Energy Research & Social Science 111 (2024) 103484

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

# Are Dutch homeowners willing to invest in sustainable heating systems? Comparing intentions and determinants in four scenarios

Menno D.T. de Jong *, Remco Pieterse, Sikke R. Jansma

*University of Twente, Faculty of Behavioural, Management and Social Sciences, Department of Communication Science, Cubicus Building, P.O. Box 217, 7500 AE Enschede, the Netherlands*

ARTICLE INFO

*Keywords:*
Climate change
Energy transition
Homeowners
Natural gas-free
Sustainable heating

ABSTRACT

The energy transition, replacing fossil fuels with renewable energy, requires everyone's efforts to succeed. In the Netherlands, homeowners are expected to invest in sustainable heating. This article describes a cross-sectional survey among Dutch homeowners ($N = 302$) investigating determinants of their intentions to make such investments. Unlike earlier research, this study problematized the concept of investment intentions, assuming that intentions and determinants might vary between different investment scenarios. Four scenarios were distinguished: (1) long-term *status quo* intentions, (2) short-term *status quo* intentions, (3) intentions in the case of higher natural gas prices, and (4) intentions in the case of government support. The results show that homeowners' investment intentions differed significantly between the four scenarios: Government support led to the highest intentions, followed by, respectively, long-term *status quo* intentions, intentions in the case of higher gas prices, and short-term *status quo* intentions. Furthermore, the behavioral determinants differed considerably between the scenarios. The overall conclusion is that strategies to promote homeowners' investments in sustainable heating must be aligned with the scenarios foreseen. For each scenario, our study lists determinants that could be emphasized.

## 1. Introduction

The world is fighting climate change. In line with the Paris agreement, countries must replace fossil-based energy systems with renewable energy [1]. To achieve its sustainability aims, the Dutch government focuses, among other things, on retrofitting homes and other buildings with sustainable heating systems before 2050. Due to natural gas reserves in the province of Groningen, the Dutch energy system has a large share of natural gas: In 2019, 92 % of the households used natural gas for heating [2]. Households account for 9 % of the Dutch $CO_2$ emissions [3]. The most prominent alternatives for natural gas-based heating systems are heat pumps and district heating [4].

Homeowners thus play an important role in the energy transition [4,5]. They can significantly lower the Dutch $CO_2$ emissions. However, the transition is a major technological and societal challenge, requiring substantial efforts of all involved. National, regional, and local governments must get homeowners on board. Many homeowners choose to wait and see before seriously considering large investments [5–7]. They are not sure whether the government will really live up to its ambitions, have doubts about currently available sustainable solutions, hesitate about costs and benefits of sustainable heating, and hope for government subsidies.

Many studies in various national contexts have investigated homeowners' and other citizens' willingness to invest in sustainable energy solutions (see [8] for an overview). Intentions and behaviors studied ranged from generic (e.g., energy-saving activities; [9]) to specific (e.g., particular heating systems; [10]). The research has identified many potential determinants of sustainable intentions and behaviors. However, the concept of willingness to invest in sustainable solutions has thus far not been problematized: How do long-term and short-term intentions relate to each other and what is the possible influence of rising energy costs or government support?

To address these issues, we compared Dutch homeowners' intentions to invest in sustainable heating systems in four different investment scenarios: short-term and long-term *status quo* situations, as well as situations of higher natural gas prices and government support. We not only compared differences in homeowners' intentions, but also zoomed in on the salience of determinants in the four scenarios. Our research question is: To what extent and how does Dutch homeowners' willingness to invest in sustainable heating systems relate to the proximity of

* Corresponding author.
*E-mail addresses:* m.d.t.dejong@utwente.nl (M.D.T. de Jong), remcopieterse@icloud.com (R. Pieterse), s.r.jansma@utwente.nl (S.R. Jansma).

https://doi.org/10.1016/j.erss.2024.103484
Received 8 February 2023; Received in revised form 30 January 2024; Accepted 15 February 2024
Available online 24 February 2024

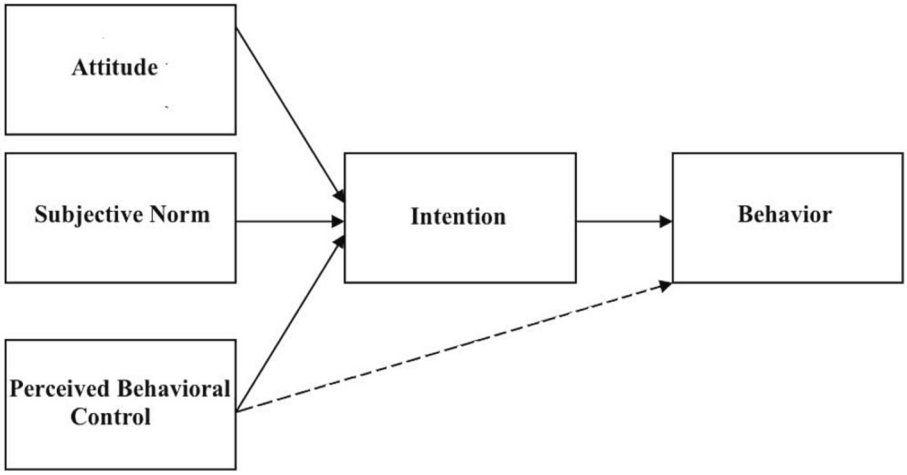


**Fig. 1.** Theory of planned behavior.

the investment decision (short-term vs. long-term) and possible external influences (rising natural gas prices or government support)? Earlier studies predominantly investigated determinants of sustainable intentions in one particular scenario or compared the intentions and determinants of different groups of citizens. This study compares, within a nonrepresentative sample of Dutch homeowners, how investment intentions regarding sustainable heating may depend on different investment scenarios and to what extent the salience of determinants of these investment decisions may differ between the scenarios.

## 2. Literature review

Below, we first discuss earlier research on the transition toward sustainable heating systems. We then briefly introduce the theory of planned behavior (TPB) as our theoretical framework, describing its three antecedents (attitude, subjective norm, and perceived behavioral control). After that, we zoom in on beliefs that may underly homeowners' attitudes. Finally we present our research model.

### 2.1. Earlier research

Earlier studies on the Dutch transition toward sustainable heat focused on homeowners' attitudes [5–7]. Scholte et al. found 49 % of the homeowners in favor, 16 % neutral, and 27 % against transitioning toward sustainable heat; 8 % had no opinion [5]. Homeowners generally acknowledged the urgency of climate change and the need to reduce $CO_2$ emissions, but were nonetheless reluctant to contribute themselves. They waited for the right moment, wanted to be sure of making the right decision, anticipated technological developments or lower costs in the future, and/or wanted to be sure the government will indeed maintain its sustainable policies [7]. Jansma et al. found no differences in attitude toward becoming natural gas-free between homeowners living in a neighborhood receiving government subsidy for becoming sustainable and those living in a neighborhood without such subsidy [6]. This might indicate that government support not necessarily results in more positive attitudes. These studies show that Dutch homeowners' attitude toward the transition to sustainable heating is divided. While most agree with the energy transition, many have a wait-and-see attitude.

People's intentions to make sustainable investments have been investigated using various theoretical and methodological approaches. One such approach is agent-based modeling, a computational technique explaining renewable energy adoption using a relatively limited number of predictors [11,12]. These studies confirm that economic considerations and social dynamics play an important role; in addition, the hassle factor [11] and psychological variables [12] appeared to be relevant. Another approach involves experimental research, which can be subdivided into discrete-choice experiments and traditional experiments. Discrete-choice experiments focus mostly on the influence of (combinations of) contextual, economic, and technical variables on adoption or willingness to pay; behavioral determinants only play a subordinate role [10,13–16]. Traditional experiments investigate the effects of limited sets of variables, such as public information [17], framing [18,19], and renewability of energy [20]. Hai [21] used a qualitative interview approach to intrinsically distinguish groups of Finnish people based on their willingness to adopt solar energy (from adopters to non-adopters, with more nuanced positions in between). Karytsas and Choropanitis [22] conducted a principal component analysis of survey data to make sense of barriers that complicate people's adoption of renewable energy and inventory diffusion actions that could solve them.

The majority of the research, however, uses survey data to explain people's willingness to invest in sustainable innovations [9,23–38] or to compare adopters and non-adopters [39–41]. Several studies used pragmatic constructs. In studies with a theoretical angle, the TPB was most prevalent [9,27,30–32,36,38]. Other theoretical perspectives were the motivation-opportunity-ability framework [29], attitude-behavior-context theory [35], and expectancy theory [40]. Studies using the TPB generally confirmed the usefulness of this approach for research into energy innovations, with considerable proportions of explained variance and significant roles for the three antecedents.

Although the available studies did not differentiate between the four scenarios we used, they underlined the possibility that the weights of determinants might be contextual: they appeared to vary between different products [10,23,26,35], between groups who had adopted, only planned to adopt, and did not plan to adopt energy innovations [39,40], and between national contexts [32].

In all, the available research is diverse. The studies involved different national contexts, focused on different sustainable solutions, varied in dependent variables, and used different sets of potential determinants. The studies proposed various potential determinants that may be considered. The TPB appears to be suitable for systematically investigating determinants of investment intentions.

### 2.2. Theory of planned behavior

The TPB (Fig. 1) aims at explaining or predicting people's non-routine behaviors [42]. According to the TPB, people's behaviors can be explained by their behavioral intentions, although many things might prevent them from translating intentions into actual behavior. Behavioral intentions, in turn, are explained by three determinants: attitude, subjective norm, and perceived behavioral control. The latter may also directly affect people's behavior.

