city centre also affect residential satisfaction. Besides neighbourhood and locational characteristics, neighbourhood satisfaction has been shown to be an important predictor of residential satisfaction (Galster & Hesser, 1981; Lu, 1999; McCray & Day, 1977). The locational characteristics can be divided in physical and social features.

Physical features. Baum et al. (2010) and various other literature show that the proximity of amenities contributes to residential satisfaction. Proximity to amenities, especially walking distance, ensures that residents can look after their needs without too much effort, costs and travel time. Necessary amenities, such as shops, schools and medical facilities, have a positive effect on residential satisfaction of public tenants (Huang & Du, 2015; Mohit & Azim, 2012). Besides proximity, the quantity and quality of amenities also play a role in residential satisfaction (Perez et al., 2001; Amerigo & Aragones, 1997). Accessibility, public facilities, open spaces, parks (Li et al., 2019), quietness, greenery and cleanness (Baum et al., 2010) all correlate positively with higher residential satisfaction of tenants. Amerigo & Aragones (1997) and Galster & Hesser (1981) find evidence that housing type, period built, maintenance in the neighbourhood and the number of decayed buildings are also important determinants of residential satisfaction. Urbanity and density both influence residential satisfaction, although there are conflicting findings in the literature. Campbell et al. (1976) and Li et al. (2019) show that residents in central cities are less likely to feel satisfied with their living situation than residents in rural areas, while Levy-Leboyer (1993) concludes that residents in central areas are more satisfied than rural residents. The latter could be due to the proximity of amenities.

Social features. Amerigo & Aragones (1990) show that the relationship with neighbours contributes to housing satisfaction. Amerigo & Aragones (1997) show in a later study that the duration of residence in the neighbourhood, feeling involved in the neighbourhood, participating in neighbourhood activities and visiting neighbours contribute to residential satisfaction. Being part of and being able to identify with the neighbourhood (Fried, 1986), community spirit, friendliness and friendship (Parks et al., 2002; Sirgy & Cornwell, 2002) are also important determinants of residential satisfaction. Andersen (2008) merges all these elements and calls this 'social interaction'. Social interaction has a significant impact on residential satisfaction (Andersen, 2008). Karsten (2007) emphasizes the importance of family life in the neighbourhood. Greenery, open spaces, safety and low crime rates (Karsten, 2007; Salleh, 2008) play an important role in creating a child-friendly neighbourhood. This will boost the residential satisfaction of families. In addition, proximity to amenities has the advantage that parents have more time free for their children (Karsten, 2007). The physical features of neighbourhoods are intertwined with the social features. The 'part value' and 'total value' concept also holds for the neighbourhood characteristics (Boumeeser et al., 2011). The locational characteristics are shown in *Table 2*.

Locational Characteristics		
Type and size of local council	Amenities	Parking places
Type of neighbourhood	Public transport	Safety
Type of housing	Green and water	Space and building density
Period built	Semi-public areas (parks etc.)	Urban development design

Table 2: The most used locational characteristics. Source: Boumeester et al. (2011). Edited by author.

2.3 Compositional Characteristics

***Personal and Household Characteristics*.** The compositional characteristics are the residents' personal and household characteristics. Personal and household characteristics play a role in research into residential satisfaction in two ways. Firstly, personal and household characteristics on its own influence living satisfaction. Secondly, dwelling and neighbourhood characteristics have varying degrees of impact on the residential satisfaction due to different personal and household characteristics of residents. Galster & Hesser (1981) use the family life-cycle model (Rossi, 1955) to estimate residential satisfaction. According to this model, households go through different phases in their life, such as family formation, expansion, contraction and divorce. These phases lead to changes in the size and composition of households, so that housing preferences and needs change over time. These new preferences and needs can ensure that the current homes and neighbourhoods of households no longer meet their expectations, which leads to dissatisfaction. Galster & Hesser (1981) use age, marital status and the number of children to simulate the life-cycle model to assess the satisfaction of households.

The household composition is an important determinant of residential satisfaction. Smaller family size is related to higher residential satisfaction (Campbell et al. 1976; Galster & Hesser 1981). However, Galster (1987) and Li et al. (2019) show that a greater family size has a positive impact on residential satisfaction. Huang & Du (2015) shows that this is due to different preferences of different groups. Some cultures prefer large families, and others do not. Norms, values and what people have received from their parental homes affect the impact of the household composition on residential satisfaction. Karsten (2007) indicates that children can positively influence residential satisfaction, although it depends on the availability of amenities, open spaces, greenery and safety in the neighbourhood. Lu (1999) shows that married couples with children are relatively more satisfied than singles and single parents given the same dwelling and neighbourhood characteristics. Age is another significant determinant of residential satisfaction (Amerigo & Aragones, 1997; Li et al., 2019; Lu, 2002). Older people have a higher level of residential satisfaction than younger people with similar conditions for other features (Campbell et al., 1976; De Jong et al., 2011; Galster & Hesser, 1981; Lu, 1999). Higher education level has a positive effect on residential satisfaction (Ren et al., 2014), however Dekker et al. (2011) found the opposite results. Lu (1999) finds that education has an insignificant effect on residential satisfaction.

***Financial Characteristics*.** The financial characteristics are not dealt with specifically in Galster & Hesser (1981), but they are important for this study. Income is an important determinant of housing satisfaction (Flambard, 2017; Li et al., 2019). A higher income level correlates with higher residential satisfaction (Campbell et al., 1976; Galster & Hesser 1981; Lu, 1999). Lu (1999) shows that lower rents lead to higher residential satisfaction. He also concludes that public housing tenants were found to be more satisfied with their homes than private renters, although living in public housing correlates with lower neighbourhood satisfaction. This might be due to qualitative lower facilities and buildings

in the neighbourhood. James (2008) shows that in the United States subsidized renters are more satisfied with their homes than non-subsidized renters. Subsidized rents are common in the Dutch public housing market. The benefit of subsidized rents is that tenants have to pay less net rent. The total housing costs of the tenant will therefore decrease, and lower housing costs lead to higher residential satisfaction (Lu, 1999). In addition to subsidized rents, energy bills and loans affect the total monthly costs of households.

2.4 Energy Labels

Energy efficient dwellings have a positive correlation with higher sales premiums in the Netherlands (Brounen & Kok, 2011; Brounen et al., 2009; Chegut et al., 2016). The literature review showed that this also applies to other European countries and the United States. Kahn & Kok (2014) conclude that homes without energy labels were sold for less than homes with energy labels. The presence of energy labels can be seen as a feature of the dwelling and each higher level of energy rating adds incremental value to it. Feige et al. (2013), Im et al. (2017) and Cajias & Piazolo (2013) show that energy efficient features increase the housing rent prices. The higher rental premiums are mainly due to the lower operating expenses for tenants (Reichardt, 2013). Private landlords and housing associations may want to increase the rents to earn back their investment in upgrading the energy ratings (Kim et al., 2014). This could lead to dissatisfaction among residents, despite a better energy rating for their dwelling. The extra costs can be particularly burdensome for people with lower incomes.

The decreasing operating expenses are due to the various technical implementations in a dwelling. Renewable energy technologies such as solar panels and wind turbines, energy efficient lighting, water conservation devices, rainwater harvesting system, double-pane doors and windows, efficient cooling and heat system, and passive design for natural cooling and heating are some of the features which implies a higher energy rating for dwellings (Banfi et al., 2014; Tan, 2014). This kind of measures ensure dwellings to be more energy efficient and reduce energy costs. However, Majcen (2016) shows that there is a discrepancy between the foreseen and actual energy usage in quite a number of households. Some dwellings are even performing significantly less than they should be. Guerra Santin (2010) shows that the actual energy consumption in dwellings with high energy ratings are higher than it should be. The rents may increase due to higher energy ratings, but the cost savings for households may lag behind. This can lead to residential dissatisfaction among tenants, while private landlords and housing associations profit from higher rental income. For homeowners this means lower sales premiums then they had expected. The margin between their investment in upgrading their dwelling and the added price premium can be lower than expected. Higher energy ratings may lead to residential dissatisfaction in these conditions.

To minimize the unforeseen differences in actual and theoretical energy consumption, stricter supervision of the implementation of "green adjustments" is needed (Eichner & Runkel, 2014). In addition, residents must be informed in order to create more capacity for green housing. Informing

residents with lack of awareness of energy ratings leads to appreciation of energy efficient measures (Brounen & Kok, 2011; Davis & Metcalf, 2014). Eichner & Runkel (2014) show that in countries with a green subsidy, the market is more willing to invest in clean sectors. Michelsen & Madlener (2017) find that information and campaign on clean energy have a positive impact on the residential satisfaction of homeowners. However, information is not always complete and according to Marmolejo-Duarte & Bravi (2017), this could lead to incorrect cost-benefit perception for the residents. An incorrect cost-benefit perception may lead to dissatisfaction among residents. In general, low incomes are less aware of energy labels than higher incomes and they value energy labels less than higher incomes (Murray & Mills, 2011). This may lead to less residential satisfaction for lower incomes compared to higher incomes with the same dwelling energy labels.

An increasing amount of consumers is paying attention to sustainability when consuming products and services (Middlemiss, 2018). Housing is a form of consumption. Due to the growing concern about climate change, residents are increasingly paying attention to sustainability in their living spaces to reduce the impact on the environment (Fuerst et al., 2015). Furthermore, a well-insulated and energy efficient home provides a more comfortable living experience, which could lead to higher residential satisfaction. High energy ratings and energy efficient living spaces give some residents a satisfied feeling, as they consider it important to conserve the environment.

As shown in the theoretical framework, the degree of energy labels could lead to both residential satisfaction and residential dissatisfaction. Saving on energy costs, lower total monthly costs, information on energy measures, increasing awareness in green living and comfortable living could lead to residential satisfaction. Lower sales premiums, increasing rents, discrepancy between foreseen and actual energy usage, and wrong or incomplete information could lead to residential dissatisfaction.

3. RESEARCH PROBLEM STATEMENT

Figure 1: Conceptual Model. Source: Author.

Figure 1 shows the conceptual model that has been compiled based on the theory. It is an overview of which mechanisms are involved in residential satisfaction, and will be a guide in constructing the regression model later on. The dwelling, locational, personal and financial characteristics are the classic attributes in research on residential satisfaction. Energy labels is the main attribute on which this research focuses. The five categories of attributes have a joint effect on the housing satisfaction of residents. Additionally, residents can be divided into homeowners, private tenants and public tenants. The theory showed that these three housing tenure groups are exposed to different factors and their residential satisfaction may differ, given their living conditions. Furthermore, the literature shows that different income groups can experience energy labels differently. This may result in different effects of energy labels on residential satisfaction. As a result, this study analyses how the residential satisfaction of the three income groups is affected by energy labels. The WoON2018 data include variables such as residential satisfaction, energy labels of homes, dwelling attributes, rent prices, mortgage payments and family status. These specific attributes give the possibility to conduct such a research. This study will be structured with the help of a main question and four sub-questions.

The main question of this study is: *What is the effect of home energy labels on the residential satisfaction of residents in the Netherlands?*

The first sub-question is: *Which determinants have an effect on residential satisfaction according to the literature?* The literature review showed what already has been written on energy labels and residential satisfaction. This revealed that there was a clear gap in the literature on the relationship between energy labels and residential satisfaction. The theoretical framework has described the specific theory and literature that fits in with the rest of the research. From this, the conceptual model is compiled, hypotheses will be formed later in this section and the regression models for the

analytical part will be prepared in the next section. Furthermore, the theory and literature help to clarify the mechanisms and relationships between the different concepts that are relevant to the main question. The theory helps explaining which mechanisms are behind the regression results that will be obtained. Therefore, the results in the analytical part are interpreted on scientific grounds.

