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Unravelling Dutch homeowners' behaviour towards energy efficiency renovations: What drives and hinders their decision-making?

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ABSTRACT

The housing stock has a considerable share of 40% in energy consumption and 36% of CO_2 emissions in the EU. In accordance to energy efficiency and emissions targets set by EU, The Netherlands has aimed to renovate 300,000 homes each year, leading to 50% reduction in CO_2 emissions, by 2050. Many factors including low renovation rates create uncertainties in achieving these targets. The current study aims for understanding the barriers and drivers towards energy efficiency renovations (EERs) amongst Dutch homeowners, and to aid in gaining a better insight into the role of public authorities in promoting EERs. First, the extrinsic drivers, including policies and other initiatives in the EER process are explained. Second, the intrinsic drivers and intrinsic/extrinsic barriers are explored. Regression analyses are performed on the national Dutch survey data for renovators and potential renovators. Our main findings include: (a) desire to enhance the quality of their life, rather than the financial benefits, etc. is identified as the main driver; (b) the main barriers are the costs of EERs, complexities in the process, information barriers, and finding reliable experts and information; (c) For improvement in meeting renovation targets, the current Dutch policies need to consider all the decision criteria by homeowners, such as: Reducing the complexities; Time needed to obtain loans and subsidies; and Facilitating access to information.

1. Introduction

Many countries have realised the need to save energy and transition to renewable energies. Member states of the European Union (EU) aim to complete the change towards renewable energy sources by 2050. This energy transition includes: shifting away from fossil fuels; electrifying the heating demand, increasing the awareness of residents; and amending energy taxes in favour of renewable energies. In the Netherlands, the Ministry of Economic Affairs has issued a new policy to encourage actions that would help people eliminate the use of natural gas in the heating sector by 2050, and, by then, to completely use renewable energy (Government of the Netherlands, 2017; van Leeuwen et al., 2017). Yet, despite defining these targets, in recent years, the renovation rates have not been fast enough in achieving the policy targets (Baginski and Weber, 2017; Filippidou et al., 2017; CBS, 2017).

Energy efficiency programmes at both national and international levels contribute to reaching the energy saving targets. These programmes aim to remove the barriers and facilitate the process of Energy Efficiency Renovations (EERs) (Murphy, 2016). In the EU, the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) are the main legislative instruments that guide the adoption of energy efficiency renovations. For both new and old buildings, they promote these measures by the building approval procedures and the energy performance certificates/labels, respectively (Visscher et al., 2016). At the national level, the Dutch government defines national policies that shall be achieved by local authorities. For instance, Dutch housing associations and municipalities contribute to the achievement of energy targets. Together with its members, the Dutch association of social housing organisations (Aedes) undertakes action on the non-profit housing stock. In the rental sector, social housing associations and national tenant unions facilitate and ensure EERs, for instance, by making a voluntary agreement among the responsible organisations to operate an energy programme (Tambach et al., 2010). However, in the owner-occupied sector, homeowners are entirely responsible themselves for carrying out EERs. In the case of in multi-family properties such as apartments, homeowners are required to organise themselves in an association of apartment owners, but even then, it appears difficult to reach an agreement about joint investments in energy saving (Filippidou et al., 2017).

In 2017, the Dutch owner-occupied sector accounted for 69.4% of the building stock, and currently, the overall average energy label performance is at the mid-point 'D' on a scale from A to G (Government

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of the Netherlands, 2016, 2017; Ministry of the Interior and Kingdom, 2014). Considering the significant share of the housing stock in total annual energy consumption, and relatively low average energy label, there is a considerable energy-saving potential in the owner-occupied sector. Moreover, the processes of EERs are not easy, and homeowners encounter issues in finding: (a) financial support; (b) reliable information; and (c) contractors (Wilson et al., 2015). For instance, homeowners cannot easily raise money to renovate their buildings, and the procedures associated with EERs are very complicated. In the Netherlands, mortgages by private banks are the most important financial support, and so mortgages more than the house value are allowed to cover additional costs, such as renovations and taxes. However, the complexities of these procedures might prevent homeowners from considering mortgages, and the expected benefits of EERs (in terms of saving money) are either not higher or only marginally higher than the costs of mortgages (Schilder et al., 2016).

From economic perspective, the behavioural aspects and transaction cost (TC) factors are among the main influencing factors in the consumers' decision-making processes. Behavioural factors mainly illustrate a range of personal, contextual and external factors influencing homeowners' cognitive decision-making processes. The personal factors include cognitive awareness, attitudes and beliefs, experience and skills, while the contextual factors contain homeowners' features, socio-demographics and property characteristics. Also, behaviour can be influenced by external factors, such as other people's behaviours. The transaction cost (TC) means any hidden cost that has not been included in the cost analysis and that has been generated owing to a transaction with an external source. Asset specificity, uncertainty in the decision-making processes, and frequencies are the determinants of TC. Examples are time and effort to acquire knowledge, information and finding reliable experts (Fan et al., 2016; Mundaca, 2007; Mundaca T et al., 2013; Wilson et al., 2015, 2018).

The aim of this paper is to evaluate the influencing factors in EERs among Dutch homeowners. We intend to fill the literature gap by addressing the drivers and barriers to EERs from the behavioural research and TCs perspectives, and evaluating recent Dutch policy instruments. The behavioural research studies are mainly reviewed to investigate the drivers of EERs. The TC studies are used to identify the non-monetary cost barriers. The main question is 'Which factors influence the decision-making processes of Dutch homeowners towards EERs?' Through this study, the current policy instruments are examined to indicate whether these policies match the needs of homeowners. Hence, the results of this study aim to facilitate EER processes for homeowners, and to help in designing more effective policy instruments. The WOON2012 energy module database (housing survey on energy uses in rental and private building stocks in the Netherlands) is used to quantitatively analyse the impacts of the factors influencing the decisions of Dutch homeowners.

The remainder of the paper is structured as follows. Section 2 reviews scholarly investigations under two headings: (1) the recent policies/initiatives to promote EERs in the European countries and the Dutch owner-occupied sector; and (2) drivers and barriers towards EERs in the owner-occupied sector. Section 3 describes the methodology, explains the WOON2012 energy module database, and then continues the analysis by logistic regression. Sections 4, 5, and 6 present subsequently the results of the analyses (Section 4), discussion on these results (Section 5), and conclusions and policy implications (Section 6).

2. Review of earlier studies on policies/initiatives and drivers/barriers in relation to energy efficiency renovation (EER)

2.1. European policies in the owner-occupied sector

For owner-occupiers, the lack of awareness, the absence of sufficient knowledge and the lack of cost effectiveness and funding are often seen as the main barriers to undertake energy efficiency measures. However every homeowner is confronted with its own individual and personal barriers that largely are related to their household, dwelling characteristics and their personal beliefs and convictions. Schleich (2019) studied the adoption of energy efficiency technologies by income categories in eight European Union countries, and recommended that the financial supports should address "poor homeowners".

Over the last decades the Member States of European Union have undertaken serious efforts to promote energy efficiency in the housing sector. Ambitious energy saving goals were set and national, regional and local authorities have designed a mix of policy instruments to conquer the barriers homeowners are confronted with. Although the definition of policy instruments is not completely unanimous in the research literature, a distinction is usually made between regulatory, economic, organisational and communicative instruments (e.g. (Itard, 2008; International Energy Agency, 2010; Klinckenberg and Sunikka, 2006)). The precise contents and goals of these national policy instruments vary, but the common goal is to motivate and stimulate owners to undertake action by tackling the barriers that prevent them from renovating their dwellings in an energy efficient way.

Over recent years the importance of the role of local authorities has increased in European countries (e.g. (Gram-Hanssen et al., 2018)). It is in this respect predominantly acknowledged that, instead of a common national policy approach, an approach is needed that is based in local authorities and its neighbourhoods. In order to change the individual behaviour and perspectives of owners, policies throughout Europe are increasingly based on identifying the individual needs, possibilities and wishes of homeowners and connecting their demands with the supply side. In this way, policy instruments can play an important role in helping to eliminate the above mentioned barriers (e.g. (Kivimaa and Martiskainen, 2018; Martiskainen and Kivimaa, 2018; Killip et al., 2018; Beillan, 2013; Fawcett et al., 2013)).

2.2. Dutch policies and private/public-private initiatives in the owner-occupied sector

Only a few studies have comprehensively examined the Dutch policy instruments (Murphy et al., 2009, 2012; Tambach et al., 2010; Vringer et al., 2016; Visscher et al., 2016; Visscher, 2017). Tambach et al. (2010) analysed the policies for the housing sector. The significant part of their research is assigned to the interviews with local actors regarding the barriers and needs for energy transitions, including the means to influence attitudes of agents towards energy-saving. They concluded the Dutch system needs a stable and long-term financial support to build trusts in the owner-occupied sector. Vringer et al. (2016) mentioned that the Dutch policy instruments are not too strong, and homeowners need more governmental interventions. They proposed that if the current taxes depend on homeowners' energy label, the homeowners will be more motivated in doing EERs. Murphy, Meijer, and Visscher (2012) explored and evaluated the underlying theories of policy instruments. They found the objectives often change during the implementation, with the result that achievement of those objectives remains uncertain. The majority of policies emerge and fade over short-time periods. Moreover, the current policies are not effectively combined to achieve the targets of energy efficiency. The authors recommended to examine the precise impact of policies and to consider elements beyond the effectiveness of policies, such as equity.