The TPB has been used in many different studies, particularly when it is reasonable to assume that people more or less consciously decide about their behaviors; it is not suitable to investigate non-rational or routine behaviors. Homeowners' investment intentions clearly fall within the scope of TPB, as they involve impactful and complex one-time decisions. Meta-analyses show that the TPB explains substantial proportions of the variance (20–50 %) in people's behavioral intentions [43,44].

*Attitude* refers to the degree to which homeowners have positive or negative overall evaluations of investing in sustainable heating, weighing all relevant beliefs about its pros and cons. Attitudes are considered pivotal in explaining and predicting human behavior [42]. Several studies confirmed the importance of attitude for explaining intentions [9,27,30–32]. This leads to the following hypothesis:

**H1**. Attitude toward investing in sustainable heating is positively related to homeowners' investment intentions.

*Subjective norm* involves the influence other people have on homeowners' intentions to invest in sustainable heating. When people in their social circle have favorable opinions, already invest in sustainable heating, or encourage them to do so, homeowners may be more inclined to invest themselves. Earlier research confirmed the relevance of subjective norm [9,27,30–32,38]. Specifically for decisions about heating equipment, several studies drew attention to a special type of social influence: Heating installers, who visit households on a regular basis for service contracts and repairs, might also affect homeowners' intentions to invest [45–51]. They are seen as trustworthy, independent, and accessible experts and are therefore an important source of information about sustainable investments [52]. They may have favorable or unfavorable professional views on sustainable heating. A less favorable view might be that the technology is still developing and that better and cheaper products will become available in the future [47]. This leads to the following two hypotheses:

**H2a**. Subjective norm (social circle) is positively related to homeowners' investment intentions.

**H2b**. Subjective norm (heating installers) is positively related to homeowners' investment intentions.

*Perceived behavioral control* refers to homeowners' self-estimated ability to actually make investments in sustainable heating. It involves factors that may promote or hinder the behavior, often related to skills, resources, and obstacles [42]. Earlier research confirms the relevance of perceived behavioral control [9,27,30–32,38]. A precondition mentioned in the literature involves financial resources. If homeowners think they may have the required resources, their investment intentions will be higher [28,38,40]. A second factor is knowledge. Decisions about sustainable investments involve many complexities and uncertainties. Having access to trustworthy information and being able to oversee all relevant aspects are important for homeowners to confidently make investment decisions. Ozaki, for instance, found that access to information about green technologies correlated positively with people's intention to adopt green tariffs [53]. Two hypotheses regarding perceived behavioral control were formulated:

**H3a**. Perceived behavioral control (financial resources) is positively related to homeowners' investment intentions.

**H3b**. Perceived behavioral control (knowledge) is positively related to homeowners' investment intentions.

### 2.3. Beliefs underlying attitude

For more specific insights in factors related to homeowners' investment intentions, we inventoried beliefs underlying their attitude. Earlier literature (see [8] for an overview) identified and investigated a multitude of potential beliefs that could be considered. We prioritized beliefs that involved the main reason for the energy transition, the value that sustainable heating systems may bring for homeowners, and a policy perspective. Eventually we distinguished four groups of beliefs: environmental concern, potential costs and benefits of having sustainable heating, potential drawbacks of adopting sustainable heating, and trust in the nationwide energy transition.

#### 2.3.1. Environmental concern

A first underlying belief involves homeowners' *environmental concern*. Although there are detailed and multidimensional conceptualizations of environmental concern [54–56], we used a generic definition: "the extent to which people feel responsible for the environment and are willing to take actions" [6,p.3]. If homeowners are aware of the environmental challenges and their personal responsibilities, they will be more inclined to invest in sustainable heating. Earlier research has shown the impact of environmental concern on attitudes and intentions regarding sustainability and the energy transition [6,10,26,28,37,38,57,58]. This leads to the following hypothesis:

**H4**. Environmental concern is positively related to homeowners' attitude toward investing in sustainable heating.

#### 2.3.2. Potential costs and benefits of having sustainable heating

Three types of potential costs and benefits of sustainable heating were distinguished: environmental impact, utilitarian advantages, and hedonic (dis)advantages. *Environmental impact of sustainable heating* involves the extent to which homeowners expect that investments in sustainable heating will really make a difference for the environment. Environmental impact is an important reason for considering and adopting sustainable heating systems and several studies indeed found evidence that it affects people's attitude or intentions regarding sustainable purchases [16,20,31,58,59]. This leads to the following hypothesis:

**H5**. Environmental impact of sustainable heating is positively related to homeowners' attitude toward investing in sustainable heating.

*Utilitarian advantages* refer to the practical and monetary benefits sustainable heating systems might bring for homeowners. Benefits may involve monthly energy costs, the value of their homes, safety perceptions, or feelings of being future-proof. Economic gains and independence from fossil fuels are reasons for adopting renewable energy systems and have been shown to positively affect attitude and intentions regarding energy innovations and energy-efficient products [10,16,32,40,59–61]. The following hypothesis was formulated:

**H6**. Utilitarian advantages are positively related to homeowners' attitude toward investing in sustainable heating.

*Hedonic (dis)advantages* refer to affective aspects of sustainable heating, relating to feelings of warmth and comfort that heating systems are supposed to bring. This is a disputed feature. Some people have negative expectations regarding living comfort. Heat pumps may produce noise and occupy relatively much space; others fear that it may be hard to reach comfortable temperatures in winter [6]. This would be problematic, as comfort is one of the top drivers for adopting renewable energy systems [20,28,39,40,61–63]. We formulated the following hypothesis:

**H7**. Hedonic advantages and a lack of hedonic disadvantages are positively related to homeowners' attitude toward investing in sustainable heating.

#### 2.3.3. Potential drawbacks of adopting sustainable heating

Potential drawbacks of adopting sustainable heating systems are initial purchase costs and expected inconveniences. *Initial purchase costs* involves homeowners' views on the amount of money needed to buy sustainable heating. We already included costs under perceived behavioral control, referring to homeowners' ability to invest. It seems

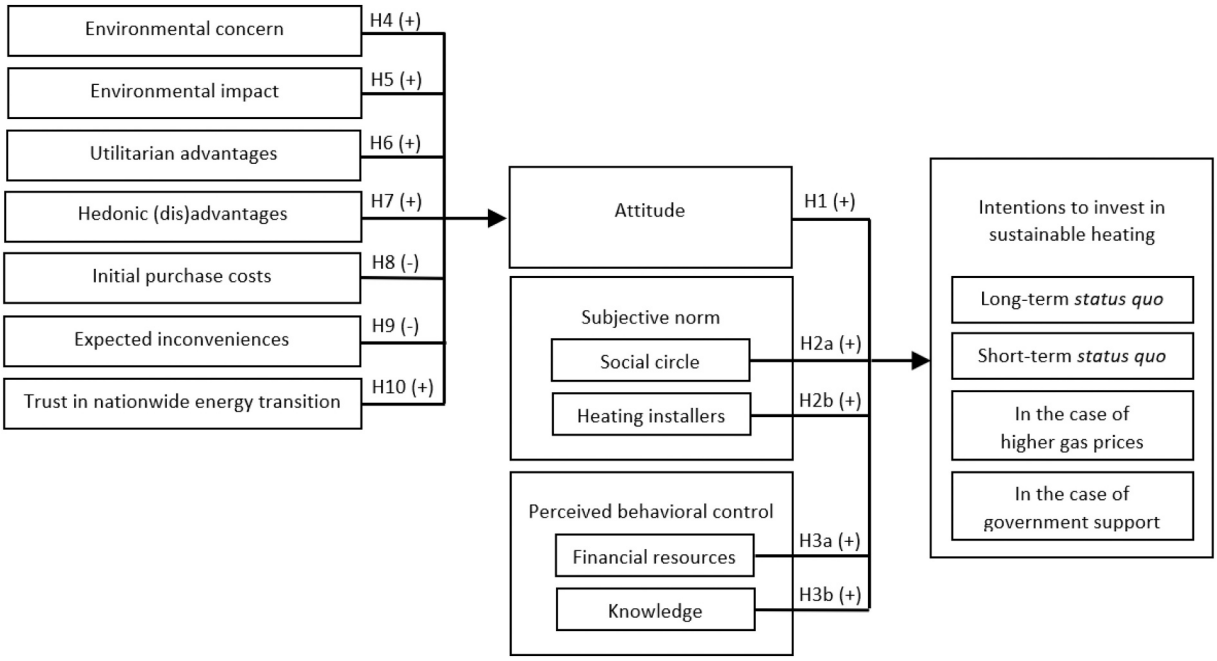


**Fig. 2.** Initial research model.

important, however, to also include perceptions of the reasonableness of the costs and willingness to invest. In the Netherlands, initial purchase costs appear to be the largest concern among homeowners [7]. Depending on the type of home, retrofitting with a sustainable heating system requires an investment between 7000 and 40,000 euros, with a payback period from 16 to 95 years [64]. Even among homeowners who can afford it, such amounts may still be seen as an important drawback of adopting sustainable heating systems [22,24,29,32,34]. This leads to the following hypothesis:

**H8**. Initial purchase costs are negatively related to homeowners' attitude toward investing in sustainable heating.

*Expected inconveniences* involve homeowners' expectations of the invasiveness of installing sustainable heating systems. Installing such systems may cause problems and disruptions in daily life [61]. Common inconveniences during the installation may negatively affect sustainable home renovations [28,65]. De Vries et al. [66] drew attention to the "hassle factor," assuming that obstacles and inconveniences in the process from considering sustainable measures to having them installed may negatively affect homeowners' attitudes and intentions toward investing. Such inconveniences may include finding the right suppliers and scheduling the renovation [67], administrative paperwork [68], and major home renovations [28]. We therefore formulated the following hypothesis:

**H9**. Expected inconveniences are negatively related to homeowners' attitude toward investing in sustainable heating.

#### 2.3.4. Trust in the nationwide energy transition

The transition to sustainable heating is a government-initiated process that is planned to take place in almost thirty years. Considering the comprehensiveness and longevity of the transition and the dynamics of national and international politics, homeowners' *trust in the nationwide energy transition* might play a role in their attitude toward investing in sustainable heating: Do homeowners expect that the requirement to be natural gas-free will indeed be maintained by 2050? Will the government continue to be committed to the energy transition and will it be able to realize its ambitious plans? Earlier research showed that people do not entirely trust the government as a driving force behind the energy transition [7] or in related policy areas such as pollution [69]. Jansma et al. came to similar conclusions on the municipal level: Homeowners questioned municipalities' intentions and abilities to keep the local energy transition on track and their trust in the local government was positively related to their attitude toward the transition [6]. This is supported by Scholte et al., who argued that policy goals and trust in the people behind them are crucial for supporting a transition toward sustainable heating [5]. We therefore formulated the following hypothesis:

**H10**. Trust in the nationwide energy transition is positively related to homeowners' attitude toward investing in sustainable heating.