The second sub-question is: *What are the effects of home energy labels on the residential satisfaction of homeowners, private tenants and public tenants?* This part will use quantitative methods to estimate what the impact of energy labels is on residential satisfaction. Besides the home energy labels, the four other classic categories of attributes will be examined. By doing this, a more complete picture is created in which element have an effect on residential satisfaction. *Figure 1* shows that dwelling, locational, personal and financial characteristics influence residential satisfaction. The main attribute in relation to residential satisfaction is however energy labels in this study. The four other 'classic' characteristics will be the control factors. This will show how energy labels affect the residential satisfaction combined with the four other characteristics. The exact attributes per characteristic will be chosen and argued in the next section.

The third sub-question is: *What are the differences of the impact of energy labels on residential satisfaction between income levels?* The results of the previous part might show higher or lower residential satisfaction due to energy labels. However, Murray & Mills (2011) show that low incomes attach less value to energy labels, so that their satisfaction is less affected by this. The theory indicates that there might be difference in awareness and appreciation of energy labels between different income groups. For this reasons, it will be examined whether lower incomes consider energy labels less important than higher incomes, by dividing the household in high, middle and low incomes.

The theory showed that homeowners are more satisfied with higher energy labels than tenants, since they profit from price premiums on their property values (Brounen & Kok, 2011; Brounen et al., 2009; Chegut et al., 2016). Murray & Mills (2011) state that low incomes are less aware of energy labels than higher incomes and they value energy labels less than higher. Based on the findings in the theory, the main question, the sub-questions and the available data, the following two hypotheses are formulated:

Hypothesis 1

H_0 = Homeowners are more satisfied with higher energy labels than public tenants.

H_1 = Homeowners are less satisfied with higher energy labels than public tenants.

Hypothesis 2

H_0 = Lower incomes are less satisfied with higher energy labels than higher incomes.

H_1 = Lower incomes are more satisfied with higher energy labels than higher incomes.

4. DATA & METHODOLOGY

4.1 Data Report

Data from the 'WoonOnderzoek Nederland 2018' (WoON2018) is used to conduct this research. The 'WoonOnderzoek' is carried out every three years by the Central Bureau of Statistics (CBS) on behalf of the Ministry of the Interior and Kingdom Relations (BZK). The state of the Dutch housing market is mapped out by conducting the research periodically. The aim of the 'WoonOnderzoek' is to develop knowledge and to gain insight into the housing situation of Dutch households, their housing wishes, their wishes and behaviour for relocation, the quality of life, and the choices that households made on the housing market. All this knowledge and insights are indispensable for the Dutch housing policy. The data-set is also used in scientific studies on housing satisfaction, relocation behaviour, and housing price and rent developments. The data collection must meet a number of preconditions, such as a certain number of response, the sample design, the approach strategy and various quality requirements (Janssen-Jansen, 2018). After establishing these preconditions, the data collection took place from August 2017 up to April 2018. A total of 115,000 people were invited to participate, which ultimately had to yield 65,000 responses. This condition was achieved with 67,523 responses. The size of the WoON2018 is such populous that it provides support for reliable statements at national, provincial and local level (Janssen-Jansen, 2018). Of the respondents, 37,641 are homeowners, 6,329 are private tenants and 14,633 are public tenants. The other respondents live at their parental home, in a healthcare institution or in other forms of housing. *Appendix B* shows how the data cleaning is performed. After the cleaning process, a total of 51,001 observations are left in the data-set.

The respondents are at least 17 years old and from all over the Netherlands, so that general conclusions about the Dutch housing market can be drawn. The locations of the respondents are known to the municipal level and the degree of urbanity of the respondents' neighbourhood is also known. In addition, respondents of different age groups, marital status and household forms are involved in the surveys, and they are living in different housing types, so that the effect of housing types can be measured. Furthermore, registration files are used in the data-set. For example, the household income is determined by data from the Tax Authorities.

Housing energy labels are a relatively new feature of residential buildings after they became mandatory in 2015. As a result, the number of homes for which the energy labels are known has increased sharply. The WoON2018 is the first version of the 'WoonOnderzoek' after the introduction of energy labels for homes. The theory showed that energy efficiency and sustainability are becoming increasingly important for consumers in their consumption behaviour. The introduction of the energy label scheme in 2015 could have increased awareness among residents. Energy-efficient homes can therefore contribute significantly to residential satisfaction. The theory showed that higher energy labels can also have negative aspects to it. The WoON2018 data include variables such as home satisfaction, personal and household features, total monthly housing costs, dwelling features and

neighbourhood features. Furthermore, the data distinguish home satisfaction, neighbourhood satisfaction and general satisfaction in life which makes statements and conclusions exclusively on residential satisfaction possible. The availability of such a complete data-set and the comprising home energy label policy make the Dutch housing market suitable for conducting this research.

4.2 Operationalising Variables

The *dependent variable* in this study is the residential satisfaction. In the WoON2018 data this variable is determined by asking the respondent the next question: How satisfied are you with your current home? The answer possibilities were (1) very satisfied, (2) satisfied, (3) not satisfied, but not dissatisfied either, (4) dissatisfied and (5) very dissatisfied. The answers of the respondents are based on a Likert-type scale and this indicates an ordinal dependent variable. Individuals tend to conform or adapt to their residential environment over time to close the gap between the actual and aspired residential situation, as the theory showed. Consequently, respondents report a high level of satisfaction in most surveys (Amerigo & Aragones, 1990). *Table 3* shows that this applies for this data-set. The 'very dissatisfied' category is only accounted for 0.88% of the total observations, thus 'very dissatisfied' will be joined with 'dissatisfied'. The residential satisfaction will therefore consist of (1) very satisfied, (2) satisfied, (3) neutral and (4) dissatisfied.

Satisfaction with current home	Frequency	Percentage	Cumulative
Very satisfied	20,439	40.08	40.08
Satisfied	23,817	46.70	86.77
Not satisfied, but not dissatisfied either	4,999	9.80	96.58
Dissatisfied	1,295	2.54	99.12
Very dissatisfied	451	0.88	100.00
Total	51,001	100.00	

Table 3: Frequency of residential satisfaction. Source: WoON2018.

The *independent variable* is the energy label. The level of energy label per dwelling is determined by the registered file of the Netherlands Enterprise Agency (RVO) and concerns data from 2018. The distribution of the energy labels are relatively equal among the respondents. Only energy label C stands out (*Table 4*). Elements like solar panels, heating, isolation, double-pane windows and the quality of the interior and exterior are determining what energy label a dwelling receives. In most studies, these attributes are treated as part of the control variables within the dwelling characteristics. In this study however, the energy label is detached from the dwelling characteristics and serves as the main explanatory variable. The effect of energy labels on the residential satisfaction is explicitly the focus in this study.

Energy Labels	Frequency	Percentage	Cumulative
A	4,525	8.87	8.87
B	7,923	15.53	24.41
C	15,900	31.18	55.58
D	3,909	7.66	63.25
E	6,457	12.66	75.91
F	5,783	11.34	87.25
G	6,504	12.75	100.00
Total	51,001	100.00	

Table 4: Frequency of energy labels. Source: WoON2018.

The *control variables* consist of four groups of characteristics: Dwelling, locational, personal and household, and financial. These characteristics are derived from the theory and are the often used traditional characteristics in studies on residential satisfaction. The dwelling characteristics consist of housing type, number of rooms, total net surface area, interior layout of the house and maintenance of the house. For the housing type there are two possibilities: Single family home or multi-family home. Tests showed that there were no significant differences between the originally five housing types in the data, and are therefore merged into two categories. The number of rooms are continuous and range from one to twelve chambers. The interior layout of the house is whether respondents are satisfied or not with their house interior. The same applies to whether the dwelling is well maintained or not.

The locational characteristics consist of whether the respondent lives in the largest four municipalities of the Netherlands (G4), the largest forty municipalities (G40) or the rest. Further, the degree of urbanity of the neighbourhood and the attachment to the neighbourhood are included. The difference between G4, G40 (*Appendix C)* and other municipalities gives an indication whether people in urban areas are more or less satisfied than respondents in rural areas. The urbanity degree of the neighbourhood is divided in urban, suburban and rural. The attachment to the neighbourhood gives an indication on the social features of the neighbourhood. Social interaction with neighbours and a child-friendly neighbourhood may positively affect the residential satisfaction.

The personal and household characteristics consist of age, household composition, education and whether the respondent moved to the current dwelling in the past two years. The age is divided in four categories: 17-34 year, 35-54 year, 55-74 year and 75+ year. The amount of younger respondents is low compared to older ages, therefore the younger ages 17-24 and 25-34 are aggregated in one category. The household composition is classified in five categories: Single person, couples, couples with child(ren), single parent and non-family households. The latter category appears mainly at the very young respondents which may indicate students who live together. Because there are already few young respondents in the database, the non-family households are not excluded from the database. The database contains education levels between primary education and master's degree of respondents, and is thoughtfully classified in low, middle and high education levels. The theory indicated that people are moving to match their current living situation with their aspired living situation (Galster & Hesser,

1981; Rossi, 1955). Therefore, respondents who moved to the current dwelling in the past two years might be more satisfied since the new home is most likely desired by them.

The financial characteristics consist of net income per household and total monthly housing costs. The data only contain net income on household level. Both net income and total monthly housing costs are log transformed. Net income is preferred over gross income, because the amount of which an household can spend in a month is believed to have more impact on the residential satisfaction. The data contain information about the rent and mortgage payment of respondents. However, the respondents are divided into homeowners and tenants, thus different variables for each tenure type should be used. Fortunately, the database contains a variable that has calculated the total monthly costs of a household including the rent or mortgage payment, the rent benefit, the energy costs, water costs, municipal costs, and all other housing costs. This single variable gives the possibility to analyse the impact of higher housing costs on residential satisfaction for all tenures.

Tables 5 and *6* show the summary statistics for the categorical and continuous variables. The mean, standard deviation, minimum and maximum are not shown for the categorical variables. A mean of 1.5 for residential satisfaction would imply something between very satisfied and satisfied. For categorical variables these values are not meaningful and do not indicate an actual value, since these values are not continuous. The means of categorical variables would represent the underlying codes that are given to ordinal ranks such as satisfied, neutral. These codes by themselves are meaningless. For this reason, it is preferred to show this variant of the summary statistics. *Table 5* shows that homeowners (67.71%) are relatively in the majority compared to both groups of tenants (24.43% and 7.86%). Notice that homeowners and private tenants possess relatively more lower energy classes and public tenants more higher energy classes. More high incomes have energy label A for their dwelling compared to both tenant tenures in relative terms. For energy label G this is exactly the opposite. This may be an indication that homeowners upgrade their homes for the price premium as showed in the theory, while there are homeowners who cannot afford such upgrades, thus still having energy label G dwellings. *Table 5* shows that the energy label distribution for ‘very satisfied’ and ‘satisfied’ respondents are relatively equal. However, the ‘neutral’ and ‘dissatisfied’ respondents are relatively more represent in the lower energy labels. Besides the energy labels, four other energy variables are included in the model. These variables indicate how the respondent think about the level of energy efficiency of their dwelling, whether the energy class of their dwelling should be upgraded and what the consequences are for the environment. These variables will help interpreting the regression results. The ‘single-family’ homes, ‘G40’ and ‘single person’ categories have ‘base’ written in front of their names which indicates that these serve as the reference category in the regression analysis.