The Energy Efficiency Directive (EED) aims to reduce the energy consumption by 20% in 2020. Article 4 of the EED obligates European Member States to build a long-term strategy for the renovation of the buildings. The Dutch Energy Agreement signed in 2013 by 40 parties (public and private) is the response to the mandatory objectives of the EED. At the end of 2016, the Energy Agenda was presented by the Dutch Cabinet. The agenda outlines the extensive long-term lines by 2050 (EC, 2018).

In the Energy Agreement and Energy Agenda, several actions are

planned and implemented to promote energy-saving in the owner-occupied sector. A new public funding has been available since 2014 for the building sector and part of this funding is devoted explicitly to the homeowners and housing cooperatives under the name of 'National Energy Fund' (Janeiro et al., 2016).

In the building sector in the Netherlands, the energy transition policies are designed to entirely move to the use of renewable energy resources. These policies include: 1) Nearly zero energy indicators for new buildings by 2020; 2) Large scale energy renovations for lower EPC (Energy Performance Certificate)-Levels (D and F); 3) Subsidies for heat from renewable sources, more use of solar PV; 4) Raising the awareness of households about renewable energy resources, and 5) Switching to electricity for energy use (van Leeuwen et al., 2017).

Besides the policies at the national level, private or public-private parties, such as energy providers, start initiatives to enhance the energy efficiency in the building sector. For instance, in mid-2014, the Association of Dutch Municipalities (VNG) ,[1] supported by the Ministry of the Interior and Kingdom Relations, launched a programme aimed at accelerating and scaling up the energy efficiency of the private owner-occupied housing. All municipalities have committed themselves in 29 regions and worked together with companies and social parties on energy savings and energy generation in private homes. The plans of these regions have been summarised as the most crucial action points. The summary of these policy instruments, initiatives, and underlying hypotheses are presented here in Tables 1 and 2. The data are collected based on the energy agenda introduced by the Dutch cabinet at the end of 2016.

2.3. Behavioural aspects influencing the homeowner cognitive decision-making process

Drivers and barriers can be categorised as 'intrinsic' and 'extrinsic' factors. Intrinsic ones are the consequences of the interaction between an individual's internal wishes, ambitions, preferences, with their situations. Extrinsic factors can be the rules, financial costs and incentives, and so on (Jakob, 2007).

The energy efficiency renovations (EERs) usually need high upfront costs compared to repairing/improving the energy efficiency measures (Wilson et al., 2015). Monetary costs might be covered by homeowner saving, loans from families, friends, governments, or the banking system (Jakob, 2007). The banking system is a potential financial supporter and the interest rates influence the feasibility of renovations. Thus, an interest rate threshold exists and higher rates might demotivate the EERs (Howarth and Andersson, 1993; Jakob, 2007; Murphy, 2014).

Households perform renovations when they have the capabilities and expectation to achieve the potential benefits. The assumption is: an individual does not get involved in an action, either whenever it incurs high risks and/or the expected benefits are not favourable (Jakob, 2007). Factors that can be used to evaluate the homeowners' decision-making processes include: 1) bounded rationality, referring to the cognitive burden in collecting and processing information; 2) expected time and financial support to accomplish the renovations; and (3) expected faster return on investment, even though the renovations have long-term gains (Frederiks et al., 2015; Wilson et al., 2015).

Many research studies illustrate that the drivers of and barriers to individual behaviours are more influential than monetary costs (Kahneman, 2003; Wilson and Dowlatabadi, 2007). Consequently, behavioural researchers aim to integrate more powerful psychological insights into the homeowner decision-making processes by considering a range of personal and contextual factors to explain the decision. Personal factors include cognitive awareness, attitudes and beliefs, experience, and skills, whereas contextual ones contain homeowner characteristics (e.g., size, composition, and number of children), socio-demographic variables (e.g., age, education, income, and employment), and property characteristics (e.g., construction period). To accomplish renovations requires advanced cognitive and emotional involvement on the part of homeowners (Baginski and Weber, 2017; Wilson et al., 2015; Wilson and Dowlatabadi, 2007). A recent study identified a strong differences in the adoption of energy efficiency technologies by income groups in eight European countries. Lowest income groups has less willingness to invest for all types of energy efficient technologies (Schleich, 2019).

When individuals' basic needs are satisfied, they pursue safety, social engagement, self-esteem, and self-actualisation. For instance, pro-environmental behaviours are expected when a household has already achieved its basic needs and has the resources (time, money, and energy) to act generously. Some drivers, such as cost saving and thermal comfort, are more common in the applied behavioural and sociological research, and some, such as draughts, condensation, air quality, and property value, are occasionally mentioned (Wilson et al., 2015).

Fig. 1 explains different stages in the decision-making process. In general, the stages consist of understanding the needs, information searching, pre-evaluating, finalising the decision, implementing, and post-evaluating (Baginski and Weber, 2017). Renovations initially depend on the current conditions of life, and so the factors influencing the renovation decision change during the process. In the considering phase, the socioeconomic factors (e.g., education and income) are important when thinking and acquiring knowledge of renovations. In the planning phase, an awareness of the benefits can persuade homeowners to renovate (Murphy, 2016; Stieß and Dunkelberg, 2013; Wilson et al., 2015, 2018). In the planning and implementing phases, access to information regarding the methods and/or means in conducting the EERs is essential. After implementing and experiencing the EERs, the bad and/or good experiences are circulated through social networks and communication channels. The circulation of these feedback data also influence the next up-coming renovation processes for the users (Wilson and Dowlatabadi, 2007).

2.4. Transaction cost factors as barriers in the decision-making process

Coase (1960) defined a transaction cost (TC) as any indirect cost inevitable in producing goods and services, and essential in a transaction. TC negatively affects the renovation decision. Mundaca et al. (2013) interpreted it as a sub-category of 'hidden costs' that have not been adequately considered in the cost analysis. The determinants of TCs are shown in Fig. 2, namely: asset specificity, uncertainty, and frequency. When an asset, such as physical/human, have been assigned for a particular purpose/in a specific location/for a particular agent, it generates additional costs since it cannot easily be used for other purposes (Fan et al., 2016). These factors are essential in the considering and planning phases, since the homeowners need to evaluate the advantage of investment in a specific renovation type. Moreover, homeowners are responsible for renovations, and when they plan to do it themselves, they need to acquire specialised skills and knowledge before implementation. Two types of uncertainties are relevant: 1) uncertainty on the expected benefits; and 2) uncertainty arising from opportunistic behaviour. The latter occurs for instance because of lack of trust between parties including the professional contractors in executing renovation. When agents are doing more renovation projects, the uncertainties reduce because of the experience they have gained during the renovation process itself (Fan et al., 2016; Hongjuan et al., 2017).

TCs also represent time and efforts to acquire knowledge and information. This type of TC is inevitable in energy renovations since information acquisition usually takes time and might be expensive

[1] VNG cooperates intensively with umbrellas organisations (and private) associations such as Bouwend Nederland, Uneto-VNI, Netbeheer Nederland and VvE Belang, with partners such as Milieu Central and HIER Opgewekt (https://vng.nl/regionale-aanpak-particuliere-koopwoningen).

Table 1
The main Dutch (policy) instruments for homeowners' EERs.

Policies at the national level	*Underlying hypothesis*	Date active
More national revolving fund for energy-saving, (€ 50 million), reducing the interest rates	Providing financial support	Issued in 2016.
Cheaper mortgages in return for energy efficiency (depending on the bank)		the mortgages are lowered in the 1st half of 2016.
'Save Energy Now!' - Applying for a grant/low-interest loan. - Encouraging homeowners by a campaign with an energy label C/lower	Reducing financial & information barriers	2017–2020
'Energy-saving at home subsidy scheme', - A budget of € 60 million for homeowners, - At least two major insulation measures, -For an integral and extremely low-energy package (the insulation package with a zero-energy home): A bonus of €4000 over and above the subsidy is available. A subsidy is also available for energy recommendations and for creating a green long-term maintenance programme for owners' associations.	Providing financial support	1st September 2016
Providing a 'sustainable providers' profile, who supply homeowners more suitable products/services for energy-saving measures.	Removing the barriers in finding reliable experts	The profile was available at the end of 2016.
Steering group: they ensure the cooperation between responsible organisations for energy saving in the regions.	Reducing the complexities in the working process	2017–2020
Legal anchoring of object-related financing in Coalition Agreement. Adaptation of the Wet Vet (= Bill on the progress of energy transition) that enables the role of network companies in the sustainability of housing.	Aim to remove the current obstacles	Part of it in the 1st July 2018. The rest will be on 1st January 2019.
Further elaboration of the care and financing model for the private homeowners. Building on experiences in the regulated rental sector, further developing a tender system for upscaling, innovation and price reduction.	Providing financial supports	2018 and beyond

Table 2
The main Dutch private/public-private initiatives for homeowner EERs.