### 2.4. Initial research model

Fig. 2 summarizes the initial research model of our study. Our research was limited to homeowners' investment intentions; actual investments were beyond the scope of the study. We used four scenarios as dependent variables: short-term and long-term *status quo* investment intentions and intentions in the case of higher natural gas prices and government support. At the center of the model are the three TPB variables (attitude, subjective norm, and perceived behavioral control), some subdivided into two separate variables. On the left, we included the seven beliefs underlying homeowners' attitude toward investing in sustainable heating.

## 3. Method

To investigate the relationship between the various determinants and homeowners' investment intentions in four scenarios, we conducted an online survey among Dutch homeowners. The study was approved by the ethics committee of the University of Twente (file number 211350). Below we outline the details of the research.

### 3.1. Respondents

Only homeowners living in the Netherlands could participate. Respondents were recruited in four ways: (1) via social media posts on Facebook, LinkedIn, and Instagram, (2) via messages in Facebook groups distributing links to surveys, (3) via emails among employees of a

network operator, and (4) via snowball sampling (asking respondents to forward the survey link to other homeowners they knew).

In total, 382 people started filling out the questionnaire. Of them, 26 did not finish, 35 were not homeowners, and 19 already lived natural gas-free. These respondents were excluded, leaving 302 respondents for further analysis. Respondents were aged between 20 and 84 years old (mean = 43). The male-female ratio was almost in balance (52–48 %). Most respondents lived in the province of Zuid-Holland (40 %), followed by Overijssel (37 %), and Utrecht (15 %). The types of homes they had varied, with terraced houses (30 %), semidetached houses (21 %), corner houses (20 %), and apartments (19 %) as most frequently mentioned categories. Most of their homes were built between 1961 and 1980 (33 %), followed by 2001–2021 (21 %), 1981–2000 (18 %), and 1941–1960 (15 %). Their political orientations largely corresponded to the 2021 seat distribution in the House of Representatives. Respondents estimated that their heating system needed replacement within four years (20 %), between five and nine years (48 %), or in ten or more years (32 %).

In all, our sample had a good variety in terms of personal and property characteristics. However, due to its size and sampling procedure, it cannot be a representative sample of all Dutch homeowners. Although some variables aligned with the characteristics of the population (gender, political preference), others were clearly skewed (geographical location). However, it should be noted that our main research purpose was to make within-subjects comparisons of intentions and determinants.

### 3.2. Procedure

The online survey started with an introduction, stressing that participating was voluntary and anonymous, after which respondents were asked for informed consent. Then two questions were asked to ensure they belonged to the research population (being a homeowner and not already living natural gas-free). After that, respondents answered background questions about themselves and their homes. The lion's share of the questionnaire focused on, respectively, respondents' behavioral intentions, the three TPB variables, and the underlying beliefs. At the end of the questionnaire, respondents could leave their email address if they wanted to receive a summary of the findings. Finally they were thanked for their cooperation. The survey took on average 11 min to complete. Data were collected between December 1, 2021 and January 7, 2022.

### 3.3. Measures

The questionnaire was in Dutch and used seven-point Likert scales. Below, an overview is given of the types of items per construct (the examples are translated). An overview of all items can be found in Appendix A.

*Long- and short-term status quo intentions* were measured with two similar sets of four questions. Only the time frame differed: 15 years for long-term and 5 years for short-term intentions. The items were based on [70,71] (e.g., "I am willing to get natural gas-free heating within [15/5] years"). We added one item about the situation in which respondents' current heating system needed replacing.

*Intentions in the case of higher natural gas prices* were measured with a self-developed three-item scale (e.g., "If my energy contract becomes more expensive, I am willing to get natural gas-free heating"). We did not specify the extent to which natural gas prices would rise, leaving it up to respondents' own estimations of what would be possible in this respect. The main reason for this choice is that we were primarily interested in the general idea of higher gas prices; adding a particular percentage would have been arbitrary.

*Intentions in the case of government support* were also measured with a self-developed three-item scale (e.g., "If the government provides more subsidies, I expect to purchase natural gas-free heating"). Again, we did not go into detail regarding the amount of government subsidies or the proportion between costs and subsidies, but instead focused on the general idea of getting government support.

*Attitude toward investing in sustainable heating* was measured using four items based on [72,73], focusing on respondents' overall feelings toward investing in sustainable heating (e.g., "I find investing in natural gas-free heating for my home appealing").

*Subjective norm (social circle)* consisted of two items based on [70], investigating the influence of the views and behaviors of family and friends (e.g., "My family and/or friends think I should switch to natural gas-free heating") and two similar items focusing on respondents' immediate social contacts.

*Subjective norm (heating installers)* was measured using a self-developed four-item scale focusing on installers' opinions about natural gas-free heating and their expected advice on this (e.g., "I think installers of heating systems would advise me to switch to natural gas-free heating").

*Perceived behavioral control (financial resources)* was measured with three items. One was based on [38] ("I have the financial availability to invest in natural gas-free heating"); the other two items were self-formulated.

*Perceived behavioral control (knowledge)* was measured using a self-developed four-item scale focusing on respondents' knowledge and the availability and clarity of relevant information (e.g., "There is enough information available about the possibilities of natural gas-free heating in my home").

*Environmental concern* was measured using eight items based on [6,58,74], focusing on respondents' concerns about climate change and their overall desire to combat it (e.g., "I am worried about climate change").

*Environmental impact of sustainable heating* was measured using four items based on [58,74], focusing on the positive environmental effects of natural gas-free heating (e.g., "By investing in natural gas-free heating I do something against global warming").

*Utilitarian advantages* was measured using a four-item scale based on advantages identified by [61]: lower monthly energy costs, increased home value, safety, and being future-proof (e.g., "Natural gas-free heating leads to cost savings on my utility bills").

*Hedonic (dis)advantages* was measured using a self-constructed four-item scale based on findings by [6,63], including two possible advantages (comfortable heating and better air quality) and two possible disadvantages (the space occupied by systems and the noise they produce) (e.g., "Natural gas-free heating produces a lot of noise").

*Initial purchase costs* was measured using a self-constructed four-item scale, focusing on the absolute costs of purchasing natural gas-free heating systems as well as on relative costs compared to their benefits (e.g., "In general, natural gas-free heating is an expensive investment").

*Expected inconveniences* were measured using two existing items [53], complemented with two self-formulated items focusing on the time, effort, and renovations needed for installing natural gas-free heating systems (e.g., "Major renovations are needed for the installation of natural gas-free heating").

*Trust in the nation-wide energy transition* was measured using five self-formulated items based on findings by [5,7,75], focusing on respondents' estimation of a successful energy transition by 2050 and of the government's determination and decisiveness in this respect (e.g., "The national government will keep its promises to be natural gas-free by 2050").

### 3.4. Scale construction

All items were subjected to two complementary analyses. First, a principal component analysis (with varimax rotation) was used to check the constructs' discriminant validity. The initial analysis showed that the attitude items were scattered in the factor structure. We therefore removed the attitude construct from the research model and aimed for a

**Table 1**
Cronbach's alphas of the constructs.

| Construct | Number of items | Deleted items | Cronbach's alpha |
|---|---|---|---|
| Long-term *status quo* intentions | 3 | • When my central heating needs replacing in the next 15 years, I plan to switch to sustainable heating | 0.93 |
| Short-term *status quo* intentions | 3 | • When my central heating needs replacing in the next 5 years, I plan to switch to sustainable heating | 0.94 |
| Intentions in the case of higher natural gas prices | 3 | | 0.90 |
| Intentions in the case of government support | 3 | | 0.90 |
| Subjective norm (social circle) | 4 | | 0.94 |
| Subjective norm (heating installers) | 4 | | 0.92 |
| Perceived behavioral control (financial resources) | 3 | | 0.93 |
| Perceived behavioral control (knowledge) | 3 | • The available information on natural gas-free heating is difficult to understand | 0.86 |
| Environmental concern | 6 | • Society needs to do something about climate change<br>• I am willing to do everything I can to fight climate change | 0.94 |
| Environmental impact | 4 | | 0.91 |
| Utilitarian advantages | 3 | • Natural gas-free heating makes my home safer | 0.89 |
| Comfort of living | 2 | | 0.85 |
| Expected discomfort | 2 | | 0.76 |
| Startup challenges | 8 | | 0.96 |
| Trust in nation-wide energy transition | 5 | | 0.88 |

factor solution with fifteen constructs. In addition to the problems with the attitude construct, six other items appeared to be confounded, loading on more than one factor. After removing them, we ended up with a factor structure in which (1) the items of initial purchase costs and expected inconveniences merged into one new construct (*startup challenges*), and (2) the items of hedonic (dis)advantages were divided into two new constructs: *comfort of living* (air quality and comfortable heating) and *expected discomfort* (space occupied and noise). An overview of the final principal component analysis can be found in the Appendix A.