Table 5: Summary Statistics for categorical variables (N = 51,001). Source: WoON2018.

Variables	Energy Labels									
	A	**B**	**C**	**D**	**E**	**F**	**G**	**Total**	**Perc.**	**Cum.**
Tenure										
Homeowners	3,070	6,121	10,414	3,185	2,430	4,533	4,781	34,534	67.71%	67.71%
Public tenants	1,110	1,343	4,585	598	3,267	973	581	12,457	24.43%	92.14%
Private tenants	345	459	901	126	760	277	1,142	4,010	7.86%	100.00%
Income level										
High	1,417	2,767	3,273	945	488	1,498	1,948	12,336	24.19%	24.19%
Middle	1,978	3,264	7,402	1,915	2,295	2,594	2,772	22,220	43.57%	67,76%
Low	1,130	1,892	5,225	1,049	3,674	1,691	1,784	16,445	32.24%	100.00%
Residential satisfaction										
Very satisfied	2,321	3,884	5,864	1,667	1,547	2,386	2,770	20,439	40.08%	40.08%
Satisfied	1,890	3,349	7,951	1,844	3,228	2,685	2,870	23,817	46.70%	86.77%
Neutral	256	497	1,626	321	1,154	534	611	4,999	9.80%	96.58%
Dissatisfied	58	193	459	77	528	178	253	1,746	3.42%	100.00%
Energy efficiency home										
Agree	3,549	4,714	6,513	1,511	1,786	1,740	1,663	21,476	42.11%	42.11%
Neutral	730	2,194	5,884	1,456	1,981	1,975	1,992	16,212	31.79%	73.90%
Disagree	246	1,015	3,503	942	2,690	2,068	2,849	13,313	26.10%	100.00%
Improvement home										
Agree	1,420	3,365	8,265	2,058	3,877	3,311	3,822	26,118	51.21%	51.21%
Neutral	1,372	2,573	4,761	1,139	1,571	1,482	1,663	14,561	28.55%	79.76%
Disagree	1,733	1,985	2,874	712	1,009	990	1,019	10,322	20.24%	100.00%
Environmental effect										
Agree	4,109	7,068	13,865	3,408	5,649	5,082	5,738	44,919	88.07%	88.07%
Neutral	346	697	1,670	408	626	578	607	4,932	9.67%	97.75%
Disagree	70	158	365	93	182	123	159	1,150	2.25%	100.00%
Home is easy to heat up										
Yes	4,320	7,564	14,961	3,685	5,579	5,349	5,974	47,432	93.00%	93.00%
No	205	359	939	224	878	434	530	3,569	7.00%	100.00%
Housing type										
(BASE) Single-family	2,913	5,792	12,818	3,894	2,133	5,720	4,435	37,705	73.93%	73.93%
Multi-family	1,612	2,131	3,082	15	4,324	63	2,069	13,296	26.07%	100.00%
Net useable surface										
Less than 50 m2	388	930	570	354	35	518	1,045	3,840	7.53%	7.53%
50-69 m2	793	1,881	1,476	834	88	815	1,023	6,910	13.55%	21.08%
70-89 m2	1,066	1,750	3,782	1,344	299	1,221	1,093	10,555	20.70%	41.77%
90-119 m2	1,364	1,779	6,768	1,184	1,831	1,911	1,437	16,274	31.91%	73.68%
120-149 m2	674	885	2,022	148	2,500	1,015	910	8,154	15.99%	89.67%
150-199 m2	162	555	1,039	34	1,438	260	657	4,145	8.13%	97.80%
More than 200 m2	78	143	243	11	266	43	339	1,123	2.20%	100.00%
Satisfied with layout										
Yes	4,077	7,128	14,055	3,571	5,350	4,961	5,502	44,644	87.54%	87.54%
No	448	795	1,845	338	1,107	822	1,002	6,357	12.46%	100.00%

	A	B	C	D	E	F	G	Total	Perc.	Cum.
Home is well maintained										
Agree	4,164	6,827	12,581	3,187	4,102	4,458	4,792	40,111	78.65%	78.65%
Disagree	361	1,096	3,319	722	2,355	1,325	1,712	10,890	21.35%	100.00%
Size municipality										
G4	547	611	887	20	1,030	447	1,562	5,104	10.01%	10.01%
G40	1,176	2,142	4,025	630	1,792	1,446	1,216	12,427	24.37%	34.38%
(BASE) Others	2,802	5,170	10,988	3,259	3,635	3,890	3,726	33,470	65.63%	100.00%
Urbanity neighb.										
High	1,909	2,877	6,822	754	4,867	2,649	3,331	23,209	45.51%	45.51%
Moderate	1,049	2,018	4,379	1,028	916	958	702	11,050	21.67%	67.17%
Low	1,567	3,028	4,699	2,127	674	2,176	2,471	16,742	32.83%	100.00%
Attached to neighb.										
Totally agree	576	1,118	2,122	685	696	1,118	1,355	7,670	15.04%	15.04%
Agree	1,605	3,103	6,780	1,718	2,557	2,574	2,788	21,125	41.42%	56.46%
Neutral	1,317	2,292	4,002	950	1,425	1,208	1,352	12,546	24.60%	81.06%
Disagree	808	1,113	2,310	451	1,318	695	781	7,476	14,66%	95.72%
Totally disagree	219	297	686	105	461	188	228	2,184	4.28%	100.00%
Age										
17-34 year	465	836	1,938	736	1,011	711	527	6,224	12.20%	12.20%
35-54 year	1,227	3,195	7,056	1,669	2,070	2,197	2,347	19,761	38.75%	50.95%
55-74 year	1,992	3,093	5,039	1,134	1,976	2,064	2,368	17,666	34.64%	85.59%
75 and older	841	799	1,867	370	1,400	811	1,262	7,350	14.41%	100.00%
Household composition										
(BASE) Single person	1,197	2,042	4,765	881	3,139	1,543	1,798	15,365	30.13%	30.13%
Couple	1,394	2,823	5,714	1,727	1,609	2,057	2,399	17,723	34.75%	64.88%
Couple with child(ren)	1,647	2,579	4,236	1,092	959	1,773	1,778	14,064	27.58%	92.45%
Single parent	237	408	1,046	173	598	335	326	3,123	6.12%	98.58%
Non-family households	50	71	139	36	152	75	203	726	1.42%	100.00%
Education										
High	1,898	3,006	4,790	1,253	1,623	2,065	2,921	17,556	34.42%	34.42%
Middle	1,404	2,600	5,324	1,233	2,120	1,751	1,949	16,381	32.12%	66.54%
Low	1,223	2,317	5,786	1,423	2,714	1,967	1,634	17,064	33.46%	100.00%
Moved in past two years										
Yes	666	914	1,526	336	1,018	629	1,006	6,095	11.95%	11.95%
No	3,859	7,009	14,374	3,573	5,439	5,154	5,498	44,906	88.05%	100.00%

Variable	N	Mean	Std. Dev.	Min	Max
Dwelling					
Number of rooms	51001	4.4734	1.4701	1	12
Financial					
Net income by household	51001	43,317.37	23,359.53	10,002	199,900
Total monthly housing costs	51001	877.78	444.3724	13.57	9,828.79

Table 6: Summary Statistics for continuous variables (N = 51,001). Source: WoON2018.

The Spearman (1910) correlation matrix is shown in *Appendix D*. The Spearman correlation matrix tests the level of correlation between the predictors in the model. High correlation is undesirable because this means that two predictors explains more or less the same. This would indicate the presence of multicollinearity in the model. The absence of multicollinearity is one of the assumptions of the Ordered Logistic Regression (Williams, 2019). Spearman correlation matrix is preferred over Pearson correlation matrix, since the Spearman variant does not require linearity between variables (Hauke & Kossowski, 2011). The Pearson variant would also have violated the normality requirement of the data-set, since normality is not required in Ordered Logistic Regression. *Appendix D* shows that most correlations lie between -0.2 and +0.2. This indicates low correlation between variables, since the levels of 0.5 or 0.7 are mostly used as the boundary for high correlation. Only six correlations have a value above 0.5. None of these are above the 0.7 limit. The highest correlation is between 'Surface' and 'Rooms' with a score of 0.642. Both variables are kept in the model, because dwellings can have a large surface although there are few rooms. The room stress per resident in a dwelling could lead to dissatisfaction despite the large dwelling.

4.3 Methodology

In this study, quantitative methods are used to analyse the influence of energy labels on the residential satisfaction of homeowners, private tenants and public tenants. In order to use these quantitative methods in the correct manner and to justify the methods used, this methodology is drawn up. The dependent variable 'residential satisfaction' is a categorical variable instead of a continuous variable, thus Linear Regression Models are not suitable. Methods such as the Ordinary Least Square Regression assume linearity, normality and homoscedasticity, which is not required for Ordered Logistic Regression (McCullagh, 1980; McKelvey & Zavoina, 1975; Williams, 2016). In addition, it has been shown that in surveys on housing satisfaction, respondents tend to rank their housing satisfaction high (Amerigo & Aragones, 1990). In the WoON2018 data-set, most respondents are very satisfied or satisfied with their homes, which indicates a skew distribution. As a result, there is a chance that the predicted probabilities lie outside the unit interval, which means that hypotheses cannot be accepted or rejected with certainty by using linear regression models.

The Binary Logit Model is a popular method that is used for categorical variables. However, this method is used for dichotomous categorical responses, such as "yes" and "no" or "satisfied" and "dissatisfied". The range of the binary dependent variable lies between 0 and 1. The Multinomial Logit Model makes it possible to use the Binary Logit Model for dependent variables with more than two outcomes, however the ordinal nature of the dependent variable outcomes is lost with the Multinomial Logit Models (Lu, 1999). This makes Multinomial Logit Models useful for nominal dependent variables, while the dependent variable in this study has ordered categorical outcomes. The outcomes are based on a Likert-scale type of measurement with five categories for residential satisfaction. After joining 'very dissatisfied' with 'dissatisfied', four categories left: (1) Very satisfied, (2) satisfied, (3)

neutral and (4) dissatisfied. Merging the answers into two categories would aggregate the respondents' answers too much and is not clear if 'neutral' should become satisfied or dissatisfied. Additionally, the disadvantage is that information about the orders of the responses is thrown away. The categories 'very satisfied' and 'satisfied' were deliberately not merged, because these two categories contain the most responses, and the skew between satisfied and dissatisfied would have become even greater. Lu (1999) shows that an Ordered Logistic Regression with four categories for residential satisfaction results in plausible and acceptable coefficient outcomes.