Private/public-private parties initiatives	Underlying hypothesis	Date active
'Get out of your chair' (both homeowners and companies): An initiative from energy providers. - Promoting energy saving by the advertisements - Informing the benefits, available services and products, and financial supports to EERs by the municipalities. - For a two-week period, commercials were circulated on television and radio. - Energy companies post their energy saving products on a campaign website.	Informing the benefits of using the energy -saving measures	Two weeks in 2016.
Innovative Approaches Owner-occupied Homes By VNG coordinates the programme in collaboration with the Dutch entrepreneurial organisation for construction and infrastructure. - Municipalities, together with local entrepreneurs and energy cooperatives, - Renovate private owner-occupied homes in 51 Innovative Approaches innovative. - The scheme focuses on alliances with innovative ideas to encourage homeowners to renovate their homes to energy-neutral. - An independent assessment committee checks the applications and the progress of the approaches, - Municipalities, together with local entrepreneurs and energy cooperatives, contribute of up to € 200,000. - To speed up the transition to an energy-neutral housing stock	Reducing the complexities of the work/process	Launched at the end of 2016
The Energy Saving Explorer - Three branch organisations for brokers and appraisers (VastgoedPRO, VBO Makelaar, and NVM). - Developing an online tool, the energy saving explorer, with a 'cash value calculation' that enables valuers, brokers, banks and mortgage lenders to quickly calculate the potential energy savings that their customers could generate.	Reducing the complexities in applying loans/subsidies	Since 2017

(Brown, 2001; Itard, 2008). Additionally, the imperfect and asymmetric information might hinder the energy renovation since decision-makers encounter high costs to find reliable information (Mundaca, 2007). Homeowners might not invest if they do not have the information regarding the nature and costs of energy efficiency renovations. Moreover, they are not usually educated in the basic construction technology, nor the construction industry and must find a way to learn or completely transfer the physical operations to an expert (Stieß and Dunkelberg, 2013; Wilson et al., 2015). The complexity in the decision-making process is also part of TCs: the cognitive burden of making complex and irreversible decisions, and the anticipated 'hassle factor' of having home-life disrupted during the renovations. Where an individual encounters difficulties to make proper and precise expectations, they might not invest optimally in energy efficiency renovations (Howarth and Andersson, 1993; Wilson et al., 2015).

2.5. *Drivers, barriers, & determinants related to initiatives, behavioural, and transaction cost factors*

Tables 3 and 4 summarise the influencing factors and determinants in energy efficiency renovations. These factors are categorised based on the initiatives by government, behavioural aspects and TCs. All the factors are explained in the last sub-sections (2.1–2.3).

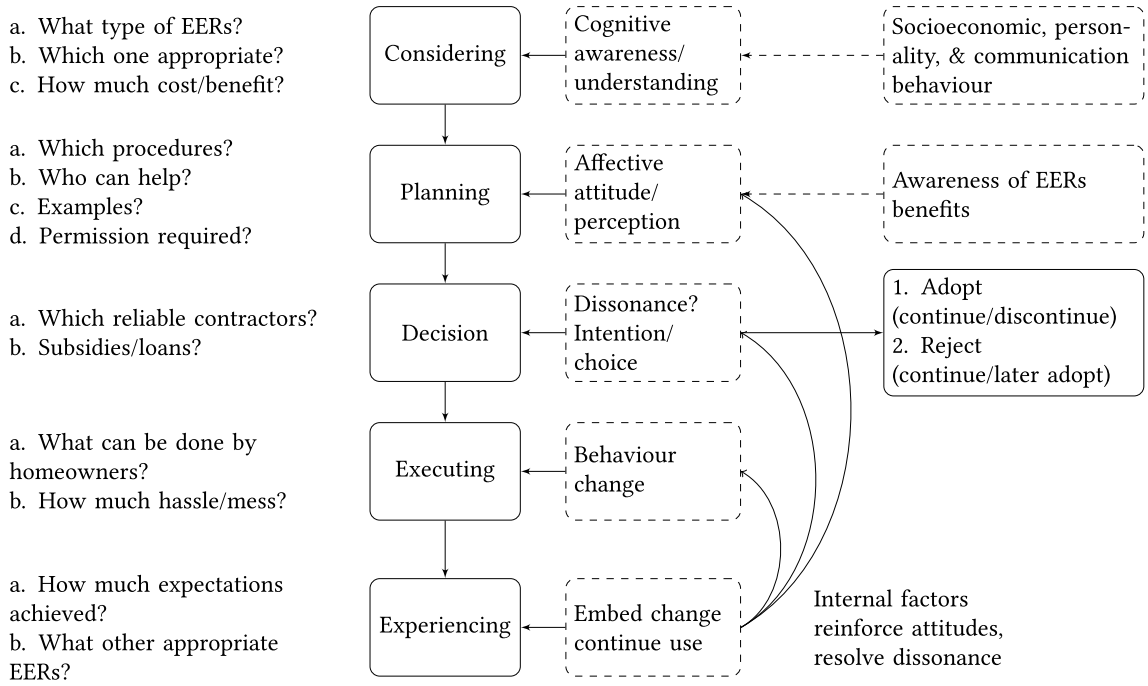

Fig. 1. Behavioural aspects influencing homeowner cognitive decision-making process (compiled from several sources).

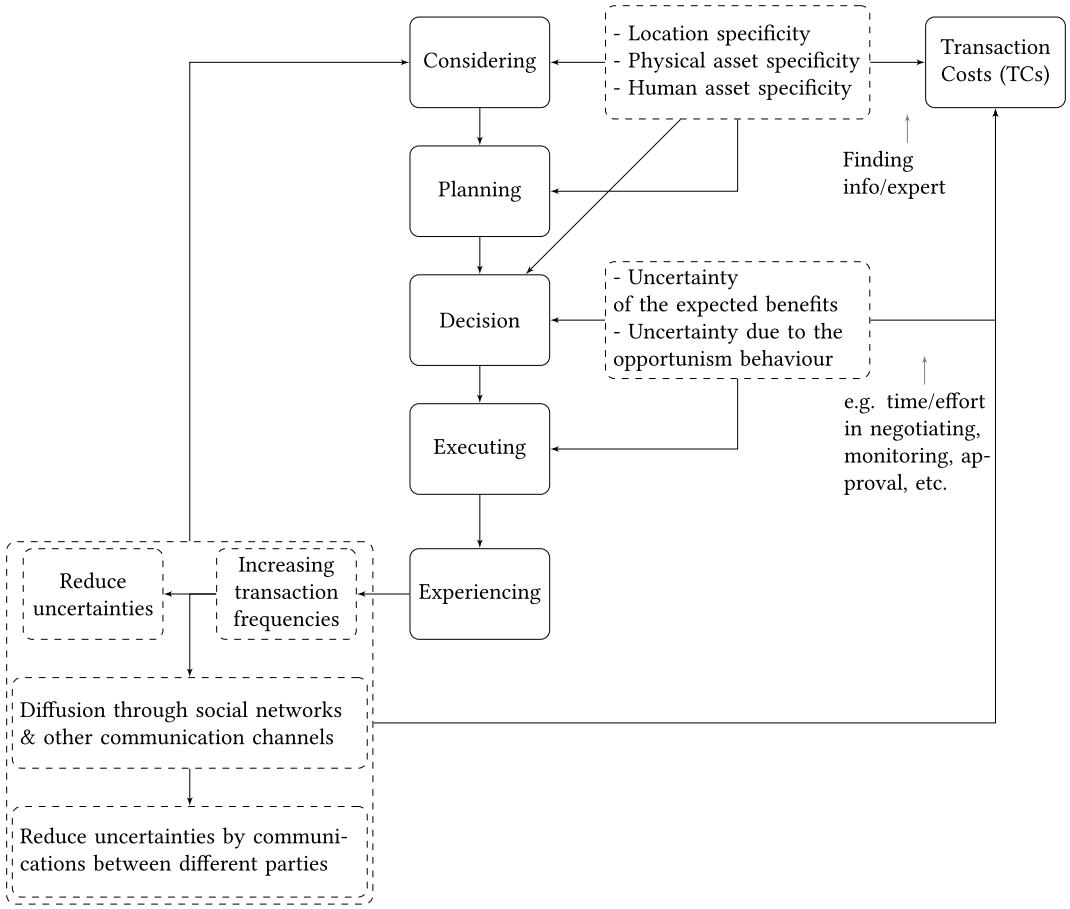

Fig. 2. Transaction cost factors influencing the decision-making process (compiled from several sources).

3. Methodology

In subsection 3.1, the status of the Dutch housing stock is presented to give a general picture of the sector and the share of owner-occupied sector in the energy consumption. In subsection 3.2, the WOON 2012 energy module is described. The homeowner profiles and buildings features, the dependent and independent variables, and the limitation of the database are explained in this subsection. In subsection 3.3, the

Table 3
Drivers, barriers, and determinants regarding the initiatives and behavioural aspects from literature review.

Category	Drivers	Barriers	Determinants
Initiatives	Promotion by public authorities	Lack of support by public authorities	-
Behavioural aspects	*Financial benefit* Cost-saving Increasing the house value Making the house easier to sell	*Cost* Capital costs & interest rate Uncertainty on energy costs/benefits & payback period.	Age Education Income Employment Moved to a new house Household composition
	Enhancing the life quality Repairing/replacing equipment Increasing comfort Reducing noise *Environmental concerns* Protecting environment *Other's experiences* Following others	Delayed payoffs	Property features Number of people Cognitive awareness Attitudes & beliefs Experience& skills

Table 4
Barriers and determinants regarding the transaction costs (TC) from literature review.

Category	Barriers	Determinants
TC	*Information* Time & efforts in finding info *Credibility* Searching & finding reliable information and experts. *Self/support* Time/effort in finding support & help. *Work/Process (W)* Disruption in the ordinary life and anticipated hassle factor Perceiving the EERs as not essential and a complicated process Complexities in acquiring the knowledge & skills Dissatisfaction of the past experience Time/effort apply for loans/subsidies, doing the work	Asset specificity Uncertainty Frequency

logistic regression including the pre-assumptions of running this model and validation are described.