The next step was a reliability analysis. Table 1 gives an overview of the Cronbach's alphas of all constructs. With Cronbach's alphas ranging between 0.76 and 0.96, all constructs were sufficiently reliable.

Based on the scale construction phase, the initial research model and hypotheses were adjusted. The largest adjustment was that the mediated relations between beliefs underlying attitude and investment intentions were changed into direct relations. Furthermore, one of the original beliefs was split into two different beliefs, while two of the original beliefs were merged into one belief. The reasoning behind the hypotheses remained the same. Fig. 3 presents the revised research model and Table 2 gives an overview of the revised hypotheses that were eventually tested.

## 4. Results

Below, we first compare the four dependent variables: the homeowners' investment intentions in the four scenarios. After that, we present the descriptive results of the independent variables in the research model. The section ends with a series of multiple regression analyses explaining the variance in investment intentions in the four scenarios.

### 4.1. Homeowners' investment intentions in the four scenarios

To analyze the homeowners' intentions to invest in sustainable heating, we computed mean scores and 95 % confidence intervals (Fig. 4). The four non-overlapping confidence intervals indicate significant differences between the four scenarios. Short-term *status quo* intentions had the lowest score (below the midpoint of the scale): Investments within five years without external incentives did not seem very likely. Long-term *status quo* intentions scored significantly higher (above the midpoint of the scale), showing a general awareness that investments will be inevitable in the future. The two external incentives (higher natural gas prices and government support) had significantly different effects. Higher gas prices led to an indeterminate intentions score, in between long-term and short-term *status quo* intentions (not significantly different from the midpoint of the scale). At the time of data collection—before the war in Ukraine, which led to a considerable increase of natural gas prices—it is conceivable that the homeowners thought of this incentive as a gradual and moderate one and not as a call to action. Government support resulted in the highest intentions scores (significantly above the midpoint of the scale). A (partial) compensation for their investments, which might only be available for a limited time, had a significantly stronger effect on homeowners' investment intentions than higher gas prices.

### 4.2. Descriptive results of the determinants

Fig. 5 gives an overview of the mean scores and 95 % confidence intervals of all independent variables in our model. Using confidence intervals, three groups of constructs could be distinguished, with: (1) scores that are favorable for the investment decision, (2) scores that are unfavorable for the investment decision, and (3) indeterminate scores. Two variables (expected discomfort and startup challenges) were inherently negative; we did not recode them, but took into account that negative scores on these variables must be interpreted as favorable for the transition to sustainable heating. Of course, these descriptive findings should be treated with caution, as our sample was not representative of the population of Dutch homeowners.

On the positive side, the homeowners in our sample were generally concerned about climate change, believed that sustainable heating would make a contribution, and saw extra utilitarian advantages of sustainable heating. They also thought that heating installers are positive about such a transition and did not see important discomforts of having sustainable heating. On the negative side, the homeowners generally did not have the financial resources to make the required investments and expected considerable startup challenges. They also did not see their social circle as an encouraging factor to make the change and had negative expectations of how natural gas-free heating would affect their comfort of living. Scores were indeterminate for two variables. The homeowners were not sure whether they had the knowledge needed to make wise investment decisions and had doubts about the nationwide energy transition.

### 4.3. Explaining homeowners' investment intentions

To analyze how homeowners' investment intentions in the four scenarios relate to the determinants in our research model, we conducted four regression analyses (see Table 3). Regression analysis is an accepted technique for determining the relationship between a set of predictor

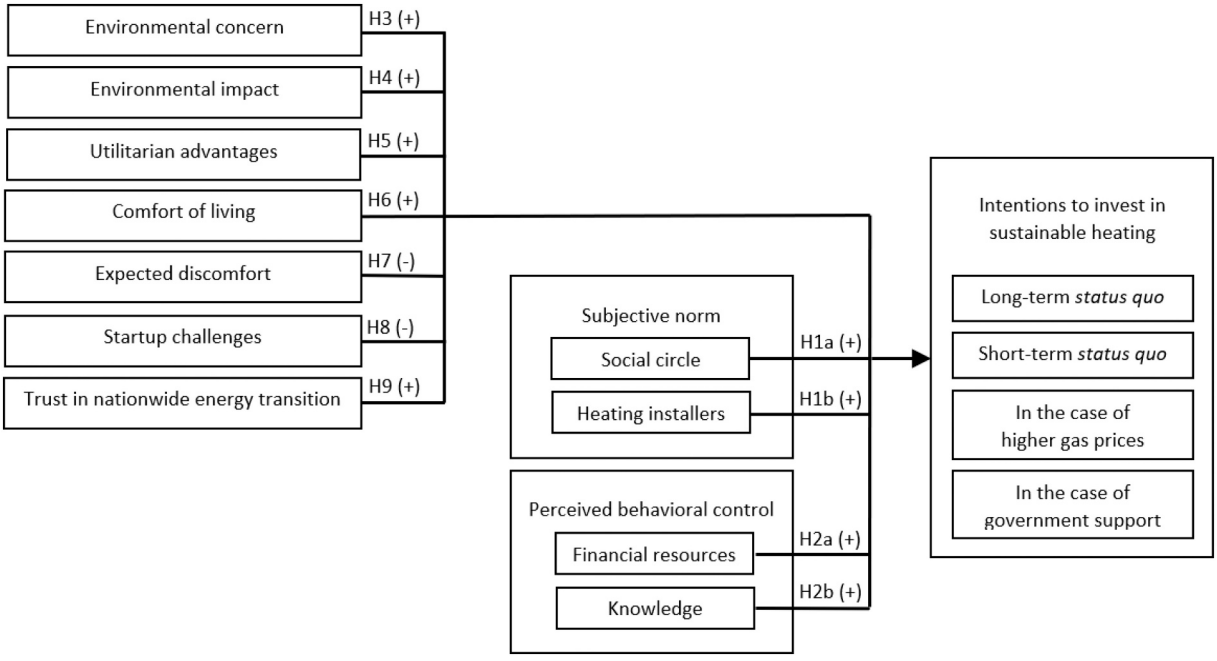


**Fig. 3.** Revised research model.

**Table 2**
Final set of hypotheses tested.

| Hypothesis | |
|---|---|
| H1a | Subjective norm (social circle) is positively related to homeowners' investment intentions. |
| H1b | Subjective norm (heating installers) is positively related to homeowners' investment intentions. |
| H2a | Perceived behavioral control (financial resources) is positively related to homeowners' investment intentions. |
| H2b | Perceived behavioral control (knowledge) is positively related to homeowners' investment intentions. |
| H3 | Environmental concern is positively related to homeowners' investment intentions. |
| H4 | Environmental impact of sustainable heating is positively related to homeowners' investment intentions. |
| H5 | Utilitarian advantages are positively related to homeowners' investment intentions. |
| H6 | Comfort of living is positively related to homeowners' investment intentions. |
| H7 | Expected discomfort is negatively related to homeowners' investment intentions. |
| H8 | Startup challenges are negatively related to homeowners' investment intentions. |
| H9 | Trust in the nationwide energy transition is positively related to homeowners' investment intentions. |

variables and a dependent variable, providing insight in the total percentage of variance explained and the explanatory value of each predictor. The regression analyses confirm that most determinants included in the research model matter for at least one of the four scenarios, thus partially confirming most of the hypotheses. Only for three hypotheses no support was found. Comfort of living (H6) and expected discomfort (H7) had no significant relation with any of the four intentions scores. Trust in the nationwide energy transition (H9) had a significant relation with intentions in the case of government support, but in the opposite direction. The only determinant that contributed significantly to all four intentions scores, and thus was fully supported, was subjective norm (social circle) (H1).

Comparisons of the four scenarios show that their determinants differed in two respects. First, the explanatory value differed considerably: Long-term *status quo* intentions had the highest percentage of explained variance (56 %), followed by, respectively, short-term *status quo* intentions (48 %), intentions in the case of government support (36 %), and intentions in the case of higher natural gas prices (30 %). Intentions in the more hypothetical scenarios thus appeared to be harder to explain than those in the *status quo* scenarios.

Second, the selections of influential determinants differed as well. For long-term *status quo* intentions, a comprehensive range of relevant determinants was identified: Both types of subjective norm (social circle and heating installers) played a role, as well as the knowledge component of perceived behavioral control, homeowners' environmental concern, and the environmental impact of sustainable heating. The homeowners also took utilitarian advantages and startup challenges into consideration. For short-term *status quo* intentions, the determinants tended to be more pragmatic. In addition to the subjective norm (social circle), homeowners focused specifically on both types of perceived behavioral control (financial resources and knowledge), utilitarian advantages, and startup challenges. For homeowners' intentions in the case of higher natural gas prices, the only two significant determinants involved subjective norm (social circle and heating installers). Instead of making their own decision, homeowners seemed to have a wait-and-see attitude, mainly looking at others for guidance. For homeowners' intentions in the case of government support, the determinants were opportunistic: Two practical advantages (environmental and utilitarian benefits) complemented the influence of subjective norm (social circle). Remarkably, trust in the nationwide energy transition had a negative relation with intentions. Feelings that the support might be temporary and could end at one point stimulated homeowners in their intentions.

## 5. Discussion

This study aimed at understanding Dutch homeowners' investment intentions regarding sustainable heating. We used an online survey to collect their intentions in four scenarios and their scores on a comprehensive set of potential determinants (based on the TPB). Below we give an overview of the main findings, followed by limitations and suggestions for future research, and practical recommendations.