McCullagh (1980) developed an extended version of the Binary Logit Model: The 'Ordered Logit Model'. The Ordered Logit Model makes use of the Ordered Logistic Regression to estimate the ordered log odds of explanatory variables. Just like the Binary Logit Model, the central idea of the Ordered Logit Model is that the ordinal response variable, noted as y, is seen as the discrete realization of an underlying latent (unobservable) continuous random variable y^* (Long & Freese, 2014). The y is the observed ordinal variable and we can only observe the underlying latent variable y^* when it crosses thresholds. Thresholds are the boundaries between the dependent variable outcomes. For instance, an increase from 'dissatisfied' to 'neutral' is crossing a threshold. Unlike the Multinomial Logit Model, the ordinal nature of the outcomes of dependent variables are not lost in the Ordered Logit Models. The ordered logit model is for ordinal dependent variables the appropriate model, because Ordered Logistic Regression techniques allows to estimate the effects of the independent variables on the underlying y^*. The categories of the ordinal variables can be seen as contiguous intervals on the continuous scale (Lu, 1999). Therefore, the underlying latent variable can be noted as:

$$y^* = \beta x + \varepsilon \quad (1)$$

where β is the regression coefficient, x the covariate and ε the error term. The continuous, unmeasured latent variable y^* determines the values of the observed ordinal variable y as follows:

$$y_i = j \text{ if } \alpha_{j-1} \leq y_i^* \leq \alpha_j, \; j = 1,2, \ldots, J \quad (2)$$

where α represents the unknown cut-points (category boundaries) in the distribution of y^*, with $\alpha_o = -\infty$ and $\alpha_J = \infty$ (Lu, 1999). J = 4 in this study, since there are four categories for the ordinal dependent variable. The chance that a respondent shows a certain degree of satisfaction is represented as $P_i = P(y = i / x)$. Using the Proportional Odds Model, a set of comparisons is made for cumulative probability distributions of the category outcomes of the dependent variable, which are the four levels of residential satisfaction in this study. Equation three shows how the log odds of the explanatory variables in the model are estimated:

$$\log \frac{P_i}{(1-P)} = \alpha_i + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \quad (3)$$

where P_i is the probability of an outcome <=i and α_i is the intercept for outcome <=i. x are the covariates and β are the coefficients.

The model of the Proportional Odds Model for this study is as follows:

$$\text{Very satisfied} = \log \frac{P1}{P2+P3+P4} \tag{4}$$

$$\text{Very satisfied or satisfied} = \log \frac{P1+P2}{P3+P4} \tag{5}$$

$$\text{Very satisfied, satisfied or dissatisfied} = \log \frac{P1+P2+P3}{P4} \tag{6}$$

where P_1 = Very satisfied, P_2 = Satisfied, P_3 = Neutral and P_4 = Dissatisfied. P stands for the probability that a respondent feels more or less satisfied with his or her home. P4 = Dissatisfied is the base category in the model. Hereby, the interpretation of the log odds will focus on under what circumstances residents feel more satisfied, where positive values indicate a higher level of satisfaction and negative values lower level of satisfaction.

The coefficients in the Ordered Logistic Regression show the log odds. The log odds should not be confused with odds ratios. Odds ratios are the exponentiated outcomes ($exp^{logodds}$) of the log odds (DeMaris, 1995). The calculation from odds ratio to percentage is straightforward: (Odds Ratio – 1) * 100. Thus, an odds ratio above 1 indicates an increase and an odds ratio below 1 indicates a decrease in the likelihood of being satisfied at a higher unit of the predictor. "Because there are monotonic relationships among the log odds, the odds, and the probability, any variable that is positively related to the log odds is also positively related to the odds and to the probability" (DeMaris 1995, p.959). The assumptions of the Proportional Odds Model are (McCullagh, 1980; Williams, 2016):

1. The dependent variable is ordered.
2. Ordinal independent variables must be treated as either continuous or categorical.
3. No multicollinearity.
4. Proportional odds.

Like mentioned earlier in this study, the dependent variable is measured at an ordinal level by using the Likert-scale method. The outcome of the dependent variable lies between 'very satisfied' and 'dissatisfied'. There are more than two outcomes and a clear order between the outcomes, which meets the first assumption. The ordinal explanatory variables will be treated as continuous, thus the second assumption is also met. The Spearman correlation matrix showed that all independent variables are below the 0.7 limit for high correlation, and six independent variables are higher than the 0.5 limit. The problem with multicollinearity is that it can lead to incorrect understanding of which variable contributes to the prediction of the dependent variable and this could lead to wrong interpretations. Six out of 171 correlations are rated higher than 0.5 (*Appendix D*). The third assumption will be tested in the analysis section by using the Variance Inflation Factor (VIF).

The last assumption is the fundamental assumption of an Ordered Logit Model, which is called a Proportional Odds Model when the proportional odds assumption is met. The proportional

odds assumption applies when explanatory variables have identical effect on the odds regardless of which of the cumulative split of the ordinal dependent variable is estimated (Fu, 1998; Williams, 2016). There are four outcomes for the ordinal dependent variable in this study: Very satisfied, satisfied, neutral and very dissatisfied. There are four ordinal outcomes in this study, which means that there are three calculates cumulative log odds of the ordinal measures, which refers to the three thresholds between the four ordinal categories. In theory, the model in this study meets the last assumption, therefore the Proportional Odds Model will be used to estimate the log odds by using the Ordered Logistic Regression (*ologit)* in Stata version 15 (StataCorp, 2017). Since the Proportional Odds Model is nonlinear, it needs to be estimated by maximum likelihood method (Lu, 1999).

The Brant test assesses the proportionality in the Proportional Odds Model for Ordered Logistic Regressions (Brant, 1990). The proportional odds assumption is that the number added to each of the log odds to get the next, is the same for every category. A Brant test showing a p-value greater than alpha=0.01 (p>chi2) for a large N indicates that the proportional odds assumption holds (Lu, 1999; Williams, 2016). The Likelihood-Ratio test assesses the goodness-of-fit of competing statistical models, in which the one is nested in the other (Buse, 1982). The goal is to find a model that maximizes the likelihood of parameter estimates with the most likely outcomes. In addition, it can be used to test whether adding variables in the model increases the robustness of a single model. The dwelling, neighbourhood, personal and financial characteristics are added on top of energy attributes, and the likelihood-ratio assesses whether adding these improves the model fit. A p-value lower than alpha=0.05 (p>chi2) indicates a more robust model. The Likelihood-Ratio test also estimates the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), where lower values for these criteria implies a better fitting model. The Wald (1943) test assesses also the goodness-of-fit by only using one model. A p-value lower than alpha=0.05 (p>chi2) enables to reject the null hypothesis indicating that the coefficients are not simultaneously equal to zero, which means that the explanatory variables result in a significant improvement in the fit of the model (UCLA, 2016). The last test is the McFadden (1974) pseudo R^2 test. R^2 measures the proportion of the variance for a dependent variable that is explained by the explanatory variables. The McFadden pseudo R^2 is a rho-squared based variant of the R^2 and uses the log likelihood of the full model to calculate the pseudo R^2. A value between 0.2 and 0.4 is similar to 0.7 and 0.9 range of a 'regular' R^2 (McFadden, 1979).

The subgroup for housing tenures were already classified in the data-set between homeowners, private tenants and public tenants. The income levels are classified as follow: High income above €80,000, middle income between €80.000 and €36.000 and low income lower than €36.000. For net income and total monthly housings costs the natural logarithm (log) is used. The net income is removed from the second regression for income levels, because including the net income resulted in odd values for the most log odds. This could be due to the high correlation between the net income and the gross income, from which the incomes are classified in high, middle and low. Except the net income, the same variables are used in both regressions.

5. ANALYSIS

The Ordered Logistic Regression results are presented in this section. The results in *tables 7* and *10* provide an insight in how energy labels contribute to residential satisfaction. The determinants of residential satisfaction were taken from the theoretical framework. The methodology showed which methods are used and which tests are performed to set up a robust model. The Ordered Logistic Regression estimates the log odds of predictors. Log odds cannot be used to interpret the magnitude of the predictors on the outcome variable, because the log odds differ by a scale factor. A log odds value of +0.5 does not mean that the predictor causes 50% more or higher residential satisfaction. Since the ordinal dependent variable has many categories, a positive log odds means that the predictor increases the odds of being in a higher category of residential satisfaction. For example, a log odds value of +0.5 for energy label means that the respondent is more likely to be in a higher satisfaction category when the energy label increases, which indicates that energy labels contribute positively to residential satisfaction. The odds ratio would be $exp^{0.5} = 1.65$, which means an increase of (1.65 – 1) * 100 = 65%. The cutpoints are the intercepts showing where the latent variable is cut to create the four satisfaction categories, and are basically the thresholds between categories. The significance of log odds are tested at the p<0.01(***), p<0.05(**) and p<0.1(*) levels.

The Variance Inflation Factor (VIF) in *Appendix E* shows that the highest score for the housing tenure regression is 1.858 and for the income regression 2.069. The assumption is that there is multicollinearity when the VIF score is greater than four (Miles & Shevlin, 2001). Some sources even use ten as the boundary. *Appendix F* shows that the tenure regression passed the Brant test with p>chi2=0.213, while the income regression has some issues. Three (heating, layout and maintenance) out of twenty-two variables are significant at the 0.01 level, and are therefore not proportional. However, Lu (1999) and Williams (2016) report that when a vast share of the variables are proportional, there should be no major issues in conducting the Ordered Logistic Regression, as Williams (2016) reports a partial proportional odds. The Likelihood-Ratio test in *Appendix G* shows that the full model fits the best for the income regression. For the tenure model, the personal attributes leads to a less fitting model. After testing the variables one-by-one it was the age which caused a less fitting model for tenure. This could be due to the fact that age is divided into categories (e.g. 17-34 year) in the data-set. However, age is an important determinant of residential satisfaction and the theory showed its importance (Amerigo & Aragones, 1997; Galster & Hesser , 1981; Lu, 2002). The age variable is therefore kept in the model since keeping it in is not a violation of the Ordered Logistic Regression, however the model is slightly less robust. The AIC and BIC values show that the impact of age is very little (*Appendix G*). The Wald test in *Appendix H* shows that both regressions are significant at the 0.05 level, which means that the explanatory variables result in a significant improvement in the fit of the model. This also supports in keeping the age variable in the model. The McFadden pseudo R^2 for the housing tenure regression is 0.195 and for the income regression 0.218.

Table 7: Ordered Logistic Regression of residential satisfaction per housing tenure.

	Homeowners		Private Tenants		Public Tenants	
Variables	**Log odds**	**St. Err.**	**Log odds**	**St. Err.**	**Log odds**	**St. Err.**
Energy						
Energy labels	0.0087**	(0.0042)	-0.0242**	(0.0114)	0.0288**	(0.0124)
Energy efficiency home	0.3405***	(0.0173)	0.3026***	(0.0483)	0.4371***	(0.0271)
Improvement home	-0.2430***	(0.0161)	-0.3000***	(0.0518)	-0.2727***	(0.0279)
Environmental effect	-0.0137	(0.0286)	0.0195	(0.0840)	-0.0249	(0.0429)
Home easy to heat up	0.7448***	(0.0627)	1.0879***	(0.0943)	0.9325***	(0.0545)
Dwelling						
Single-family home	base	base	base	base	base	base
Multi-family home	-0.1851***	(0.0410)	-0.1872**	(0.0824)	0.0238	(0.0471)
Number of rooms	0.0312***	(0.0101)	0.0431	(0.0303)	0.0158	(0.0239)
Useable surface area	0.1713***	(0.0118)	0.1316***	(0.0291)	0.1013***	(0.0246)
Interior layout dwelling	1.4091***	(0.0410)	1.2922***	(0.0836)	1.1847***	(0.0481)
Dwelling maintenance	1.0713***	(0.0367)	1.3514***	(0.0751)	1.2526***	(0.0434)
Locational						
Municipality other	base	base	base	base	base	base
Municipality G4	-0.0402	(0.0506)	-0.0017	(0.0957)	0.0969	(0.0594)
Municipality G40	0.0170	(0.0288)	0.1243	(0.0836)	0.0404	(0.0450)
Urbanity degree neighb.	0.0160	(0.0149)	-0.1064**	(0.0496)	0.0090	(0.0262)
Attachment to neighb.	0.5843***	(0.0123)	0.4730***	(0.0310)	0.5071***	(0.0181)
Personal/Household						
Singles	base	base	base	base	base	base
Couples	0.1140***	(0.0349)	-0.0228	(0.0854)	0.2073***	(0.0533)
Couples with child(ren)	0.5008***	(0.0419)	0.5622***	(0.1244)	0.5720***	(0.0766)
Single parents	0.4150***	(0.0612)	0.2925**	(0.1310)	0.5204***	(0.0670)
Non-family	0.5107***	(0.1365)	0.1005	(0.1419)	0.3881**	(0.1598)
Age	0.1951***	(0.0180)	0.0202	(0.0388)	0.1509***	(0.0233)
Education	0.0171	(0.0157)	0.1026**	(0.0457)	0.0932***	(0.0267)
Moved in the past 2 years	0.7671***	(0.0414)	0.4612***	(0.0767)	0.5841***	(0.0593)
Financial						
Net income (log)	0.3457***	(0.0356)	0.0377	(0.0904)	0.0091	(0.0735)
Total monthly housing costs (log)	-0.3629***	(0.0305)	0.0452	(0.0998)	-0.2389***	(0.0804)
Cutpoints						
Very satisfied - Satisfied	1.6608	(0.4481)	6.7407	(1.1173)	5.2841	(0.7690)
Satisfied - Neutral	5.1010	(0.4499)	9.8522	(1.1241)	8.5839	(0.7720)
Neutral - Dissatisfied	7.3430	(0.4541)	11.8519	(1.1293)	10.5606	(0.7745)
N	34,534		4,010		12,457	
McFadden pseudo R2	0.195					

St. Err. = Standard Error. *** p<0.01, ** p<0.05, * p<0.1. **N** = 51,001.