3.1. Dutch dwelling stock and the owner-occupied sector

The owner-occupied sector has a considerable share about to 70% of the Dutch housing stock. The demand of owner-occupied houses has risen because of a more stable market and very low mortgage interest rates. The number of owner-occupied houses is estimated to increase by nearly 300,000 in the next five year period 2018–2022 (ABFResearch, 2018). Fig. 3 shows the share of the owner-occupied and rental sectors during the period 2012–2017.

A large amount of natural gas is consumed in the Dutch housing stock (almost 72% of total energy consumption (Eurostat, 2016)). However, in recent years, the average gas consumption is reduced mainly due to double glazing, high-performance boilers and better housing insulation (PBL, 2014). Fig. 4 shows the average gas consumption in the owner-occupied sector, rental and total dwelling stock. In 2017, the reduction in average gas consumption in the owner-occupied sector and rental sector, respectively, was equal to 16% and 22% compared to 2012 (Fig. 4).

3.2. WOON energy module database

Dutch Ministry of the Interior and Kingdom Relations is responsible for carrying out a survey every 5–6 year about energy uses in rental and private building stocks as a part of a larger survey of Dutch dwellings (Woon – Woon Onderzoek Nederland, which stands for Housing Survey Netherlands). The survey is conducted among the households in the owner-occupied, social housing and private rental sectors. Besides the survey, other sources of relevant data collection are dwelling inspections and reports on energy consumption. The WOON database contains the details data on variables about occupant behaviour and more detailed data from the building inspections. In this study, the WOON2012 energy module, the most recent one, has been used. This database covers 4800 houses in which 58% (2784) are homeowners. Few researches evaluated the representative of the WOON2012 energy module for the Dutch housing stock (Rijksoverheid, 2014; Majcen et al., 2015). In the following sub-sections, the variables in the quantitative analysis are explained.

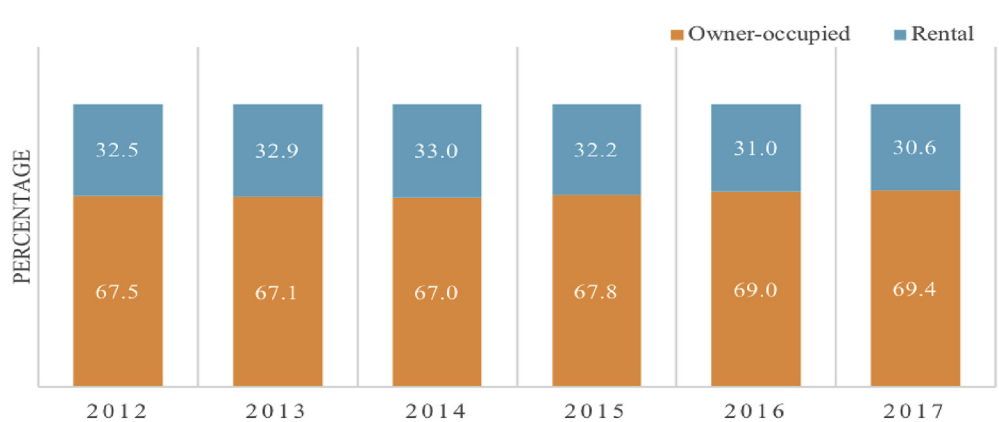

Fig. 3. Share of the owner-occupied and rental sector in the Dutch dwelling stock (CBS, 2018)

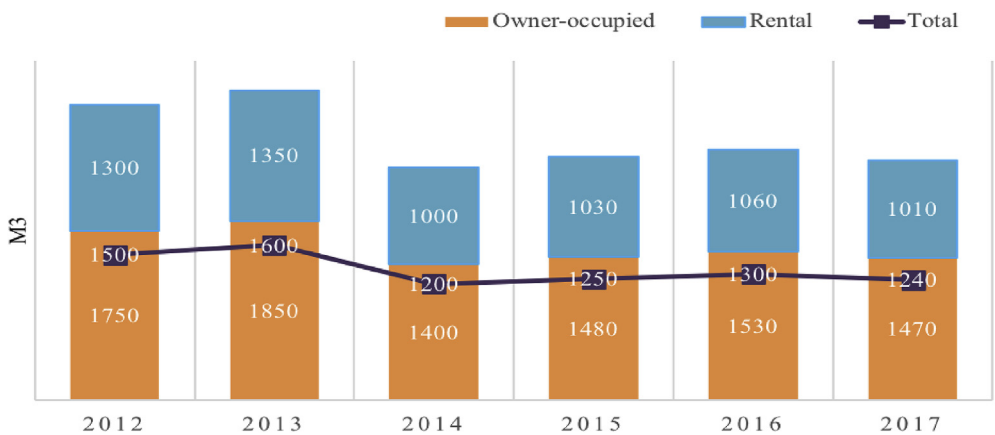

Fig. 4. Average energy consumption of the Dutch dwelling sectors (CBS, 2018)

Table 5
Profile of the Dutch homeowners.

Homeowners' profile	Categories/Averages	Frequency	Percent
Age (Four classes)	17–34 year	348	12,5
	35–44 year	515	18,5
	45–54 year	605	21,7
	54 and older	1.316	47,3
Gender	Man	1.483	53,3
	Woman	1.301	46,7
Education	Lower - High school	1.520	54,6
	University degree	1.250	44,9
Income (per year)	41.484	2.744	98,6
Working hours (per week)	32,53	1.807	64,9
Moved in the past 2 years	No	2.562	92
	Yes	222	8
Total		2.784	100

Table 6
Building features.

Buildings features	Categories/	Frequency	Percent
One/multifamily	one	2.316	83,2
	more than one	468	16,8
Construction period	1945 and older	654	23,5
	1946–1990	1.369	49,2
	1990 and newer	761	27,3
Number of people in the house	1	604	21,7
	2	1.195	42,9
	3	343	12,3
	4	448	16,1
	(5–8)	194	7
Type of the buildings	Detached	562	20,2
	2 houses-under-1-roof	552	19,8
	Corner house	367	13,2
	Row house	761	27,3
	Maisonettes	462	16,6
	Other	61	2,2
Total		2.784	100

3.2.1. Households' profiles and buildings features

Table 5 shows the Dutch homeowners' profile, such as 50% of homeowners are 54 years old/and more, and in 83% of the houses, only one family is living. Many of them are the determinants of the behavioural aspects.

The importance of building features are examined in many studies. These features explain 42% of energy consumption in the houses. Therefore, they are included in the regression analysis (Majcen et al., 2013; Santin et al., 2009; Filippidou et al., 2016). About 30% of the houses are row houses type. Detached houses, 2 houses-under-1-roof, and Maisonettes are ranked second and third in terms of numbers (see Table 6).

Fig. 5 shows the distribution of dwellings based on the year of construction in the owner-occupied and rental sectors. The owner-occupied sector has the highest share in the very old and very new dwellings.

3.2.2. Renovators and potential renovators

The WOON energie module 2012 contains questions with binary choices: a) Yes (1), b) No (0). We defined the renovators and potential renovators using the following questions:

(a) Renovators, *Question 43 of the database: "have you installed insulation/double glazing in the past five years? "*

In the database, there are 849 positive responses.

(b) Potential renovators, *Question 59 of the database: Will you install insulation/double glazing in upcoming two years?*In the database, there are 338 positive responses.

3.2.3. Drivers to energy efficiency renovations

In the survey, series of questions are defined regarding the motivations. For instance, What does encourage them in doing/planning for the EER - Was it 'cost savings on the energy bill'? The answers to the questions are (yes = 1, or No = 0). Therefore, the variables of drivers to energy efficiency renovations are binary. Based on the questions 43 and 59, we divided the database to calculate the frequency and percentage of positive responses for each driver (Table 7).

3.2.4. Barriers to energy efficiency renovations

In the survey, a series of questions are defined regarding the hindrances. For instance, What does discourage them in doing/planning the EERs- Was it the time and effort in finding the information? The answers to the questions are (yes = 1, or No = 0). Therefore, the variables of barriers to energy efficiency renovations are binary. We divided the database to calculate the frequency and percentage of positive responses for each barrier (Table 8).

3.2.5. Limitations of the database

There are limitations in using the WOON energy module dataset:

(a) The WOON energy module datasets are published only every 5/6 years due to high costs. The newest version is for 2012. The analysis would be more in line with the policy instruments by the newer version.
(b) We aimed to investigate the whole process of decision-making

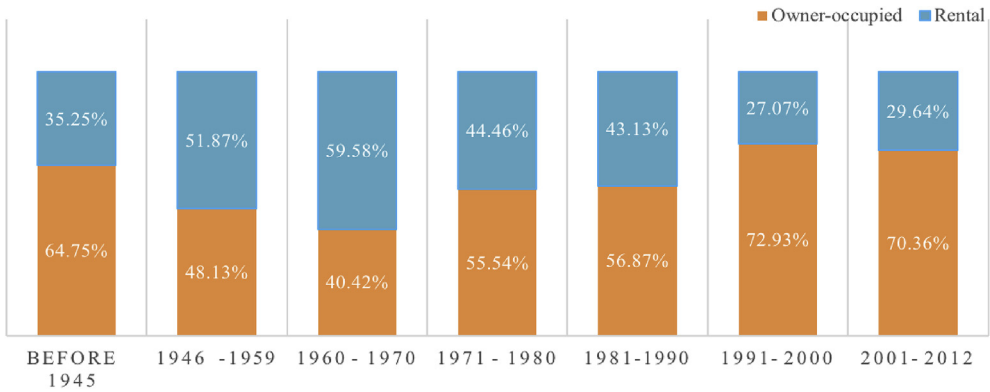

Fig. 5. Comparison of building year between owner-occupied and rental sector.