### 5.1. Main findings

Our research question involved the extent to which Dutch

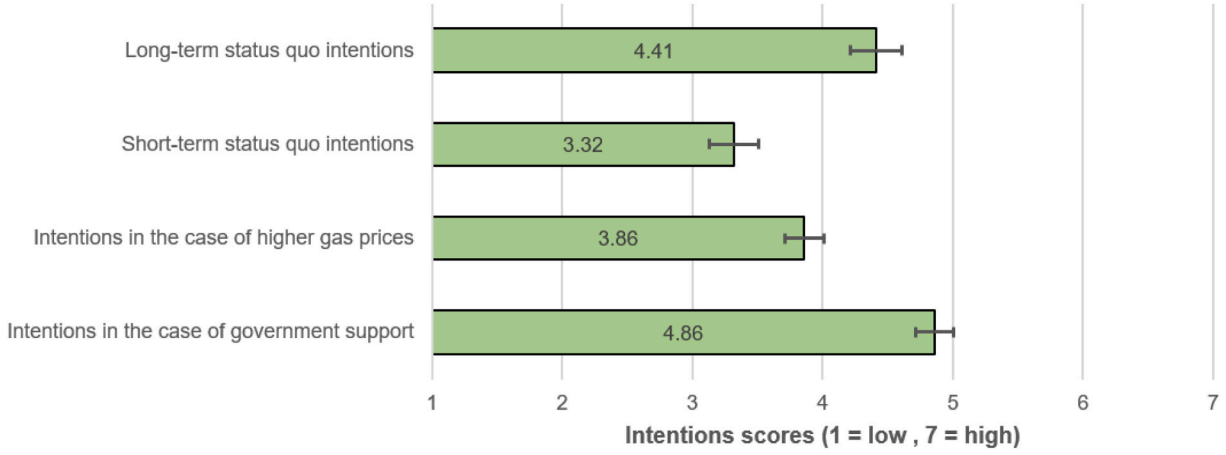


**Fig. 4.** Mean scores and 95 % confidence intervals of the four investment intentions.

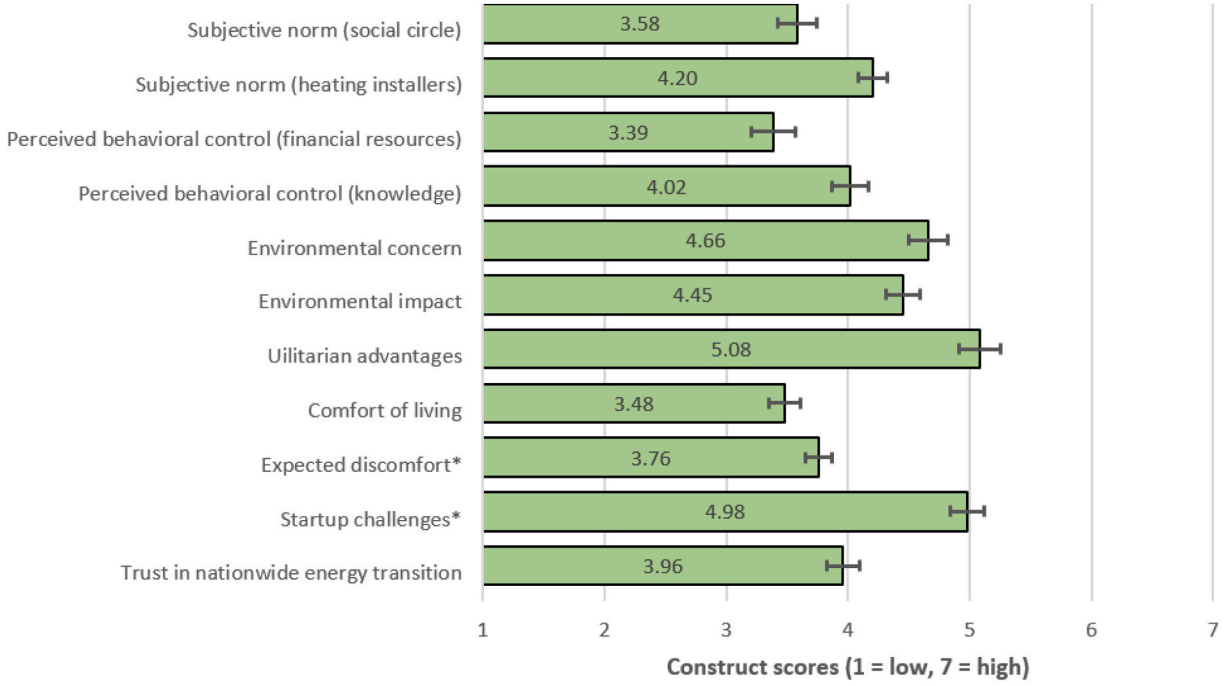


**Fig. 5.** Mean scores and 95 % confidence intervals of the determinants.
Note: * = inherently negative variables.

homeowners' intentions to invest in sustainable heating systems and the underlying determinants of their intentions differed between four scenarios, representing the proximity of the intentions (long-term versus short term) and the effects of two kinds of incentives (higher gas prices and government support). We investigated this question in a non-representative sample of Dutch homeowners, which means that the descriptive findings should be treated with caution.

Our first finding is that homeowners' investment intentions vary depending on the scenario they are in. Their long-term *status quo* intentions were quite favorable. The homeowners in our sample generally understood and accepted that sustainable investments will be needed in the next fifteen years. Their short-term *status quo* intentions, however, were considerably less favorable. They were generally not prepared to make the required investments within five years. The difference between long-term and short-term intentions entails the risk that long-term intentions may not materialize in practice. The two hypothetical scenarios had differential effects. Higher natural gas prices led to higher investment intentions compared to the short-term *status quo* intentions, but drastic improvements seemed unlikely. As an explanation, homeowners might see increases in gas prices as a gradual, slow-moving process. In such circumstances it can be hard to make decisions about sustainable investments. Government support led to considerably higher intentions. A possible explanation for this is that homeowners might realize that the support involved a temporary opportunity to substantially benefit themselves.

Our study is the first to use such a scenario approach when investigating sustainable investment intentions. Earlier studies predominantly focused on single operationalizations of behavioral intentions, sometimes differentiating between different products [10,23,26,35] or groups of people (adopters vs. non-adopters or nationality) [32,39,40]. In our study, we compared investment intentions in four scenarios within the same sample of homeowners.

Looking at the determinants in our model, we found that there are several that had favorable scores for the transition to sustainable

**Table 3**
Results of the linear regression analyses.

| | Long-term *status quo* intentions | | Short-term *status quo* intentions | | Intentions in the case of higher gas prices | | Intentions in the case of government subsidies | |
|---|---|---|---|---|---|---|---|---|
| | Beta | Sig. | Beta | Sig. | Beta | Sig. | Beta | Sig. |
| Subjective norm (social circle) | 0.194 | $p < .001$ | 0.328 | $p < .001$ | 0.151 | $p < .05$ | 0.153 | $p < .05$ |
| Subjective norm (heating installers) | 0.133 | $p < .05$ | 0.092 | $p = 119$ | 0.159 | $p < .05$ | 0.111 | $p = .094$ |
| Perc. behav. Control (financial resources) | 0.008 | $p = .189$ | 0.167 | $p < .001$ | 0.007 | $p = .896$ | −0.035 | $p = .466$ |
| Perc. behav. Control (knowledge) | 0.099 | $p < .05$ | 0.130 | $p < .005$ | 0.006 | $p = .914$ | −0.025 | $p = .612$ |
| Environmental concern | 0.234 | $p < .005$ | 0.098 | $p = .211$ | 0.138 | $p = .131$ | 0.081 | $p = .353$ |
| Environmental impact | 0.147 | $p < .05$ | 0.079 | $p = .231$ | 0.117 | $p = .126$ | 0.177 | $p < .05$ |
| Utilitarian advantages | 0.276 | $p < .001$ | 0.154 | $p < .05$ | 0.071 | $p = .407$ | 0.280 | $p < .001$ |
| Comfort of living | −0.091 | $p = .069$ | 0.009 | $p = .869$ | 0.059 | $p = .347$ | 0.095 | $p = .117$ |
| Expected discomfort | 0.088 | $p = .119$ | 0.078 | $p = .202$ | −0.017 | $p = .809$ | 0.060 | $p = .379$ |
| Startup challenges | −0.124 | $p < .05$ | −0.150 | $p < .05$ | −0.123 | $p = .095$ | −0.084 | $p = .233$ |
| Trust in the nationwide energy transition | −0.054 | $p = 298$ | −0.052 | $p = .358$ | −0.084 | $p = .201$ | −0.149 | $p < .05$ |
| Model fit | $F(11,290) = 35.854$, $p < .001$ | | $F(11,290) = 26.372$, $p < .001$ | | $F(11,290) = 12.841$, $p < .001$ | | $F(11,290) = 16.088$, $p < .001$ | |
| Adjusted $R^2$ | 0.56 | | 0.48 | | 0.30 | | 0.36 | |

heating. The homeowners in our sample generally saw the urgency of the climate challenge and wanted to contribute. They also acknowledged that sustainable heating can make a difference, with additional utilitarian advantages for their property (e.g., in terms of home value). They did not see substantial discomfort in having sustainable heating and believed that heating installers are positive about the transition. However, there were also determinants with scores that might negatively affect their intentions to invest in sustainable heating systems. Most prominently, the homeowners in our sample doubted whether they had the financial resources for the investment and expected serious startup challenges (costs, efforts, inconveniences) when making the transition. They also questioned the comfort of living with sustainable heating and did not think that people in their social circle already embraced the transition. Finally, two variables had indeterminate scores. The homeowners in our sample questioned whether they had the knowledge for making investment decisions and were unsure whether the nationwide energy transition would indeed be persevered with.