Table 7 shows the Ordered Logistic Regression results per housing tenure. The regression shows that the energy labels are significant at the 5% level for each tenure. Homeowners and public tenants with a higher energy label in their dwelling are more likely to be more satisfied with their dwelling. The log odds of energy labels for homeowners is 0.0087. This gives an odds ratio of 1.0087, which means that homeowners are 0.87% more likely to be on a higher residential satisfaction category. Brounen & Kok (2011) and Chegut et al. (2016) showed that homeowners often get a certain price premium on their homes due to higher energy labels, which is appreciated by homeowners. The log odds of energy labels for public tenants is 0.0288. This gives an odds ratio of 1.0292, which means that public tenants are 2.92% more likely to be on a higher residential satisfaction category. The impact of energy labels on the residential satisfaction of private tenants is negative. The log odds is -0.0242. This gives an odds ratio of 0.9761, which means that private tenants are 2.39% less likely to be more satisfied. The reason for this is probably that landlords and investors charge a higher rent for their properties with higher energy labels, which fits the findings of Kim et al. (2014). Upgrading homes to higher energy labels and more energy efficiency requires a certain investment. The landlord or investor wants to earn his investment back and may therefor increase the rent. Higher rents for private rental houses could lead to lower residential satisfaction for private tenants. Housing associations are restricted by rental points and maximum annual rent increases. Therefore, the residential satisfaction of public tenants may not be negatively affected, unlike the private tenants.

These findings provide an answer to the first sub-question of what the effects of home energy labels are on the residential satisfaction of the different tenure types. The regression results show that public tenants are more satisfied with higher energy labels than homeowners, and therefore the null-hypothesis of the first hypothesis is rejected.

Hypothesis 1

~~H0 = Homeowners are more satisfied with higher energy labels than public tenants.~~

H1 = Homeowners are less satisfied with higher energy labels than public tenants.

	Education			
Tenure	High	Middle	Low	**Total**
Homeowners	13,775 (39.89%)	11,382 (32.96%)	9,377 (27.15%)	34,534 (100%)
Private tenants	1,721 (42.92%)	1,225 (30.55%)	1,064 (26.53%)	4,010 (100%)
Public tenants	2,060 (16.54%)	3,774 (30.30%)	6,623 (53.16%)	12,457 (100%)
Total	17,556 (34.42%)	16,381 (32.12%)	17,064 (33.46%)	51,001 (100%)

Table 8: Education level per tenure type. Source: WoON2018.

Table 8 shows the education level of respondents per tenure type. Homeowners and private tenants are relatively more well educated compared to public tenants. The expectation would be a higher positive impact of education on the residential satisfaction for homeowners and private tenants than public tenants. However, the regression results show a more positive impact of education on the residential

satisfaction for private and public tenants than homeowners. Furthermore, the effect of higher education is expected to be a higher appreciation of energy labels, as Ren et al. (2014) imply. However, the regression results show a relatively high appreciation of energy labels for public tenants compared to homeowners. Private tenants are negatively affected by higher energy labels.

The relatively low appreciation of energy labels of homeowners could be due to the current law in the Netherlands which states that the energy label of a dwelling should be known when the property is sold. The WoON2018 data provide that 3,386 out of 34,534 homeowners did not move in the past two years. This means that most homeowners do not know, or better said, do not have to know the energy label of their homes. Despite their relatively high education there is a lack of information about their home energy label due to the current legislation. Higher education means more residential satisfaction, but the current legislation limits the effect of energy labels on the residential satisfaction.

The private tenants are the highest educated tenures out of the three tenure types. For private tenants, education results in the highest likelihood of being more satisfied (*table 7*), which corresponds to the findings of Ren et al. (2014) that higher educated people are more satisfied with their homes. However, as Kim et al. (2014) state, private tenants have to deal with landlords who want to earn their investments back for energy efficient measures, thus higher energy labels. Despite the high educational level of private tenants, high rental prices seem to negatively affect the response of energy labels on the residential satisfaction.

Public tenants are relatively less educated than the other tenures. However, the likelihood for being more satisfied with a higher education is higher than the likelihood of homeowners. This should not be interpreted as public tenants being higher educated than homeowners. It means that within the public tenants, a higher education leads to a greater likelihood of being more satisfied. This likelihood is higher than for the homeowners group. This may be an indication that a lack of information from the large group of low educated people weighs relatively heavily. Therefore, a unit increase in education results in a higher appreciation for energy labels, which explains the higher log odds for education of public tenants compared to homeowners.

Table 7 shows that homes that are easy to heat up increase the odds of being more satisfied for all tenures. The variable 'energy efficiency home' shows for all tenures that residents who believe that their home is energy efficient are more satisfied with their homes. Despite, the private tenants are less likely to be satisfied with higher energy labels. This contradiction can be the result of the discussed high rental prices in the private rental housing market. Residents who think that their dwelling should be improved in terms of energy efficiency, are less likely to be satisfied. This indicates that residents care about higher energy labels, however the low energy labels in their homes are lagging behind (Majcen, 2016). Hence the demand for improvement of energy efficiency. Homeowners and public tenants who believe that energy efficient dwellings helps reducing the environmental effect of energy usage in homes are less likely to be satisfied with their dwellings. This may be an indication of concern regarding energy inefficient dwellings (Fuerst et al., 2015). The lack of energy performance

improvement and residents' awareness of the impact of home energy usage on the environment, result in less residential satisfaction. This applies to homeowners and public tenants, since private tenants are more likely to be more satisfied if they think that energy efficiency reduces the environmental impact.

Most dwelling characteristics are significant at the 1% level. A negative value for multi-family home implies that respondents are less likely to be satisfied than respondents in single-family homes, which applies to homeowners and private tenants. Public tenants are more satisfied with multi-family homes, which contradicts the findings in the literature. This could be due to the fact that multi-family homes are over-represented in the public rental sector or simply because public tenants appreciate the relatively low rental prices of multi-family homes. Furthermore, a higher number of rooms, a larger surface area, a desired home interior layout and a well-maintained home contribute to a greater odds of higher residential satisfaction.

Homeowners and private tenants in the G4 municipalities are less likely to be satisfied compared to the smaller municipalities, as Campbell et al. (1976) and Li et al. (2019) show. Public tenants are more likely to be satisfied in the G4 municipalities compared to the smaller ones, as Levy-Leboyer (1993) shows. The latter may be due to the relatively low incomes of the public tenants, and therefore they are less able to pay for transport costs to reach certain amenities and services. They might want to live in bigger municipalities where it is easier and cheaper to reach those. The G40 municipalities increase the odds of being more satisfied for all tenures. The reason for this may be that these medium-sized municipalities offer a good mix of sufficient facilities and greenery, which is in general appreciated. A higher neighbourhood attachment provides significant odds of higher residential satisfaction for all tenures. Homeowners seem to appreciate the neighbourhood the most, since their log odds show the highest value for neighbourhood attachment. This fits within the findings of Elsinga & Hoekstra (2005), Lu (1999) and Rohe & Basolo (1997).

Most household compositions are significantly more satisfied with their homes than the singles, except for the couples being private tenants. Couples in the private rental sector may struggle to find affordable and suitable properties in the already tight housing market in the Netherlands. For older people the odds of being more satisfied increase, which corresponds to the findings of De Jong et al. (2011), Galster & Hesser (1981) and Lu (1999). Higher education is also increasing the likelihood of being more satisfied. Respondents who moved in the past two years are significantly more likely to be more satisfied with their dwelling than respondents who have not moved in the past two years. The theory indicated that people are moving to match their current living situation with their aspired living situation (Galster & Hesser, 1981; Rossi, 1955), thus this outcome is as expected.

A higher net income implies a higher likelihood of being more satisfied for all tenures. However, there are big differences between the three tenure types, especially the homeowners stand out. Homeowners with high incomes are most likely able to afford their desired home and meet their financial obligations regarding their homes, which makes them relatively more satisfied than both tenant groups. It is probably difficult for private tenants to find affordable and suiting homes in the

tight Dutch housing market. The impact on public tenants is the lowest, because there is a maximum limit of €38,035 on the incomes of families to be entitled to social rental housing (Rijksoverheid, 2019), thus high incomes are underrepresented in the public rental market (*table 9*). The main target of social housing is intended to provide housing security for those who cannot afford housing in the free market. As expected, higher monthly housing costs result in a lower likelihood of being more satisfied for homeowners and public tenants. Surprisingly, private tenants are more satisfied with higher monthly housing costs. This outcome is the most unexpected of all. The expectation is that private tenants, which are dealing with a tight private rental market and high rental prices, would be more satisfied with lower housing costs. One reason for this odd result may be the fact that it is more likely that residents live in their desired homes when the monthly costs are high. The dwelling features and the location may fit the wishes of residents, but they pay a certain price for it.

	Income level			
Tenure	High	Middle	Low	**Total**
Homeowners	11,454 (33.17%)	17,573 (50.89%)	5,507 (15.95%)	34,534 (100%)
Private tenants	518 (12.92%)	1,610 (40.15%)	1,882 (46.93%)	4,010 (100%)
Public tenants	364 (2.92%)	3,037 (24.38%)	9,056 (72.70%)	12,457 (100%)
Total	12,336 (24.19%)	22,220 (43.57%)	16,445 (32.24%)	51,001 (100%)

Table 9: Income level per tenure type. Source: WoON2018.

Table 9 shows that different income levels are distributed across each tenure type. High incomes are not necessarily homeowners or middle incomes only private tenants. Therefore, the outcomes of energy labels on residential satisfaction are different between housing tenures and income groups. *Table 10* shows the Ordered Logistic Regression results per income level. The regression shows that the energy labels are not significant at the 5% level. High incomes and middle incomes with a higher energy label class are less likely to be more satisfied with their dwelling. The log odds of energy labels for high incomes is -0.0188. This gives an odds ratio of 0.9814, which means that high incomes are 1.86% less likely to be on a higher residential satisfaction category. The log odds of energy labels for middle incomes is -0.0112. This gives an odds ratio of 0.9889, which means that middle incomes are 1.11% less likely to be on a higher residential satisfaction category. The impact of energy labels on the residential satisfaction of low incomes is positive. The log odds is 0.0041. This gives an odds ratio of 1.0041, which means that low incomes are 0.41% more likely to be on a higher residential satisfaction category.