Table 7
Drivers towards energy efficiency renovations.

Drivers	Frequency (%) (Renovators)	Frequency (%) (Potential Renovators)
Cost saving on the energy bills	558 (65.2%)	266 (78%)
Increasing the comfort	530 (62%)	211 (61.7%)
Protecting the environment	211 (24.7%)	134 (39.2%)
Improving ventilation	119 (13.9%)	55 (16.1%)
Increasing the house value	61 (7.1%)	39 (11.4%)
The boiler needed to be replaced	272 (31.8%)	29 (8.5%)
Reducing noise	90 (10.5%)	23 (6.7%)
Easiness to apply	102 (11.9%)	16 (4.7%)
Selling the house easier to sale	18 (2.1%)	9 (2.6%)
Following other people	5 (0.6%)	4 (1.2%)
VvE wanted to do it	4 (0.5%)	2 (0.6%)

Table 8
Barriers toward energy efficiency renovations.

Barriers	Frequency (%) (Renovators)	Frequency (%) (Potential R)
Cost of Energy Saving Measure	430 (50.3%)	203 (59.4%)
Limited/no subsidies	459 (53.7%)	201 (58.8%)
Time & effort: subsidies & loans	427 (49.9%)	184 (53.8%)
Reliable professional	288 (33.7%)	117 (34.2%)
Reliable information	264 (30.9%)	108 (31.6%)
Time and effort: work	275 (32.2%)	109 (31.6%)
Knowledge and skills: work	272 (31.8%)	101 (29.5%)
Time and effort: information	216 (25.3%)	99 (28.9%)
Mess and nuisance: work	229 (26.8%)	81 (23.7%)
Expecting help from friend, etc.	153 (17.9%)	54 (15.8%)
Media report	29 (15.1%)	41 (12%)
Past experiences	91 (10.6%)	26 (7.6%)
Experiences of those around you	59 (6.9%)	15 (4.4%)

process by householders. However, in the WOON energy module, the data is provided only for the main stages of implementing and planning. Therefore, we could not quantitatively analyse the overall process. It would be more comprehensive, if we had the information for other stages in the renovation process, such as considering phase, experiencing.

(c) The dataset is not very clear in distinction of energy efficiency renovation and energy saving measures. In the WOON energy module, the question is designed in a way that includes both insulation, and the higher efficiency boiler, improved efficiency boiler, or solar water heater. Implementing some energy-saving measures cannot be considered as EERs. For instance, the decision of "Replacing a boiler (improvement/repair)" is not comparable to "housing insulation (renovation)". The second one needs a more complex decision-making process.

3.3. Method of analysis

The impact of barriers and drivers are investigated, using logistic regression. In this regression, the probability of an event, occurring for randomly-selected observations are determined by any given combinations of independent variables (Cohen et al., 2014). Two separate regressions are estimated for the renovators and potential renovators. For the renovators, the dependent variable is the log of *Whether the respondents did a renovation in the past*. For the potential renovator, the dependent variable is the log of *whether the respondents are planning to do a renovation in the future*. By renovation, we mean the insulation or double glazing. By insulation, we mean the facade insulation, the internal and exterior insulation of the roof, the ground insulation, the attic, and other floors. By double glazing, we mean the double glass (HR++, no HR++, and type unknown), double glazing of the front windows, and others. The question also includes *whether the homeowners replaced the higher efficiency boiler, improved efficiency boiler, unknown type of boiler, or solar water heater*. In this analysis, explanatory variables are the social-demographic features, such as age, education, income, and the drivers, and barriers to EERs. In section 3.1.2 and 3.1.3, the drivers and barriers in the regression are specified.

Table 9 is an example of a logistic regression in Statistical Package for the Social Sciences (SPSS) (version 25.0). Coefficient B presents the changes in log of the dependent variable for every one-unit change in an independent variable. Odds ratios (column exp(B)) denote the degree of association between dependent and independent variables, and are used to compare the relative probabilities of the occurrence of the renovation, given the presence of the variables, such as households and building features, etc. Finally, A Wald test shows the significance of each coefficient in the regression.

The logistic regression has a few assumptions that need to be tested before running the regression software, including:

(a) Dependent variable is the log of the binary variables:

In the database, the original variable is whether they have done the renovation in the past or they are planning to do it in the near future. Therefore, it is binary (0,1). For renovators, the dependent variable shows the probability of the renovation in the past, and for the potential renovators, the probability of renovation in the near future.

Table 9
SPSS outcomes for logistic regression.

Independent variables	B	S.E.	Wald	df	Sig.	Exp(B)
Constant						

(b) The independent variables should not show multicollinearity.

In the logistic regression, the multicollinearity needs to be checked. Otherwise, the results are not reliable. To test the multicollinearity, examining the correlation matrix of explanatory variables might be useful but not adequate on its own. In this study, a more robust approach is followed, and multicollinearity is tested using the Variance Inflation Factor (VIF). VIF values of more than 10 are often considered as showing multicollinearity, and values of more than 2.5 is the initial point of concern (Midi et al., 2010). For the implementation and planned regression, the highest VIF values are 2.397 and 2.115, respectively, and thus, this indicates acceptability regarding the multicollinearity in the analysis.

(c) The data should cover a large sample size (Peng et al., 2002).

The sample size are sufficiently large. For the renovator and potential renovator regression, the sample sizes are 1946 and 689, respectively.

The model is specified as follows:

$$Log\left(\frac{P_{\text{renovation}}}{(1-P_{\text{renovation}})}\right) = X_{\text{householdsandbuildings'features}} + X_{\text{sourcesofinformation}} + X_{\text{stagesinhelpacquisitions}} \quad (1)$$

Where P is the probability of the events, and X represents independent variables, after estimation, the model is validated by the Omnibus tests of model coefficients and the Hosmer and Lemeshow test (Table 10). The Omnibus test shows whether the model predicts the outcome with the explanatory variables better than without (Brant, 1990). The Omnibus tests are statistically significant, and, in this study dataset, the models show better results with explanatory variables than without. The Hosmer and Lemeshow test also examines the goodness of fit. The results of this test should not be significant to indicate a good model. Based on the tests, the regressions present reasonably good models. Additionally, Nagelkerke R Squares are equal to 0.423 and 0.385, accordingly.

4. Results

First, the statistical analysis are shown to understand the overall ranking of the drivers and barriers, and then the significance of these barriers and drivers are presented according to the regression analysis.

4.1. Renovators

4.1.1. Statistical analysis

The rankings of the drivers and barriers are presented in the following sections. Additionally, the ranking of reliable sources of information, and who implements the energy efficiency renovation are presented.

4.1.1.1. Drivers. Fig. 6 shows the renovator drivers towards EERs. Renovators have mainly aimed to achieve financial benefits and to enhance the quality of their life. More specifically, the main identified drivers are 'Saving on energy bills', 'Improving comfort', and 'Increasing the efficiency of the boiler'. The least important ones are 'Decision by homeowner association (VvE)', 'Following other people in the neighbourhood', and 'Selling house easier'. Considering the influence of VvE mainly for 'More than one family in the same building' and a small share of this category among the renovators (10%), the decision by VvE is among the lowest ranking.

Table 10
Assessing the two regressions regarding the goodness of fit.

Stages	Omnibus Tests of Model Coefficients			Hosmer and Lemeshow Test		
	Chi-square	df	Sig.	Chi-square	df	Sig.
Renovators	320.904	20	.000	6.702	8	.569
Potential renovators	129.047	14	.000	8.355	8	.400

4.1.1.2. Barriers. The main identified barriers are 'Limited/no subsidy', 'Costs of Energy Saving Measures (ESMs)', and 'Time and effort: apply for loans/subsidies'. The least important identified ones are 'Experiences of those around the renovators, 'Past experiences', and 'discouraging by Media'. The energy-saving measure cost is one of the main hindrances for the renovators, and as a consequence finding the financial support to cover it and complexities in applying for subsidies and loan are other vital barriers. 33.7% of renovators have affirmed that finding a reliable expert to carry out the renovations was a barrier (Fig. 7).

4.1.1.3. Reliability of information by different parties. The homeowners answered about the reliability of the information provided by different parties. The most reliable information is acquired through the homeowner association (VvE), the Dutch government and environmental agencies. The VvE data has been explored for one family and more than one family in a building. Overall, 56.5% (440) of one family and 62.2% (143) of more than one family in the same building confirmed the reliability of information by VvE (Fig. 8).

4.1.1.4. Implementing energy-saving measures. Companies and experts mainly carry out the EERs for the renovators. About 35% of renovators have implemented the energy efficiency renovations by themselves/with help of acquaintances.

4.1.2. Regression analysis

Based on the results in Table 11, the coefficient of age, income, household types (one/more than one families), construction periods, and gender are statistically significant. The results show that the homeowners older than 35 are approximately 2.5 times more likely to renovate than the reference group (17–35). Regarding the type of family, the houses with one family are 2.7 times more likely to be renovated compared with multifamily houses, which indicates the complexity of renovation decision in multifamily buildings.