A series of regression analyses mapping the relation between determinants and investment intentions shed light on the importance of determinants. It appeared that one of the two determinants with a significantly negative score—subjective norm (social circle)—was the only one that was important in all four scenarios. The importance of people's social circle confirms earlier research regarding sustainable behavioral intentions [9,27,30–32,38]. The other negative determinant—perceived comfort of living—did not have significant relations with any of the four investment intentions. One of the two determinants with an indeterminate score—perceived behavioral control (knowledge)—appeared to be significantly related to the two *status quo* intentions. The other—trust in the nationwide energy transition—only had an unexpected negative relation with investment intentions in the case of government subsidies, presumably because it underlines the temporary nature of the opportunity. As this could also be communicated directly, it does not make sense to aim for distrust in the nationwide energy transition. For citizens' support for current and future government measures it seems important to strive for positive scores on this variable.

A comparison of the regression analyses for the four investment scenarios—long-term and short-term *status quo* intentions, intentions in the case of higher natural gas prices, and intentions in the case of government support—showed that the determinants differed per scenario. This is in line with [27], who found differences in the determinants of sustainable purchase intentions and support for sustainable policies. The scenario of long-term *status quo* intentions corresponded to a comprehensive range of significant determinants. It was the only scenario in which environmental concern mattered. The scenario of short-term *status quo* intentions corresponded to a pragmatic selection of determinants, weighing utilitarian benefits against perceived behavioral control (financial resources and knowledge) and startup challenges. The scenario of higher natural gas prices led to a wait-and-see attitude, in which others' views and behaviors (social circle and heating installers) were the only significant determinants. The scenario of government support led to an opportunistic scenario, focusing strongly mainly on benefits, while considering that the offer might be temporary. The two *status quo* scenarios had higher percentages of explained variance than the hypothetical ones.

The differences between scenarios call for a differentiated perspective on behavioral determinants. For instance, in line with several earlier studies [6,38,58,61,62] we found that environmental concern may be an important determinant, but this was especially the case for long-term intentions; its prominence diminished when the focus was on short-term intentions or when there were external incentives. Likewise, the importance of perceived behavioral control (financial resources), as found by [28,38], was confirmed, but only for short-term investment intentions; its prominence disappeared when homeowners thought about long-term intentions or when external incentives were involved.

### 5.2. Limitations and suggestions for future research

Our study is not without limitations. A first important limitation is the non-representative nature of our sample. Our group of respondents was not an accurate representation of the population of Dutch homeowners. The within-subject comparisons between the four scenarios, regarding intentions and determinants, refer to important mechanisms that must be taken into account. But the descriptive findings, such as the mean scores of the determinants, should be interpreted with caution.

Second, we investigated investment intentions, not actual investment behavior. In practice, there may be many obstacles in the translation of intentions into behavior, particularly for complex, lengthy, and comprehensive decisions about investing in sustainable heating. Social desirability may play a role in respondents' answers on investment intentions. Important new considerations that are not recognized in the very beginning may gradually emerge along the way. Future research could try to reconstruct determinants of actual investment decisions or qualitatively follow homeowners in the process from precontemplation to investment decisions.

Third, due to the cross-sectional nature of our data, it is not justified to draw causal inferences from our data. Our results show that determinants and intentions are related and we can theoretically assume that the relationship may be causal, but this does not unequivocally follow from our analyses. Future research could use longitudinal designs to shed more light on causality.

Fourth, the two hypothetical scenarios did not specify the extent to which gas prices would rise, nor the nature and height of the government support. Instead, respondents filled in the scenarios with their own

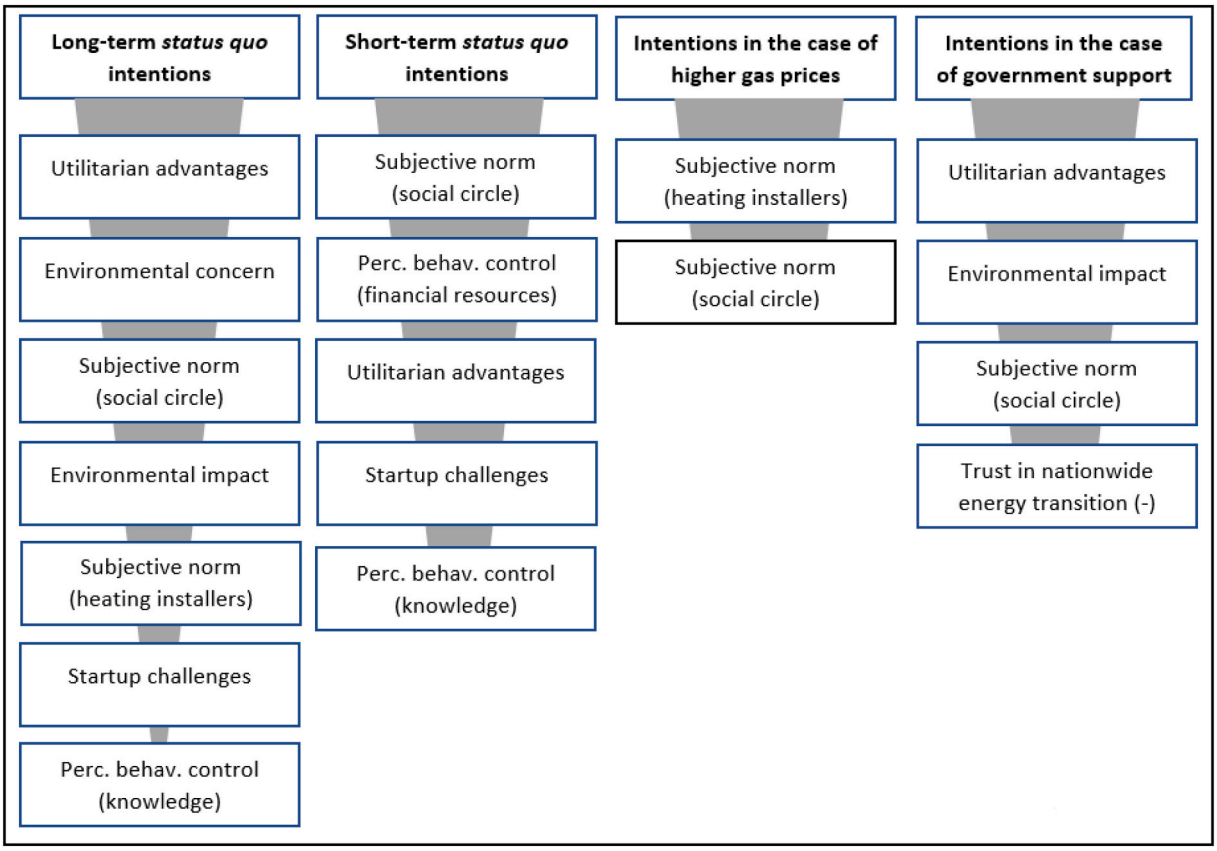


**Fig. 6.** Significant determinants per scenario (from most to least important).

expectations. For the purpose of our study—revealing differences in determinants between scenarios—this design appeared to be the right choice. Specifying one percentage of higher energy costs or one amount or percentage of government subsidy would have been arbitrary, whereas varying these percentages or amounts would have not been feasible in a study mainly focusing on determinants. Future research could expose homeowners to more detailed circumstances (including combinations of gas price developments and government support options), for instance in vignette or conjoint survey designs [76].

The fifth limitation is somewhat related: Our data were collected before the war in Ukraine, which had a huge impact on the European energy market. There was uncertainty about national gas reserves and gas prices rose beyond what homeowners could imagine at the time they filled out the survey. Still, the influence of these developments may be relativized for two reasons: (1) along with gas prices, the costs of electricity rose at a similar pace [77], and (2) government measures alleviated the pain of increasing energy prices. Nevertheless, it would be interesting to see how homeowners' intentions and determinants have developed in the current situation, in which the costs of fossil energy are much more in the spotlight than ever before.

The sixth limitation is that our study assumes homogeneity among Dutch homeowners and investment decisions that can be made and studied at the individual level. Every private citizen who owned a home qualified to participate in our study. Still it may be useful to further differentiate between homeowners in future research. For instance, it may be interesting to zoom in on differences in socio-economic status. There may also be differences between types of homes. Fr apartments, decisions about sustainable energy may not be taken at the household level, but at the level of the entire apartment building. In the case of older houses, sustainable heating may involve much more than the heating system; insulation will be a first and necessary step toward sustainable heating. In certain neighborhoods there are collective processes to replace natural gas with district heating [6]. Research focusing on specific types of homes and situations might further specify and deepen our findings.

A seventh limitation involves the specific context of the research. Our study was conducted in the Netherlands and focused on a specific type of investment decision in a specific time frame. One could question the transferability of our findings. We would argue that caution is needed in generalizing our descriptive findings to other national contexts or other types of sustainable investment decisions. However, the mechanisms we found comparing the four scenarios and their determinants could be more generalizable to other contexts. Future research, in different national contexts and/or involving different types of sustainable investments could shed more light on this.

As an additional suggestion for follow-up research, it would be interesting to also investigate the considerations and decision-making of housing corporations and landlords regarding sustainable heating.