Table 10: Ordered Logistic Regression of residential satisfaction per income level.

	High Incomes		Middle Incomes		Low Incomes	
Variables	**Log odds**	**St. Err.**	**Log odds**	**St. Err.**	**Log odds**	**St. Err.**
Energy						
Energy labels	-0.0188*	(0.0107)	-0.0112	(0.0081)	0.0041	(0.0097)
Energy efficiency home	0.4061***	(0.0294)	0.3745***	(0.0212)	0.4249***	(0.0232)
Improvement home	-0.1896***	(0.0276)	-0.2789***	(0.0204)	-0.2694***	(0.0232)
Environmental effect	0.0079	(0.0526)	-0.0451	(0.0347)	-0.0055	(0.0368)
Home easy to heat up	0.8449***	(0.0974)	0.9837***	(0.0618)	1.0191***	(0.0536)
Dwelling						
Single-family home	base	base	base	base	base	base
Multi-family home	-0.1182	(0.0787)	0.0012	(0.0439)	0.0506	(0.0420)
Number of rooms	0.0679***	(0.0161)	0.0402***	(0.0132)	0.0245	(0.0175)
Useable surface area	0.2410***	(0.0197)	0.1974***	(0.0147)	0.1565***	(0.0174)
Interior layout dwelling	1.5074***	(0.0690)	1.3163***	(0.0449)	1.2252***	(0.0458)
Dwelling maintenance	1.1927***	(0.0653)	1.3210***	(0.0398)	1.3007***	(0.0397)
Locational						
Municipality other	base	base	base	base	base	base
Municipality G4	-0.0390	(0.0756)	0.0241	(0.0564)	0.1279**	(0.0556)
Municipality G40	-0.0168	(0.0489)	0.0509	(0.0354)	0.0702*	(0.0395)
Urbanity degree neighb.	0.0234	(0.0251)	-0.0051	(0.0187)	0.0104	(0.0225)
Attachment to neighb.	0.5825***	(0.0204)	0.5710***	(0.0146)	0.5215***	(0.0164)
Personal/Household						
Singles	base	base	base	base	base	base
Couples	-0.1356	(0.0932)	0.0455***	(0.0391)	0.1804***	(0.0402)
Couples with child(ren)	0.2631***	(0.0950)	0.4195***	(0.0458)	0.6919***	(0.0781)
Single parents	0.2739*	(0.1515)	0.4938***	(0.0641)	0.4999***	(0.0587)
Non-family	0.4453**	(0.2165)	0.6527***	(0.1108)	0.0967	(0.1344)
Age	0.1519***	(0.0341)	0.1397***	(0.0208)	0.1252***	(0.0202)
Education	0.0202	(0.0280)	0.0703***	(0.0186)	0.1300***	(0.0233)
Moved in the past 2 years	0.5861***	(0.0673)	0.6933***	(0.0461)	0.5572***	(0.0515)
Financial						
Total monthly housing costs (log)	-0.4065***	(0.0481)	-0.2443***	(0.0407)	-0.3484***	(0.0483)
Cutpoints						
Very satisfied - Satisfied	5.5223	(0.4451)	6.3935	(0.3370)	5.3044	(0.4174)
Satisfied - Neutral	8.9467	(0.4529)	9.7477	(0.3425)	8.4983	(0.4216)
Neutral - Dissatisfied	11.0331	(0.4646)	11.8584	(0.3482)	10.4557	(0.4556)
N	12,336		22,220		16,445	
McFadden pseudo R2	0.218					

St. Err. = Standard Error. *** p<0.01, ** p<0.05, * p<0.1. **N** = 51,001.

	Education			
Income level	High	Middle	Low	**Total**
High incomes	7,238 (58.67%)	3,467 (28.10%)	1,631 (13.23%)	12,336 (100%)
Middle incomes	7,618 (34.28%)	8,040 (36.18%)	6,562 (29.54%)	22,220 (100%)
Low incomes	2,700 (16.42%)	4,874 (29.64%)	8,871 (53.94%)	16,445 (100%)
Total	17,556 (34.42%)	16,381 (32.12%)	17,064 (33.46%)	51,001 (100%)

Table 11: Education level per income level. Source: WoON2018.

Table 11 shows the education level per income level. High incomes mainly consist of higher educated people, middle incomes of middle educated people and low incomes of lower educated people. This is according to the expected relation between education and income. The first regression in *table 7* shows that a higher net income has the most positive impact for the homeowners, second most for the private tenants and the least for the public tenants. *Table 9* shows that homeowners consist relatively of the most high incomes, private tenants the second most and public tenants the least. Combined, these two tables show that higher income has a positive effect on the residential satisfaction for tenure types and for income groups, which corresponds to the findings of Galster & Hesser (1981) and Lu (1999). Thus, a higher income level correlates with higher residential satisfaction.

However, the effect of energy labels on the residential satisfaction shows that the lower the income level, the higher the residential satisfaction. This is an unexpected result, which is in contrast to the findings of Murray & Mills (2011). They show that lower incomes are less aware of energy labels and value energy labels less than higher incomes in the United States, but the results show that for the Netherlands this is the other way around. This may be due to the fact that there is a social system in the Netherlands that offers lower-income people the opportunity to study and develop themselves. In the United States there is more segregation between different income groups and it is harder for lower incomes to study due to a lack of a social system. However, this does not explain why the high and middle incomes are less satisfied with better energy ratings.

High incomes can afford to invest in energy efficient measures in their homes. Guerra Santin (2010) shows that the actual energy consumption in dwellings with high energy ratings are often higher than it should be. This discrepancy between the foreseen and actual energy consumption may lead to dissatisfaction (Majcen, 2016). This may explain why higher energy labels lead to lower residential satisfaction for high incomes.

The middle class in the Netherlands have difficulties to find a suitable home (NVM, 2019), which means that they often spend relatively more money on mortgage payments and rents for overpriced homes, and are therefore less satisfied in general. Higher energy labels lead to even higher selling and rent prices, which amplifies the effect on the residential dissatisfaction. This could explain the negative effect of energy labels for the middle incomes.

These results provide an answer to the second sub-question of what the differences between income levels are of the impact of energy labels on the residential satisfaction. The regression outcome shows that low incomes are more satisfied with higher energy labels than high incomes, and therefore the null-hypothesis of the second hypothesis is rejected.

Hypothesis 2

~~H0 = Lower incomes are less satisfied with higher energy labels than higher incomes.~~

H1 = Lower incomes are more satisfied with higher energy labels than higher incomes.

Homes that are easy to heat up increase the odds of being more satisfied for all tenures, and the effects are higher for income levels than for tenure types. Residents who believe that their dwelling is energy efficient are more satisfied than those who do not believe this is the case. Residents of all income groups who think that their dwelling should be improved in terms of energy efficiency, are less likely to be satisfied. This result is similar to the findings in the first regression results. This means that all income groups within all tenures agree that the improvements in energy efficiency in dwellings are lacking behind, which corresponds to the findings of Majcen (2016).

Like the first regression, most dwelling characteristics are significant at the 1% level, except the multi-family homes. The results of the dwelling characteristics are similar to the first regression. The main difference is that the impact of multi-family homes are less strong compared to the regression for tenure types. High incomes are less likely to be satisfied with multi-family homes, while middle and low incomes are more likely to be satisfied. This is contradicting the findings of Elsinga & Hoekstra (2005), Lu (1999) and Rohe & Basolo (1997). This may be an result of the rising selling and rent prices in the Netherlands in the past years (NVM, 2019). Middle and low incomes seem to appreciate the relatively lower selling and rental prices of multi-family homes in the tight Dutch housing market. *Table 10* shows a clear trend of an increasing residential satisfaction at lower income levels in the G4 and G40 municipalities. This trend was less clear in the first regression. High incomes are less likely to be satisfied in bigger municipalities, while middle and low incomes are more satisfied in those. High incomes possess the financial resources to reach the amenities and services in the concentrated cities. This makes them less dependent of the larger municipalities and may prefer the quiet and green municipalities to live in. A higher neighbourhood attachment provides significant odds of higher residential satisfaction for all income groups, which is similar to the first regression.

All household compositions are more likely to be satisfied compared to the singles, except for the couples with high incomes. Like the tenure types, all income levels have higher odds of being more satisfied with their homes at a higher age. The same applies to education, where higher educated residents are more likely to be satisfied. Residents who moved in the past two years are more likely to be more satisfied, as Galster & Hesser (1981) and Rossi (1955) showed. An increase of the total monthly housing costs results in less likelihood of being more satisfied for all income levels. This is an expected relation between housing costs and residential satisfaction.

6. CONCLUSION & RECOMMENDATIONS

6.1 Conclusion

The literature review showed that the relationship between energy labels and residential satisfaction received no attention in the literature. Because this gap in the literature, an attempt was made to investigate the effects of energy labels on the residential satisfaction of different housing tenures and income groups. Studies on energy labels mainly focus on price premiums or the technical aspects of energy labels. The theory showed that residential satisfaction measures the difference between the actual (objective) and desired (subjective) dwelling, neighbourhood, personal and household characteristics (Galster & Hesser, 1981). These characteristics are the 'classic' attributes in research on residential satisfaction. They are also used in this study, with energy labels as extra attribute on top of these. The WoON2018 data contain the required variables to achieve this. By conducting such research, stakeholders and actors in the housing market gain an insight into the relationship between energy labels and residential satisfaction. This insight can be used to improve policies, adapt to demands from the market, improve residents' living comfort and residential satisfaction, and create awareness for home energy labels, which helps to reduce environmental effects of home energy usage. To investigate the relationship between energy labels and residential satisfaction the following main question was formulated: "What is the effect of home energy labels on residential satisfaction of residents in the Netherlands?".

To answer this question, the Ordered Logistic Regression was used. This method gives the possibility to analyse the impact of explanatory variables on the ordinal dependent variable, which is the residential satisfaction. This dependent variable consists of ordered categories: The level of residential satisfaction of residents. The results of the Ordered Logistic Regression show whether the explanatory variable cause higher or lower odds of being more satisfied. The theory showed that there are differences between homeowners and tenants in how they are perceiving residential satisfaction and on which elements they attach more value on. Since the WoON2018 data contain information on the tenure types, homeowners, private tenants and public tenants were used as subgroups in the first regression. The theory also showed differences between income levels in how they perceive residential satisfaction. The second regression was divided between high, middle and low incomes. The theory implied that homeowners are more satisfied with higher energy labels than tenants, since they profit from price premiums on their property values. This established the first hypothesis that homeowners are more satisfied with higher energy labels than public tenants. The theory also stated that low-income people are less aware of energy labels and value energy labels less than high-income people. As a result, the second hypothesis was drawn up that low incomes are less satisfied with higher energy labels than higher incomes.