'Gaining financial benefits' and 'Increasing the quality of life' are the two main categories that are statistically significant. Respondents that have indicated 'increasing comfort' are 2.4 times more likely to have performed a renovation than respondents who have not indicated this driver. The other statistically significant drivers can be interpreted in the same way. Thus, respondents that have indicated 'cost-saving on the energy bills', 'increasing the house value', 'reducing noise', 'improving ventilation' are respectively about 1.4, 2.2, 3.1, and 2.7 times more likely to have performed a renovation. Protecting the environment, selling the house easier, the decision by VvE (mainly play roles in multifamily buildings), easiness to apply in the house are not statistically significant.

The main identified categories of barriers are 'Programmes by the government' and 'Credibility of experts and information'. Among the variables of these categories, both 'Limited/no subsidies', 'Lack of reliable expert' are statistically significant. The 'Reliable information provided by Do-it-yourself (DIY) companies'[2] is statistically significant, although the other source of information has higher numbers of positive responses. Similarly, 38% of the respondents indicated 'Reliable

[2] Do-it-yourself companies supply the equipment that the householders need to renovate the house.

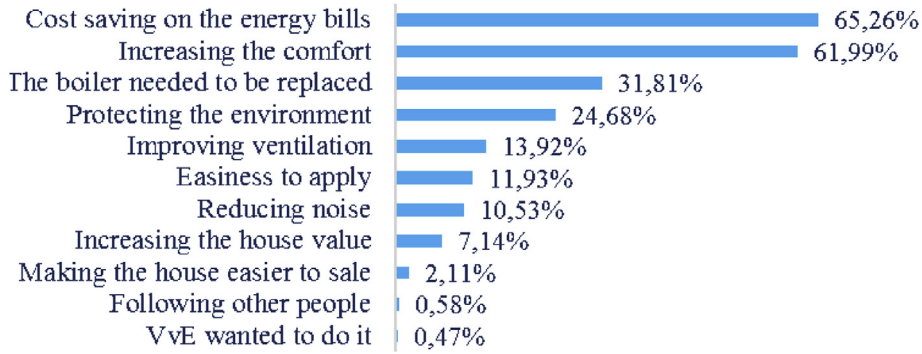

Fig. 6. The renovator drivers toward energy efficiency renovations.

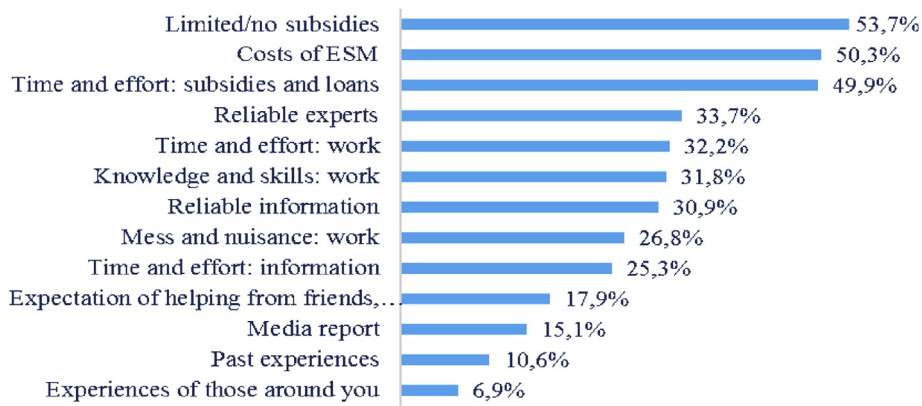

Fig. 7. The renovator barriers toward energy efficiency renovations.

experts' and 35% indicated 'Reliable information: DIY-companies' as barriers towards renovation. Although 58% of the respondents indicated limited/no subsidies as a barrier, 87% of the renovators paid themselves for the EERs. This might be due to the complicated and time-consuming process of acquiring subsidies by renovator, such that most of the renovators prefer to pay for EERs rather than applying for available subsidies. The homeowners that renovate their houses by a specialised company/expert and themselves/acquaintances are respectively 5.10 and 2.21 more probable to renovate their houses in comparison to the ones that did not implement the EERs by these agents.

4.2. Potential renovators

Similar analysis is conducted for the potential renovators. First, the statistical analysis is done to find out the overall ranking of the drivers and barriers, and then the significance of these barriers and drivers are investigated by regression analysis.

4.2.1. Statistical analysis

4.2.1.1. Drivers. Similar to renovators, 'Gaining financial benefits', 'Enhancing the quality of life', and 'Environmental concern' substantially motivate the potential renovators. More specifically, the main identified drivers are 'Cost saving on the energy bills', 'Increasing the comfort', and 'Protecting the environment'. The potential renovators insist on 'Cost saving on the energy bills' as the primary driver with the 78% votes. The least important ones are 'Decision by homeowner association (VvE)', 'Following other people in the neighbourhood', and 'Selling house easier' (Fig. 9).

4.2.1.2. Barriers. The main barriers are 'Costs of energy saving measures', 'Limited/no subsidy' and 'Time and effort: apply for loans/subsidies'. The least important barriers are 'Other homeowners' experiences', 'past experiences', and 'discouraging by Media' (Fig. 10).

4.2.1.3. Reliability of information by different parties. The most reliable information has been stated the homeowners' association (VvE), the Dutch government and environmental agencies. Regarding the

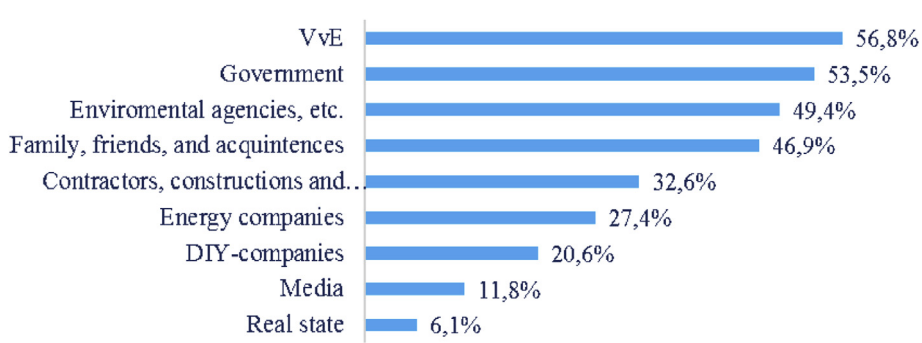

Fig. 8. The ranking of the reliable sources of information by renovators.

Table 11
Logistic regression analysis for the renovators.

Category	X	Y	B	S.E.	Wald	Sig.	Exp(B)
Socio-economic variables	Households & buildings features	Age			12.29	0.01	
		(35–44)	0.907	0.29	9.691	0	2.478
		(45–54)	0.981	0.3	11.04	0	2.668
		(54- older)	0.867	0.31	7.79	0.01	2.381
		Gender (1)	−0.42	0.18	5.642	0.02	1.52
		Multifamily	−1.01	0.29	12.03	0	2.739
		Construction period			98.86	0	
		(1946–1990)	1.068	0.21	26.86	0	2.91
		(1990–2012)	2.678	0.27	98.85	0	14.56
		Income	−0.22	0.11	3.655	0.06	0.805
Drivers	Enhancing quality of life	Increasing comfort	0.879	0.17	25.45	0	2.408
		Reducing noise	1.047	0.43	5.906	0.02	2.848
		Improving ventilation	1.005	0.32	9.639	0	2.731
		Replacing the boiler	−0.83	0.19	19.01	0	0.438
	Financial benefits	Cost savings	0.332	0.18	3.35	0.07	1.394
	benefits	Increasing the house value	0.803	0.44	3.304	0.07	2.232
Barriers	Programme by government	Limited/no subsidies	0.321	0.18	3.266	0.07	1.379
	Credibility of info	Reliable experts	−0.49	0.19	6.937	0.01	0.611
	/expert	Reliable info: DIY C.	−0.6	0.2	8.804	0	0.547
	Work/Process	By me/acquaintances	0.794	0.29	7.648	0.01	2.212
		By a C./expert	1.628	0.31	28.46	0	5.094
	Costs	Costs of ESMs	−1.96	0.79	6.167	0.01	0.142
		Constant	0.765	1.12	0.467	0.21	2.149

information provided by VvE, 64.2% (199) of one family and 65.6% (21) of multifamily in the same building confirmed the reliability of information by VvE (Fig. 11).

4.2.1.4. Implementing energy-saving measures. About 64% of potential renovators have planned to carry out the EERs by transferring to a company/an expert. 36% have aimed to do it themselves.

4.2.2. Regression analysis

Based on the results, type of households, income, and 'Moved in the past 2 years' are statistically significant (Table 12). Regarding the drivers, 'Improving the quality of life' and 'Gaining financial benefits' are the two statistically significant categories. Furthermore, the significant categories of barriers are 'Information', 'Credibility of information/expert', 'Complexities in work/processes' and 'Costs'.

Households that moved in the past 2 years are 2.3 times more likely to renovate than the ones who did not. Respondents that have implied 'Increasing comfort' and 'Improving ventilation' are 4.2 and 3.6 times more likely to plan renovations than the ones who have not indicated this driver. The 'Time and effort: information', 'Reliable information: government', 'Work done: myself/acquaintances', 'Costs of ESMs' are stated as a barrier by 63%, 69%, 68%, 62%, respectively, of potential renovators who will do renovation, respectively.