### 5.3. *Practical implications*

Two practical recommendations can be derived from our findings. The most important one is that behavioral determinants differ between the four scenarios we investigated. The generally favorable long-term scenario with many different determinants turns into shorter lists of determinants when it comes to short-term intentions, or when higher gas prices or government support enter the scene. Depending on the scenario, a different emphasis on determinants may be desirable. Getting homeowners from long-term to short-term intentions might require a stronger focus on pragmatic determinants (financial resources, knowledge, utilitarian advantages, and startup challenges). In times of higher gas prices, much depends on the dynamics in homeowners' environment (social circle and heating installers). Government support, in turn, appears to trigger opportunistic views on the transition. Government

officials and policy makers may use these insights in developing policies and communication strategies to convince homeowners to invest in sustainable heating systems. Based on our research it appears to be important to adjust policy, incentives, and/or communication strategies to the scenarios that can be foreseen or that are prevalent in the minds of homeowners. In Fig. 6 we provide an overview of potentially relevant determinants for each scenario.

A second recommendation involves the important role of homeowners' social circle, the only determinant that mattered in all four scenarios. It seems fruitful to focus more strongly on this subjective norm in communication strategies aimed at homeowners. The influence of homeowners' social circle is a variable that cannot be affected by concerted communication efforts, but it seems worthwhile to think of ways to use the influence of homeowners' social circle in the energy transition. It would, for instance, be interesting to develop and test interventions aimed at promoting more societal discourse about sustainable heating, with homeowners who already made the step sharing experiences and acting as ambassadors of the transition. More visibility of successful transitions and personal accounts of the transitions may stimulate homeowners to consider making the step themselves. As a generic mass-media alternative, quantitative indications of successful transitions and in-depth stories of such transitions might also be interesting complementary approach.

## CRediT authorship contribution statement

**Menno D.T. de Jong:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Remco Pieterse:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization. **Sikke R. Jansma:** Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

## Acknowledgment

The authors would like to thank Nick van der Hout of WestlandInfra for his help with the recruitment of respondents for this study.

## Appendix A. Appendix: Questionnaire items and principal components analysis

| Questionnaire items | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Installing natural gas-free heating takes a lot of time (R) | 0.85 | | | | | | | | | | | | | | |
| The installation costs of natural gas-free heating are very high (R) | 0.85 | | | | | | | | | | | | | | |
| A lot needs to be arranged to get natural gas-free heating installed (R) | 0.84 | | | | | | | | | | | | | | |
| Installing natural gas-free heating takes a lot effort (R) | 0.82 | | | | | | | | | | | | | | |
| Major renovations are needed for the installation of natural gas-free heating (R) | 0.82 | | | | | | | | | | | | | | |
| The purchase costs of natural gas-free heating are very high (R) | 0.80 | | | | | | | | | | | | | | |
| In general, natural gas-free heating is an expensive investment (R) | 0.79 | | | | | | | | | | | | | | |
| Natural gas-free heating costs a lot of money compared to the advantages it gives (R) | 0.76 | | | | | | | | | | | | | | |
| Fighting climate change is also my responsibility | | 0.73 | | | | | | | | | | | | | |
| Fighting climate change starts with me | | 0.69 | | | | | | | | | | | | | |
| I am worried about climate change | | 0.68 | | | | | | | | | | | | | |
| I have a share in fighting climate change | | 0.64 | | | | | | | | | | | | | |
| I find it important to use sustainable energy, such as solar or wind energy | | 0.60 | | | | | | | | | | | | | |
| I want to do something against climate change | | 0.56 | | | | | | | | | | | | | |
| The national government will keep its promises to be natural gas-free by 2050 | | | 0.78 | | | | | | | | | | | | |
| The Netherlands will succeed to be natural gas-free by 2050 | | | 0.77 | | | | | | | | | | | | |
| Future governments will stand behind the transition to become natural gas-free | | | 0.76 | | | | | | | | | | | | |

(*continued on next page*)

(*continued*)

| Questionnaire items | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| The national government is decisive enough to achieve the transition to natural gas-free | | | 0.74 | | | | | | | | | | | | |
| The national government is determined to be natural gas-free in 2050 | | | 0.65 | | | | | | | | | | | | |
| In my view, installers of heating systems are positive about natural gas-free heating | | | | 0.82 | | | | | | | | | | | |
| Installers of heating systems find natural gas-free heating a good idea | | | | 0.82 | | | | | | | | | | | |
| I think installers of heating systems would advise me to switch to natural gas-free heating | | | | 0.76 | | | | | | | | | | | |
| Installers of heating systems think that natural gas-free heating works well | | | | 0.73 | | | | | | | | | | | |
| My family and/or friends think that I should switch to natural gas-free heating | | | | | 0.86 | | | | | | | | | | |
| My immediate social environment thinks that I should switch to natural gas-free heating | | | | | 0.83 | | | | | | | | | | |
| I expect family and/or friends to invest in natural gas-free heating | | | | | 0.77 | | | | | | | | | | |
| I expect my immediate social environment to invest in natural gas-free heating | | | | | 0.77 | | | | | | | | | | |
| With natural gas-free heating I will cause less air pollution | | | | | | 0.81 | | | | | | | | | |
| Through natural gas-free heating I will lower my $CO_2$ emissions | | | | | | 0.80 | | | | | | | | | |
| By investing in natural gas-free heating I do something against global warming | | | | | | 0.72 | | | | | | | | | |
| By investing in natural gas-free heating I do something good for the environment | | | | | | 0.66 | | | | | | | | | |
| I have the money to take natural gas-free heating | | | | | | | 0.95 | | | | | | | | |
| I have the financial resources to invest in natural gas-free heating | | | | | | | 0.95 | | | | | | | | |
| I need the money I would have to spend on natural gas-free heating for other things (R) | | | | | | | 0.88 | | | | | | | | |
| If taxes on gas will rise, I expect to purchase natural gas-free heating | | | | | | | | 0.85 | | | | | | | |
| If my energy contract gets more expensive, I am willing to take natural gas-free heating | | | | | | | | 0.82 | | | | | | | |
| If gas prices continue to rise, I expect to take natural gas-free heating | | | | | | | | 0.68 | | | | | | | |
| If the government provides more support, I plan to invest in natural gas-free heating | | | | | | | | | 0.79 | | | | | | |
| If the government provides more subsidies, I expect to purchase natural gas-free heating | | | | | | | | | 0.77 | | | | | | |
| If the government provides tax reductions, I expect to take natural gas-free heating | | | | | | | | | 0.75 | | | | | | |
| I know what needs to happen to make natural gas-free heating possible | | | | | | | | | | 0.88 | | | | | |
| I have sufficient knowledge about the possibilities of natural gas-free heating in my home | | | | | | | | | | 0.87 | | | | | |
| There is enough information available about the possibilities of natural gas-free heating | | | | | | | | | | 0.82 | | | | | |

(*continued on next page*)

(*continued*)

| Questionnaire items | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I expect to purchase natural gas-free heating within 5 years | | | | | | | | | | | 0.77 | | | | |
| I am willing to get natural gas-free heating within 5 years | | | | | | | | | | | 0.75 | | | | |
| I want to invest in natural gas-free heating within 5 years | | | | | | | | | | | 0.73 | | | | |
| I expect to purchase natural gas-free heating within 15 years | | | | | | | | | | | | 0.73 | | | |
| I want to invest in natural gas-free heating within 15 years | | | | | | | | | | | | 0.68 | | | |
| I am willing to get natural gas-free heating within 15 years | | | | | | | | | | | | 0.67 | | | |
| Investing in natural gas-free heating leads to an increased value of my home | | | | | | | | | | | | | 0.63 | | |
| Natural gas-free heating leads to cost savings on my utility bills | | | | | | | | | | | | | 0.59 | | |
| Natural gas-free heating is an investment for the future | | | | | | | | | | | | | 0.40 | | |
| Natural gas-free heating systems take a lot of space (R) | | | | | | | | | | | | | | 0.76 | |
| Natural gas-free heating systems generally produce a lot of noise (R) | | | | | | | | | | | | | | 0.74 | |
| Air quality in homes will be improved due to natural gas-free heating | | | | | | | | | | | | | | | 0.74 |
| Natural gas-free heating heats homes in a comfortable way | | | | | | | | | | | | | | | 0.56 |
| Eigenvalue | 21.12 | 5.48 | 3.14 | 2.97 | 2.45 | 2.14 | 1.57 | 1.45 | 1.17 | 1.16 | 0.96 | 0.94 | 0.85 | 0.81 | 0.65 |
| Percentage of variance | 37.7 | 9.8 | 5.6 | 5.3 | 4.4 | 3.8 | 2.8 | 2.6 | 2.1 | 2.1 | 1.7 | 1.7 | 1.5 | 1.4 | 1.2 |
| Cumulative percentage of variance | 37.7 | 47.5 | 53.1 | 58.4 | 62.8 | 66.6 | 69.4 | 72.0 | 74.1 | 76.1 | 77.9 | 79.6 | 81.1 | 82.5 | 83.7 |

Note: Factor loadings under 0.40 are suppressed in this table; (R) means that the items were reverse-coded.

## References


[1] United Nations, What is the Paris agreement?, in: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement, 2015 (accessed 17 September 2023).

[2] Statistics Netherlands, 92 Procent Woningen op Aardgas Begin 2019. [92 Percent Homes on Natural Gas Early 2019], in: https://www.cbs.nl/nl-nl/nieuws/2021/07/92-procent-woningen-op-aardgas-begin-2019, 2021 (accessed 17 September 2023).

[3] P. Hammingh, B. Daniels, P. Koutstaal, M. Menkveld, Klimaat- en Energieverkenning 2021. [Climate and Energy Investigation 2021.]. https://www.pbl.nl/sites/default/files/downloads/pbl-2021-klimaat-en-energieverkenning-2021-4681.pdf, 2021.

[4] Milieucentraal, Stappenplan Aardgasvrij Wonen. [Roadmap Living Natural Gas-free.]. https://www.milieucentraal.nl/energie-besparen/aardgasvrij-wonen/stappenplan-aardgasvrij-wonen/, 2021 (accessed 17 September 2023).