The results show that homeowners and public tenants with a higher energy label in their homes are likely to be more satisfied with their homes. For homeowners these higher odds of being

satisfied are 0.87% and for public tenants 2.92%. These findings show that homeowners are not more likely to be more satisfied at higher energy labels, and therefore the first hypothesis was rejected. Homeowners get a certain price premium at higher energy labels, although the results show that the impact of energy labels on residential satisfaction is limited. The impact of energy labels on public tenants is relatively high. The reason for this could be the increasing living comfort and the limited rental increase at higher energy labels due to the rental point system in the Netherlands and a limited annual rent increase. Public tenants are 2.39% less likely to be satisfied at higher energy ratings. The reason for this is most likely landlords and investors charging higher rents for their properties, which is not appreciated by the private tenants. Upgrading homes to higher energy labels requires a certain investment, and the landlord or investor wants to earn its investment back (Kim et al., 2014).

The results show that high and middle incomes are less likely to be more satisfied at higher energy labels. The percentage of this lower likelihood for high incomes is 1.86% and for middle incomes 1.11%. Low incomes are 0.41% more likely to be more satisfied at higher energy ratings. This upward trend of likelihood for being more satisfied for lower income groups is in contrast with the findings in the literature. The results enables to reject the second hypothesis, because lower incomes are not less satisfied with dwellings with higher energy labels. Guerra Santin (2010) shows that the actual energy consumption in dwellings with high energy ratings are often higher than it should be. High incomes can afford to invest in energy efficiency, although the discrepancy between the foreseen and actual energy consumption may lead to more dissatisfaction. The middle class in the Netherlands have difficulties to find a suitable home, and the sales premiums for homeowners due to higher energy labels make it even more expensive to buy a house. The increasing rent prices due to higher energy labels leads to residential dissatisfaction for private tenants. The low incomes are entitled to rent social housing, and are secured against the rent increase from landlords. Therefore, they are less affected by the negative aspects of higher energy labels.

Reflecting on the main question "What is the effect of home energy labels on residential satisfaction of residents in the Netherlands?", there are different outcomes for different subgroups. The effect of energy labels are not standing apart from other elements that effect residential satisfaction. However, this study gives an indication on how the effect of energy labels touches different subgroups. Public tenants and low incomes seem to appreciate energy labels the most, in contrast with some of the literature. Homeowners also seems to appreciate higher energy labels. Private tenants and the middle class are less satisfied with higher energy labels. The reason is that private tenants do not receive any price premiums like homeowners do, and they do not have the protective legalisation that public tenants have. Private tenants are more vulnerable to rent price increase with energy efficient dwellings. High incomes also appreciate higher energy labels less. Thus, the findings in this study show that there is not one single effect of energy labels on residential satisfaction. It may be expected that energy labels only contribute positively to residential satisfaction, though this is not the case.

6.2 Recommendations

The results of this study showed that energy labels have both positive and negative impacts on different subgroups. However, the impact is still limited. The results showed that public tenants are most likely to be more satisfied with a better energy rating in their house, although this percentage to be more likely is only 2.92%. This percentage for other subgroups was even lower. Public tenants and the middle class are even less likely to become more satisfied with higher energy ratings, because they are affected by the negative externalities of higher energy labels, such as higher sales and rent prices.

The limited impact of energy labels on residential satisfaction can be an indication of lack of information on energy labels by the residents. If the positive aspects of energy labels were known to more respondents, then energy labels would most likely have a stronger positive effect on residential satisfaction, as Michelsen & Madlener (2017) imply. Home energy labels are a relatively new phenomenon. However, there is not enough information for residents about the energy ratings of their home. The author, too, did not consider the energy rating of his home until conducting this study. Probably more uninformed residents like the author exist. The current rule is that energy labels are only known for dwellings when they are sold or rented out. The government could make it mandatory that the energy label of every home must be fixed, even if they are not being sold or rented out. Homeowners, landlords, investors and housing associations could be forced to determine the energy labels of their residential properties. The owners of the properties have to inform both current residents and new renters about the energy labels of the dwelling. In this way, the existence of the energy labels is spread among the population. Which energy label does their home has and what does this mean for the environment? What does this mean for them financially and how can the energy label be improved? Such dilemmas can increase awareness and support of the energy labels. With higher energy labels for conscious residents, this can result in a significant contribution to the residential satisfaction in each subgroup. Thus, both the residents and their living satisfaction, and the environment can experience the benefits of this.

In addition, protection of private tenants is also required. The findings in this study showed that they in particular are less satisfied with better energy labels. This is because their landlords ask for a higher rent for better attributes for their homes. Higher energy labels contribute to higher rental prices for private rental properties. In addition, the landlords want to earn back their investment in energy-efficient upgrades. This is all at the expense of the private tenant. The public tenants have all kinds of securities, such as the rental point system and rent subsidies, while private tenants are more vulnerable. The rental point system does not apply to the private rental sector (Rijksoverheid, 2019). This system could also be implemented for the private rental sector, which will protect private tenants for high rent increases after implementing energy efficient measures. Not all private tenants are aware of the possibility to ask a judgement by the local Rent Commission. Unaware tenants pay an unnecessarily high rent. This could be prevented by implementing the same rental point system as for

the public rental market. If not, the dissatisfaction among private tenants due to higher energy labels could reduce the support for energy efficient measures in dwellings.

The final recommendation is to do more research into the effects of energy labels and residential satisfaction in the Netherlands. Research in this area is necessary after the introduction of energy labels for homes. In addition to the home attributes, energy labels can affect residents' living satisfaction. Energy attributes, such as solar panels and heating systems, can also be assessed separately, but a comprehensive ranking system such as the energy labels can show residents how well their home is performing on energy efficiency in an instant. There is a certain direction in the effects of energy labels on the residential satisfaction of subgroups, but the percentages are very small. This study has attempted to investigate the relationship between energy labels and residential satisfaction with cross-sectional data. However, there is also a need for panel data that reflects on the effects of energy labels on residential satisfaction over time. This allows us to see what the effects are if the energy labels increase after upgrades. Which subgroup experiences what kind of effects after upgrades? Extra information can be added to the panel data, so that it can be determined if and to what extent energy labels have an effect on residential satisfaction. Is it the living comfort, contribution to the environment or the financial benefits through cost savings? This kind of information is not included in the WoON2018 data. When this could be examined, then policymakers and the market can better respond to the wishes of residents regarding to energy labels. The author strives that this research can be a start for further research into the effect of energy labels on residents' residential and general satisfaction.

6.3 Self-reflection

This was the first full quantitative research conducted by the author, which means that undoubtedly certain errors have been committed. An attempt has of course been made to minimize these errors as much as possible, and to apply what has been taught during this master course. The methods and interpretations used were applied as well as possible. The author did perform this master piece in good faith knowing that mistakes are lurking.

The first self-criticism is that theories and literature are not critically discussed. The results and findings of some of the theories are controlled if they make sense, and some of the journals has been searched on the internet whether they are reliable. However, the theories are not actively discussed in the study itself. This is due to the extensive theory on residential satisfaction with several characteristics. Discussing all these theories and switching between theory and discussion would make the coherency of the text less strong and less understandable.

The second self-criticism is that not the room-stress (Lu, 1999) is used to determine the effect of rooms on residential satisfaction. A low amount of rooms does not necessarily result in lower satisfaction, because there may be only two persons in the household. The data on the size of the households were categorized, thus making the calculation for the room stress could not be performed, although this would make the results more realistic.

The third self-criticism is that some of the variables with five categories are aggregated to four or three categories, because for some of the variables there were too little observations compared to other categories. After each aggregation it is tested whether the regression results change, which was not the case for any of the aggregations. All these different regression are not reported, as this would take too much time to put every single regression in the appendix. Personally, it would not be interesting for the readers to check every regression one-by-one.

The fourth self-criticism is that there are some variables used with a ‘high’ multicollinearity according to the Spearman correlation matrix. It is not sure whether scores of above 0.5 is considered is high or not, since some sources use the 0.7 level for high correlation. Nevertheless, this is a point to be careful with. It is easy to use sources that are in benefit for the author to justify the choices that has been made during the research. Not only for this research, but in general for everyone. The VIF test showed however that there was no high multicollinearity in the model.. In this study, the highest value was 2.069, thus in this case it is not problematic or does not lead to contradicting possibilities.

The last self-criticism is that the variable ‘age’ is still used after being tested as problematic for a better fit of the model, by using the Likelihood-Ratio test. The effect of ‘age’ was a slightly less fitting model. The impact was very limited, thus it was decided to leave ‘age’ in, especially because ‘age’ was a returning attribute in studies and in the theory on residential satisfaction. The regressions showed that ‘age’ is significant at the 1% level for five out of six outcomes. It is still not clear why ‘age’ was problematic in the Likelihood-Ratio test.

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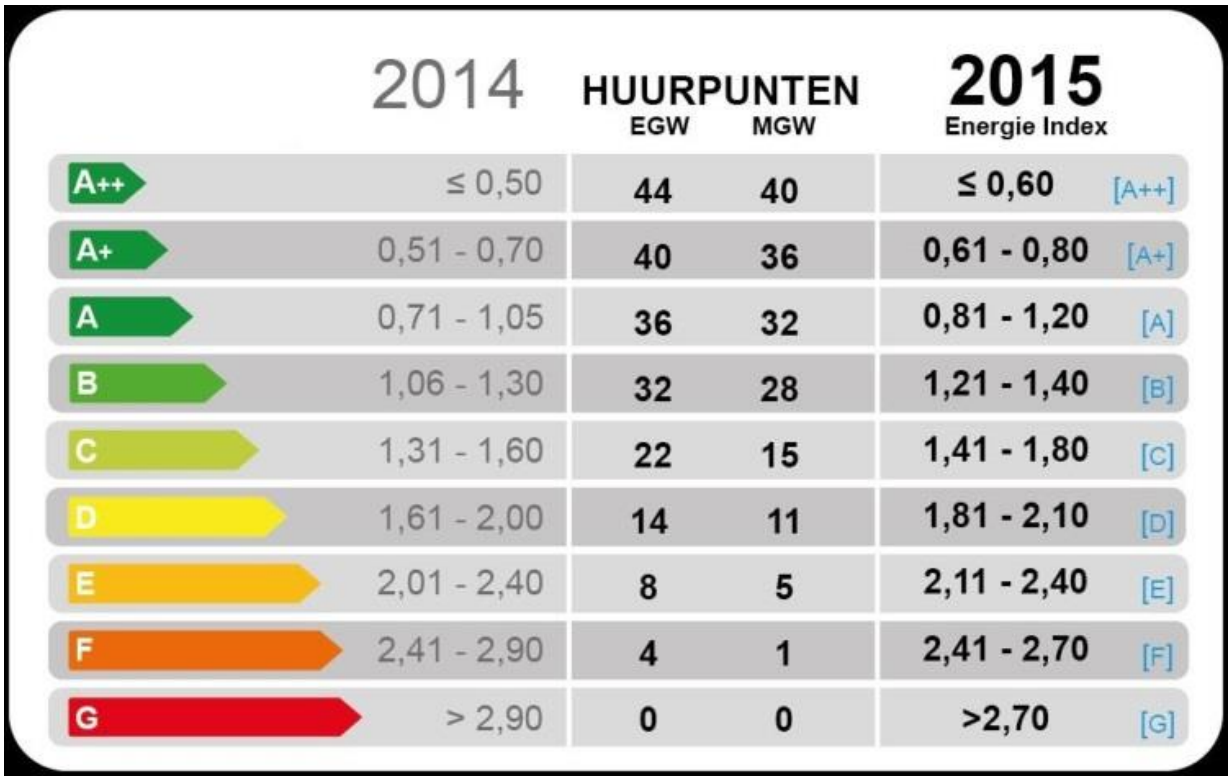
APPENDICES

Appendix A – Categories of Home Energy Labels



	2014	HUURPUNTEN EGW	HUURPUNTEN MGW	2015 Energie Index	
A++	≤ 0,50	44	40	≤ 0,60	[A++]
A+	0,51 - 0,70	40	36	0,61 - 0,80	[A+]
A	0,71 - 1,05	36	32	0,81 - 1,20	[A]
B	1,06 - 1,30	32	28	1,21 - 1,40	[B]
C	1,31 - 1,60	22	15	1,41 - 1,80	[C]
D	1,61 - 2,00	14	11	1,81 - 2,10	[D]
E	2,01 - 2,40	8	5	2,11 - 2,40	[E]
F	2,41 - 2,90	4	1	2,41 - 2,70	[F]
G	> 2,90	0	0	>2,70	[G]

Source: Innax (2016).