4.3. Significant factors of the renovators and the potential renovators regarding the renovation decisions in the regression analyses

Table 13 summarises the significant factors in the renovator and the potential renovator regressions. In the discussion, the differences in the renovators and potential renovators' influencing factors are discussed.

5. Discussion of results of statistical and regression analysis

5.1. Comparison of two groups: renovators and potential renovators

This study has attempted to investigate the barriers and drivers of two groups; the renovators and potential renovators through regression analyses. The key difference between these two regression analyses are on the drivers and barriers:

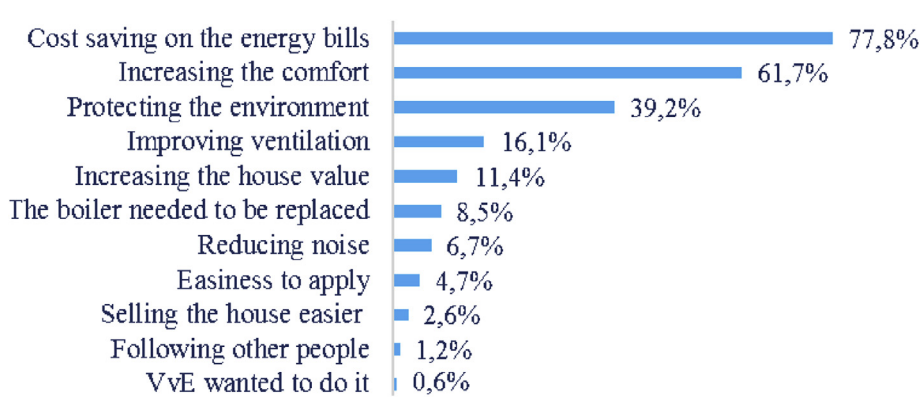

Fig. 9. The potential renovator drivers towards energy efficiency renovations.

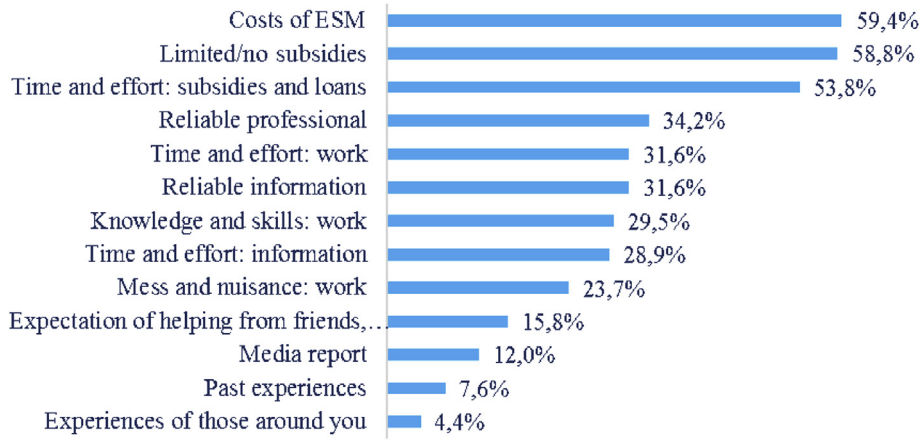

Fig. 10. The potential renovator barriers towards energy efficiency renovations.

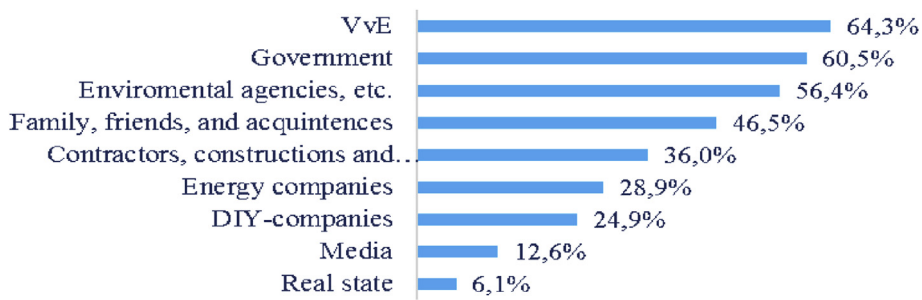

Fig. 11. The ranking of reliable sources of information by potential renovators.

(a) The main identified categories of drivers are 'Enhancing the quality of life' and 'Gaining financial benefits for both groups. These drivers are similar to the study by (Aune, 2007) and (Mlecnik and Straub, 2015). The main identified categories of barriers are 'Lack of reliable expert and information', 'Complexities in carrying out the renovations' and 'Cost' for both groups. Additionally, 'Lack of financial support from public authorities' is identified essential for renovators and 'Information barrier' is identified significant for potential renovators.

(b) The insignificant categories of drivers are 'Technical benefits', 'Environmental concern', 'Experiences of other people' for both groups. The insignificant categories of barriers are 'Past experiences' and 'Lack of support and help from family, friends, and acquaintance' for both groups.

5.2. Insights from behavioural and transaction cost factors

The behavioural and transaction cost factors are important in the homeowner renovation decision. Firstly, the behavioural aspects directly influence the renovation decision. The cognitive awareness, which can be determined by the decision-makers features, such as age, and education. Based on the findings of earlier studies, the consumer

Table 12
Logistic regression analysis for the potential renovators.

Category	Main	Y	B	S.E.	Wald	Sig.	Exp(B)
Socioeconomic variables	Households & buildings features	Household composition			7.634	0.02	
		Couple (1)	−1.17	0.45	6.701	0.01	0.312
		Couple children (2)	−1.13	0.43	6.902	0.01	0.323
		Income	0.598	0.32	3.614	0.06	1.819
		Will move	0.847	0.43	3.903	0.05	2.332
Drivers	Enhancing quality of life	Enhancing comfort	1.38	0.25	29.55	0	3.976
		Improving ventilation	1.813	0.52	11.98	0	6.127
		Boiler replacement	−1.33	0.34	15.04	0	0.264
	Financial benefits	Increasing house value	1.057	0.48	4.925	0.03	2.877
Barriers	Info	Time and effort: information	0.525	0.3	3.093	0.08	1.69
	Credibility of info/ expert	Reliable information: environmental agencies.	−0.62	0.35	3.098	0.08	0.538
		Reliable information: government	0.802	0.33	5.925	0.02	2.231
	Work /Process	Mess & nuisance: work	−0.54	0.31	3.027	0.08	0.585
		Will be performed by myself acquaintances	0.723	0.29	6.28	0.01	2.061
	Costs	Costs of ESMs	0.494	0.26	3.566	0.06	1.639
		Constant	−9.3	3.25	8.187	0	0

Table 13
Significant factors for renovators and potential renovators regarding the decision-making for renovations.

Factors	Renovators	Potential renovators
Socio_demographic factors	*Household & building features:* - Household types - Income - Age - Gender - Construction period	*Household & building features:* - Household types - Income - Construction period
Drivers	*Enhancing the quality of life:* - Increasing comfort - Improving ventilation - Boiler replacement - Reducing noise *Gaining financial benefits:* - Cost savings - Increasing the house value	*Enhancing the quality of life:* - Increasing comfort - Improving ventilation - Boiler replacement *Gaining financial benefits:* - Increasing the house value
Barriers	*Costs of energysaving measures:* - Cost of ESMs *Program by government:* - Limited_no subsidies *The Credibility of info/expert:* - Reliable experts - Reliable information: - DIYcompanies *Work/Process:* - By myself/acquaintances - By a company/expert	*Costs of energysaving measures:* - Cost of ESMs *The Credibility of info/expert:* - Reliable info: environmental agencies. - Reliable info: government *Work/Process:* - By myself/acquaintances - Mess and nuisance: work *Information barriers:* - Time & effort: information

behaviours are predominantly determined by cognitive biases, heuristics and other irrational variables. For example, finding an alternative to reduce complexity, consumers prefer greater certainty over higher risk with higher values, and when faced with a decision, they are strongly dependent on the people around them.

TCs explain the indirect costs due to the transactions with external parties or distribution channels, for instance, to find information, experts, etc. In the analysis, transaction cost factors are categorised into: a) Time and effort to find information, to apply for loan and subsidies, and to conduct the renovation; b) Difficulty in finding reliable information and experts; and c) Complexities in acquiring knowledge and skills for renovation and disruption of normal life during the renovation.

The influencing factors determine the renovation process at different stages. The socio-demographic factors (e.g., age, income, education) are more critical in the initial stages. For example, it might be easier for educated people to acquire the required knowledge, and skills to execute the process or higher income group has more possibility to invest in EERs (Schleich, 2019). The drivers (e.g., enhancing comfort) play roles in the persuasion phase and of changing the perceptions of homeowners regarding EERs (Murphy, 2016; Stieß and Dunkelberg, 2013; Wilson et al., 2018).

TCs hinder the EER processes at different stages. Initially, asset specificity is essential, while in later stages, the uncertainties in the decision-making process, such as the expected benefits and, finding reliable information, and expertise, all influence the renovation decision. Given better conditions to reduce these uncertainties, whether or not homeowners have experiences in energy-efficiency renovations, the uncertainties and the transaction costs decrease. The importance of these factors are identified using the statistical and regression analysis:

(a) Based on the statistical analysis, the monetary costs, lack of subsidies and loans are the most important barriers. The time and effort to apply for subsidies is the third important barrier. Therefore, it can be concluded that the financial factors are the most important barriers for the renovators and potential renovators. Beside monetary costs, the TCs are also identified as determining barriers (e.g., Difficulty in finding reliable expert and information, time and effort in conducting the work and finding information).