Appendix B – Data Cleaning

#	Observations cleaned	What has been cleaned?	Observations left
1	8,920	Unknown tenures	58,603
2	1,629	Incomes below €10,000 and above €200,000	56,974
3	2,989	No value for energy labels	53,985
4	330	Unknown housing type	53,655
5	64	Dwellings with more than 12 chambers	53,591
6	123	Unknown degree of urbanity of neighbourhood	53,468
7	1,715	Unknown education	51,753
8	705	Negative and missing values for total monthly costs	51,048
9	47	Odd values for surface	51,001

The initial amount of observations of 67,523 dropped to 51,001 after cleaning the data.

Appendix C – The G4 and G40 Municipalities in the Netherlands

G4 municipalities:

Amsterdam	Rotterdam
Den Haag	Utrecht

G40 municipalities:

Alkmaar	Eindhoven	Lelystad
Almelo	Emmen	Maastricht
Almere	Enschede	Nijmegen
Alphen aan den Rijn	Gouda	Oss
Amersfoort	Groningen	Roosendaal
Apeldoorn	Haarlem	Sittard-Geleen
Arnhem	Haarlemmermeer	Schiedam
Assen	Heerlen	Tilburg
Breda	Helmond	Venlo
Delft	Hengelo	Zaanstad
Den Bosch	Hilversum	Zoetermeer
Deventer	Hoorn	Zwolle
Dordrecht	Leeuwarden	
Ede	Leiden	

Source: G40 Stedennetwerk (2018).

Appendix D – The Spearman Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) Energy label	1.000																		
(2) Energy efficiency home	0.324	1.000																	
(3) Improvement home	-0.158	-0.436	1.000																
(4) Environmental effect	0.018	0.024	0.170	1.000															
(5) Heating	0.069	0.234	-0.156	-0.015	1.000														
(6) Housing type	0.003	0.078	-0.024	-0.020	0.097	1.000													
(7) Rooms	-0.010	0.065	0.007	0.016	0.084	0.583	1.000												
(8) Surface	0.108	0.154	-0.064	0.017	0.117	0.553	0.642	1.000											
(9) Layout	0.061	0.159	-0.107	0.021	0.148	0.057	0.086	0.124	1.000										
(10) Maintenance	0.141	0.329	-0.220	0.004	0.244	0.156	0.157	0.217	0.222	1.000									
(11) Municipality	-0.053	-0.072	0.069	0.035	-0.064	-0.289	-0.188	-0.217	-0.054	-0.099	1.000								
(12) Urbanity neighb.	-0.077	-0.096	0.069	0.031	-0.077	-0.378	-0.252	-0.337	-0.053	-0.111	0.464	1.000							
(13) Attached to neighb.	-0.073	0.101	-0.083	0.018	0.084	0.103	0.093	0.119	0.137	0.128	-0.032	-0.062	1.000						
(14) Age	0.016	0.143	-0.151	-0.019	0.065	0.012	-0.034	0.082	0.078	0.101	-0.099	-0.058	0.246	1.000					
(15) Household	-0.039	0.003	-0.073	-0.019	-0.001	-0.303	-0.381	-0.284	0.030	-0.036	0.044	0.081	0.042	0.356	1.000				
(16) Education	0.006	-0.023	0.095	0.101	0.030	0.045	0.179	0.165	0.004	0.045	0.119	0.073	-0.099	-0.309	-0.146	1.000			
(17) Moved past 2 years	-0.023	-0.064	0.062	0.031	-0.028	-0.136	-0.105	-0.104	-0.004	-0.056	0.063	0.059	-0.155	-0.298	-0.023	0.107	1.000		
(18) Net income	-0.078	-0.109	-0.005	-0.045	-0.119	-0.368	-0.488	-0.501	-0.082	-0.216	0.072	0.119	-0.016	0.210	0.524	-0.368	0.032	1.000	
(19) Total monthly costs	-0.020	-0.004	-0.066	-0.025	-0.067	-0.232	-0.336	-0.342	-0.059	-0.106	-0.002	0.040	0.043	0.342	0.388	-0.313	-0.093	0.537	1.000

Appendix E – Variance Inflation Factor (VIF)

Tenure	VIF	1/VIF
Surface	1.858	0.538
Rooms	1.849	0.541
Age	1.694	0.590
Energy efficiency home	1.636	0.611
Housing type	1.618	0.618
Municipality	1.599	0.626
Total monthly costs (log)	1.571	0.637
Urbanity neighbourhood	1.542	0.648
Net income (log)	1.510	0.662
Household composition	1.440	0.694
Improvement home	1.433	0.698
Education	1.394	0.718
Energy label	1.294	0.773
Moved in past 2 years	1.283	0.780
Maintenance home	1.272	0.786
Attachment home	1.197	0.835
Heating	1.110	0.901
Layout	1.100	0.909
Environmental effect	1.050	0.952
Mean	1.445	0.711

Income	VIF	1/VIF
Surface	2.069	0.483
Rooms	1.862	0.537
Housing type	1.773	0.564
Age	1.619	0.618
Energy efficiency home	1.538	0.650
Urbanity neighbourhood	1.464	0.683
Improvement home	1.398	0.715
Municipality	1.348	0.742
Maintenance home	1.339	0.747
Education	1.284	0.779
Household composition	1.275	0.784
Attachment home	1.229	0.813
Moved in past 2 years	1.204	0.831
Total monthly costs (log)	1.192	0.839
Heating	1.179	0.848
Energy label	1.150	0.869
Layout	1.140	0.878
Environmental effect	1.114	0.898
Mean	1.399	0.738

Appendix F – Brant Test of parallel regression assumption

Tenure	chi2	p>chi2	df
All	53.34	0.213	46
Energy label	3.51	0.172	2
Energy efficiency home	1.21	0.545	2
Improvement home	0.42	0.809	2
Environmental effect	0.84	0.658	2
Heating	0.46	0.794	2
Multi-family home	1.17	0.558	2
Rooms	0.83	0.661	2
Surface	3.25	0.197	2
Layout	3.04	0.219	2
Maintenance home	4.08	0.130	2
Municipality G4	0.22	0.896	2
Municipality G40	6.46	0.040	2
Urbanity neighbourhood	1.64	0.439	2
Attachment home	2.52	0.284	2
Age	0.90	0.638	2
Couples	0.75	0.686	2
Couples with child(ren)	2.40	0.301	2
Single parents	0.99	0.609	2
Non-family	6.61	0.037	2
Education	0.64	0.724	2
Moved in past 2 years	0.35	0.838	2
Net income (log)	0.10	0.950	2
Total monthly costs (log)	5.17	0.075	2

Income	chi2	p>chi2	df
All	170.58	0.000	44
Energy label	6.97	0.031	2
Energy efficiency home	3.92	0.141	2
Improvement home	4.63	0.099	2
Environmental effect	0.19	0.910	2
Heating	17.87	0.000	2
Multi-family home	2.58	0.275	2
Rooms	3.28	0.194	2
Surface	4.75	0.093	2
Layout	23.82	0.000	2
Maintenance home	36.34	0.000	2
Municipality G4	1.65	0.439	2
Municipality G40	1.45	0.483	2
Urbanity neighbourhood	1.35	0.508	2
Attachment home	13.18	0.001	2
Age	2.30	0.317	2

Couples	8.48	0.014	2
Couples with child(ren)	2.58	0.276	2
Single parents	1.16	0.560	2
Non-family	4.95	0.084	2
Education	1.91	0.385	2
Moved in past 2 years	1.04	0.594	2
Total monthly costs (log)	4.07	0.130	2

Appendix G – Likelihood-Ratio Test

Tenure:

(Assumption: Energy nested in Full) LR chi2(18) = 1113.81 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Energy	8	8962.44	9012.81
Full	26	7884.63	8048.34

(Assumption: Dwelling nested in Full) LR chi2(13) = 309.66 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Dwelling	13	8168.29	8250.15
Full	26	7884.63	8048.34

(Assumption: Locational nested in Full) LR chi2(9) = 75.73 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Locational	17	7942.36	8049.40
Full	26	7884.63	8048.34

(Assumption: Personal nested in Full) LR chi2(2) = 0.57 Prob > chi2 = 0.7518

Model	df	AIC	BIC
Personal	24	7881.20	8032.32
Full	26	7884.63	8048.24

Income:

(Assumption: Energy nested in Full) LR chi2(17) = 4620.18 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Energy	8	34575.12	34636.79
Full	25	29988.94	30181.64

(Assumption: Dwelling nested in Full) LR chi2(12) = 1506.58 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Dwelling	13	31471.52	31571.72
Full	25	29988.94	30181.64

(Assumption: Locational nested in Full) LR chi2(8) = 372.95 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Locational	17	30345.89	30476.92
Full	25	29988.94	30181.64

(Assumption: Personal nested in Full) LR chi2(1) = 52.25 Prob > chi2 = 0.0000

Model	df	AIC	BIC
Personal	24	30039.19	30224.18
Full	25	29988.94	30181.64

Appendix H – Wald Test

Tenure:

```
( 1)  [woningt]energielabel = 0
( 2)  [woningt]zuinig1 = 0
( 3)  [woningt]zuinig2 = 0
( 4)  [woningt]zuinig3 = 0
( 5)  [woningt]warm = 0
( 6)  [woningt]housingtype = 0
( 7)  [woningt]kamer = 0
( 8)  [woningt]oppervlak = 0
( 9)  [woningt]indeling2 = 0
(10)  [woningt]onderhoud = 0
(11)  [woningt]g440 = 0
(12)  [woningt]stedbuurt = 0
(13)  [woningt]tgehecht = 0
(14)  [woningt]leeftijd2 = 0
(15)  [woningt]huishouden = 0
(16)  [woningt]opleiding = 0
(17)  [woningt]verhuisd = 0
(18)  [woningt]logincome = 0
(19)  [woningt]logcosts = 0

           chi2( 19) = 1468.15
         Prob > chi2 =    0.0000
```

Income:

```
( 1)  [woningt]energielabel = 0
( 2)  [woningt]zuinig1 = 0
( 3)  [woningt]zuinig2 = 0
( 4)  [woningt]zuinig3 = 0
( 5)  [woningt]warm = 0
( 6)  [woningt]housingtype = 0
( 7)  [woningt]kamer = 0
( 8)  [woningt]oppervlak = 0
( 9)  [woningt]indeling2 = 0
(10)  [woningt]onderhoud = 0
(11)  [woningt]g440 = 0
(12)  [woningt]stedbuurt = 0
(13)  [woningt]tgehecht = 0
(14)  [woningt]leeftijd2 = 0
(15)  [woningt]huishouden = 0
(16)  [woningt]opleiding = 0
(17)  [woningt]verhuisd = 0
(18)  [woningt]logcosts = 0

           chi2( 18) = 6303.81
         Prob > chi2 =    0.0000
```