(b) Based on the regression analysis, the lack of reliable experts and information, time and effort to find information, and complexities in work/process are all identified as critical influencing factors in renovation decision.

Table 14
The Dutch policies & initiatives addressing the barriers & drivers.

Underlying hypothesis	Barriers & drivers
Providing financial supports	Financial drivers
Informing advantages of renovations	Aiming at all drivers
Removing the current obstacles and barriers	Aiming at all barriers
Informing in using more efficient material	Information & cost barriers
Helping in finding reliable energy providers	Reliable experts
Reducing the complexities by new approaches, applying for loans/subsidies	Work/process barriers

5.3. Insights for policies and private/public-private initiatives

Table 14 shows the barriers and drivers that are included in the policies and private/public-private initiatives. Based on Table 14 and comparing it with Tables 3 and 4 (barriers & drivers), the essential policies and other initiatives are covered to facilitate the renovation process in the Dutch owner-occupied sector, such as providing the financial support, helping homeowners to find reliable energy providers. The findings are similar to those in the previous studies by (Murphy et al., 2012; Tambach et al., 2010).

The following policies implications require attention:

The results of the statistical and regression analysis (section 4) have shown the importance of the trans-action cost barriers. Referring to Tables 1 and 2 on the existing policies, there are fewer policy programs that focus on eliminating these types of barriers compared to for instance policies that are focused on financial barriers. Lack of reliable information is also one of the main barriers. Based on the statistical analysis, about 30% of homeowners have stated the importance of this barrier and this factor also was significant in the regression analysis. This means that policy instruments especially should aim at tackling these types of barriers. In this respect it is not only important to provide homeowners with reliable and tailor-made information about solutions and their effects (possible savings and comfort improvements, but also to support and guide them throughout the renovation process (including finding a loan or subsidy and a contractor and installer).

Current and newly emerging policy instruments in the Netherlands contain interesting ingredients to overcome the barriers mentioned above. The 'Energy Saving Explorer',[3] developed by energy providers, is a good example. Also, many Dutch municipalities (more than 200) have installed energy desks (energieloket.nl) where homeowners can get information and tailor-made advice about the ways the energy efficiency and the comfort of their dwellings can be improved. Municipalities, construction companies and installers often collaborate and join forces in the energy desk initiatives so that homeowners also can get practical advice about technical measures and products in an accessible way.

Other interesting developments in this regard are the deployment of one stop shops or pop-ups to create awareness and to support

[3] The aim is to calculate the potential energy saving of householders by the financial support system.

homeowners during the process to improve the energy performance and comfort in their dwellings. These initiatives can not only be found in a growing number of Dutch municipalities, but also in neighbouring countries (Meijer et al., 2018).

These one stop-shops could pop-up in certain specific neighbourhoods and could also address the specific needs and wishes of individual homeowners. Although the lack of awareness, the absence of sufficient knowledge and information and the lack funding can generally be seen as the main barriers to undertake energy efficiency measures. Every homeowner is also confronted with its own individual and personal barriers that largely are related to their household, and dwelling characteristics and their personal beliefs and convictions. The first experiences of pop ups in Dutch cities as The Hague and Rotterdam show that the communication via one stop shops and pop-ups could have influence on the decision-process of the homeowners. Subsequently the homeowners are supported throughout the complete process to improve the energy performance and comfort levels of their dwelling.

6. Conclusions and policy implications

The current study contributes to identify the drivers of and barriers to Energy Efficiency Renovations (EERs), including an empirical analysis of Dutch homeowners' decision-making processes. The theoretical analysis categorised the influencing factors into: policies and private/public-private initiatives, behavioural factors, and transaction cost factors. The household renovation decision is complex and in this study, the aim was to explain the decision by using the main influencing factors derived from behavioural research. If the main behavioural aspects could be identified, the householder behaviour can be influenced by designing more comprehensive policies covering all these factors. Both the policymakers and practitioners often neglected these aspects when attempting to stimulate the energy efficiency renovations. The Transaction costs (TCs) can negatively affect the performance of policy instruments which aim to promote energy efficiency renovations (Mundaca T et al., 2013). The policies and initiatives, such as the energy saving explorer, One-stop-shop, and energieloket, can contribute in reducing the TCs.

After demonstrating the influencing factors, the relative importance of these factors was investigated using a regression analysis in the Dutch owner-occupied sector. The following policies are recommended to facilitate the upscaling of EERs both in terms of more renovators and deeper types of EERs:

(a) Enhancing the quality of life (e.g., increasing thermal comfort) is a more important factor in the householder decision-making processes (e.g., the renovators who chose “Increasing comfort” were 2.4 times more likely to renovate compared to those who did not choose this specific driver.). The policies should be designed so as to increase the awareness of householders regarding the impacts of EERs and their direct influence on the quality of their life in terms of comfort, and improving health conditions by better ventilation, and by reducing condensation.
(b) Based on the statistical and regression analysis, limited/no subsidies and the costs of EERs were identified as significant and very important barriers. A huge amount of financial supports are provided by the Dutch government (e.g., the National Grant Scheme More with Less (DutchGovernment, 2011)). However, the lack of financial supports are still perceived as an important barrier for the householders. The issue can be connected to other obstacles (e.g., complexity in applying for loans/subsidies, householders unawareness, and the unequal distribution of the subsidies and grants among householders). Therefore, in assigning the grants and subsidies, the policy makers might consider complementary policies, such as comprehensively informing the householders regarding the availability of loans and subsidies, and reducing the complexities in accessing subsidies and loans.
(c) The outcomes regarding TC barriers, e.g. reduction of information barriers, reliability of experts and information could be very useful for the policy-makers. The time and effort spent in finding information, and the reliability of information and experts were identified significant and important barriers. Policy-makers might need to invest more on provision of information and connecting the right information hubs and agencies to the householders. Additionally, the main reliable sources of information were identified (e.g., homeowners' associations and environmental agencies). The policies might consider these agents in distributing information.
(d) The current Dutch policies need to take all of the relevant factors into account, such as reducing complexities in the process, reducing the time needed to apply for loans and subsidies, and facilitating access to information. The similar results are concluded to a study in Germany (Baginski and Weber, 2017) in which homeowners also used several decision-making criteria that diminish the importance of monetary factors. Besides that it is important to rethink what should be the best way homeowners could be reached, approached and supported. It is in this respect predominantly acknowledged that, instead of a common national policy approach, an approach is needed that is based on the local level (e.g. in municipalities and its neighbourhoods). A policy that aims to change the individual behaviour of owners should after all take into account the requirements, needs and abilities of these homeowners.
(e) Whether the policy-makers use the outcomes of this paper is also important. More householders might have actual willingness to renovate their houses towards more efficiency, but only if they are fully aware of the help on offer. Additionally, whether the benefits and consequences of different renovations, such as the insulation of the facade, are made clear to the householders, it might lead to a deeper consideration of energy efficiency renovations.

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Appendix A. WOON Energy Module 2012

Appendix A.1. Description

WOON energy module database enables answering questions about energy labels, energy savings in the dwelling stock, the influence of the behaviour of residents and investments in energy-saving measures. A survey is conducted including 87 questions and focuses on the energy efficiency of the dwelling sector. It consists of the following parts:

– Part 1: Dwellings and households' characteristics (10 questions)
The questions are about the household composition, age, tenure status, living period, number of occupant, hours at the house during the day, and how often households are at home.

– Part 2: Heating and ventilation (10 questions)
The questions are about temperatures in the living room in the presence and absent of occupants, average temperature during the heat season, setting of the temperature on the thermostat for a weekday during the heat season, ventilation of living rooms/other rooms during the heat season.
– Part 3: Energy and water (7 questions)
The questions are about energy source for cooking, number of cooking hot meals, shower time and number per week, water saving shower.
– Part 4 Energy saving (10 questions)
The questions are about energy saving activities, gas and electricity consumption, comparison of energy consumption with others, perception of energy efficiency by the households, the importance of energy efficiency behaviour, barriers to energy efficiency renovations, reliability of sources of information, pleasant of the house.
– Part 5 Investments in the house (29 questions)
This section contains questions about investments that have been made in the house in the past five years. Then questions are asked about the possible investment plans for the next two years. Two types of investments are distinguished:
(a) Housing maintenance - improvement and/or expansion such as exterior painting, facade repairs, installation of an extension, conservatory or dormer.
(b) Energy efficiency renovations such as insulation, double glazing, replacement heating boiler or installing solar panels.

The householders replied to the questions, such as if they have done/will do a renovation, the type of investment, their motivations (maximum three reasons), who paid and did the work, the amount of subsidies, the role of subsidies in their decision, the actual cost, are For each type of investment.

– Part 6: Leaking roofs and wood consumption (19 questions)
A number of questions are asked about the roof of the house or storage space.

The WOON energy module consists of 1112 variables.

Appendix A.2. Variables in this research

Table A.15
Variables in this research

Part	Title	Question
1	Dwellings and households characteristics	Household composition, age, tenure status, number of occupant, construction period, type of the building
4	Energy saving	Barriers to energy efficiency renovations (EERs) (To what extent would the following barriers discourage you from EERs?)
		Reliability of sources of information (How reliable are the following sources of information for the EERs?)
5	Investment: EERs	Whether they have done/will plan to do the EERs
		The motivations on energy efficiency renovations
		Who has done/paid for the EERs
		Who will do/pay for the EERs

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