[5] S. Scholte, Y. de Kluizenaar, T. de Wilde, A. Steenbekkers, C. Carabain, Op Weg naar Aardgasvrij Wonen. De Energietransitie vanuit Burgerperspectief. [En Route to Living Natural Gas-free. The Energy Transition from a Citizen Perspective.] Sociaal en Cultureel Planbureau. https://www.scp.nl/binaries/scp/documenten/publicaties/2020/05/25/op-weg-naar-aardgasvrij-wonen/Op+weg+naar+aardgasvrij+wonen.pdf, 2020 (accessed 17 September 2023).

[6] S.R. Jansma, J.F. Gosselt, M.D.T. de Jong, Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands, Energy Res. Soc. Sci. 69 (2020) 101694, https://doi.org/10.1016/j.erss.2020.101694.

[7] A. Steenbekkers, S. Scholte, Onder de Pannen zonder Gas? [everything fine without gas?] Sociaal en Cultureel Planbureau. https://www.scp.nl/binaries/scp/documenten/publicaties/2019/09/05/onder-de-pannen-zonder-gas/Onder+de+pannen+zonder+gas.pdf, 2019 (accessed 17 September 2023).

[8] M. Alipour, S. Ghaboulian Zare, F. Taghikhak, R. Hafezi, Sociodemographic and individual predictors of residential solar water heater adoption behaviour, Energy Res. Soc. Sci. 101 (2023) 103155, https://doi.org/10.1016/j.erss.2023.103155.

[9] Z. Wang, B. Zhang, G. Li, Determinants of energy-saving behavioral intention among residents in Beijing: extending the theory of planned behavior, J. Renew. Sustain. Energy 6 (2014) 053127, https://doi.org/10.1063/1.4898363.

[10] C.C. Michelsen, R. Madlener, Homeowners' preferences for adopting residential heating systems: a discrete choice analysis for Germany, Energy Econ. 34 (2012) 1271–1283, https://doi.org/10.1016/j.eneco.2012.06.009.

[11] J.R. Snape, P.J. Boait, R.M. Rylatt, Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling, Energy Policy 85 (2015) 32–38, https://doi.org/10.1016/j.enpol.2015.05.008.

[12] T. Hadush Meles, L. Ryan, Adoption of renewable home heating systems: an agent-based model of heat pumps in Ireland, Renew. Sust. Energ. Rev. 169 (2022) 112853, https://doi.org/10.1016/j.rser.2022.112853.

[13] F.G. Braun, Determinants of households' space heating type: a discrete choice analysis for German households, Energy Policy 38 (2010) 5493–5503, https://doi.org/10.1016/j.enpol.2010.04.002.

[14] T. Krikser, A. Profeta, S. Grimm, H. Huther, Willingness-top-pay for district heating from renewables of private households in Germany, Sustain 12 (2020) 4129, https://doi.org/10.3390/su12104129.

[15] C. Wen, J.C. Lovett, E. Rianawati, T.R. Arsanti, S. Suryani, A. Pandarangga, S. Sagala, Household willingness to pay for improving electricity services in Sumba Island, Indonesia: a choice experiment under a multi-tier framework, Energy Res. Soc. Sci. 88 (2022) 102503, https://doi.org/10.1016/j.erss.2022.102503.

[16] H. Wu, J. Carroll, E. Denny, Harnessing citizen investment in community-based energy initiatives: a discrete choice experiment across ten European countries, Energy Res. Soc. Sci. 89 (2022) 102552, https://doi.org/10.1016/j.erss.2022.102552.

[17] L. Zhang, C. Sun, H. Liu, S. Zheng, The role of public information in increasing homebuyers' willingness-to-pay for green housing: evidence from Beijing, Ecol. Econ. 129 (2016) 40–49, https://doi.org/10.1016/j.ecolecon.2016.05.010.

[18] M. Nicolson, G. Huebner, D. Shipworth, Are consumers willing to switch to smart time of use electricity tariffs? The importance of loss-aversion and electric vehicle ownership, Energy Res. Soc. Sci. 23 (2017) 82–96, https://doi.org/10.1016/j.erss.2016.12.001.

[19] Y. Yang, H. Stubbe Solgaard, J. Ren, Does positive framing matter? An investigation of how framing affects consumers' willingness to buy green electricity in Denmark, Energy Res. Soc. Sci. 46 (2018) 40–47, https://doi.org/10.1016/j.erss.2018.06.006.

[20] J.P. Loaiza-Ramírez, T. Reimer, C.E. Moreno-Mantilla, Who prefers renewable energy? A moderated mediation model including perceived comfort and consumers' protected values in green energy adoption and willingness to pay a premium, Energy Res. Soc. Sci. 91 (2022) 102753, https://doi.org/10.1016/j.erss.2022.102753.

[21] M.A. Hai, Rethinking the social acceptance of solar energy: exploring "states of willingness" in Finland, Energy Res. Soc. Sci. 51 (2019) 96–106, https://doi.org/10.1016/j.erss.2018.12.013.

[22] S. Karytsas, I. Choropanitis, Barriers against and actions towards renewable energy technologies diffusion: a principal component analysis for residential ground source heat pump (GSHP) systems, Renew. Sust. Energ. Rev. 78 (2017) 252–271, https://doi.org/10.1016/j.rser.2017.04.060.

[23] T. Yue, R. Long, H. Chen, Factors influencing energy-saving behavior of urban households in Jiangsu Province, Energy Policy 62 (2013) 665–675, https://doi.org/10.1016/j.enpol.2013.07.051.
[24] S. Karytsas, H. Theodoropoulou, Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling, Renew. Sust. Energ. Rev. 34 (2014) 49–57, https://doi.org/10.1016/j.rser.2014.02.008.
[25] I. García-Maroto, A. García-Maraver, F. Muñoz-Leiva, M. Zamorano, Consumer knowledge, information sources used and predisposition towards the adoption of wood pellets in domestic heating systems, Renew. Sust. Energ. Rev. 43 (2015) 207–215, https://doi.org/10.1016/j.rser.2014.11.004.
[26] T. Decker, K. Menrad, House owners' perceptions and factors influencing their choice of specific heating systems in Germany, Energy Policy 85 (2015) 150–161, https://doi.org/10.1016/j.enpol.2015.06.004.
[27] C. Chen, X. Xu, S. Frey, Who wants solar water heaters and alternative fuel vehicles? Assessing social-psychological predictors of adoption intention and policy support in China, Energy Res. Soc. Sci. 15 (2016) 1–11, https://doi.org/10.1016/j.erss.2016.02.006.
[28] S. Karytsas, An empirical analysis on awareness and intention adoption of residential ground source heat pump systems in Greece, Energy Policy 123 (2018) 167–179, https://doi.org/10.1016/j.enpol.2018.08.001.
[29] R. Baumhof, T. Decker, K. Menrad, Which factors determine the extent of house owners' energy-related refurbishment projects? A motivation-opportunity-ability approach, Sustain. Cities Soc. 36 (2018) 33–41, https://doi.org/10.1016/j.scs.2017.09.025.
[30] X. Ru, S. Wang, S. Yan, Exploring the effects of normative factors and perceived behavioral control on individual's energy-saving intention: an empirical study in eastern China, Resour. Conserv. Recycl. 134 (2018) 91–99, https://doi.org/10.1016/j.resconrec.2018.03.001.
[31] Y. Zhang, C. Xiao, G. Zhou, Willingness to pay a price premium for energy-saving appliances: role of perceived value and energy efficiency labeling, J. Clean. Prod. 242 (2020) 118555, https://doi.org/10.1016/j.jclepro.2019.118555.
[32] C. Chen, X. Xu, J. Adams, J. Brannon, F. Li, A. Walzem, When east meets west: understanding residents' home energy management system adoption intention and willingness to pay in Japan and the United States, Energy Res. Soc. Sci. 69 (2020) 101616, https://doi.org/10.1016/j.erss.2020.101616.
[33] W. Xie, C. Chen, F. Li, B. Cai, R. Yang, L. Cao, P. Wu, L. Pang, Key factors of rural households' willingness to pay for cleaner heating in Hebi: a case study in northern China, Sustain 13 (2021) 633, https://doi.org/10.3390/su13020633.
[34] V. Kumar, A.S. Syan, K. Kaur, A structural equation modeling analysis of factors driving customer purchase intention towards solar water heater, Smart Sustain Built Environ. 11 (2022) 65–78, https://doi.org/10.1108/SASBE-05-2020-0069.
[35] M. Corbett, E. Rhodes, A. Pardy, Z. Long, Pumping up adoption: the role of policy awareness in explaining willingness to adopt heat pumps in Canada, Energy Res. Soc. Sci. 96 (2023) 102926, https://doi.org/10.1016/j.erss.2022.102926.
[36] S. Bai, F. Li, X. Wu, Green but unpopular? Analysis on purchase intention of heat pump water heaters in China, Energies 15 (2022) 2464, https://doi.org/10.3390/en15072464.
[37] M.A. Long, M. León-Corwin, K. Peach, K.L. Olofsson, J.T. Ripberger, K. Gupta, C. L. Silva, H. Jenkins-Smith, Watts at stake: concern and willingness-to-pay for electrical grid improvements in the United States, Energy Res. Soc. Sci. 102 (2023) 103179, https://doi.org/10.1016/j.erss.2023.103179.
[38] G. Liobikienė, R. Dagiliūtė, R. Juknys, The determinants of renewable energy usage intentions using theory of planned behaviour approach, Renew. Energy 170 (2021) 587–594, https://doi.org/10.1016/j.renene.2021.01.152.
[39] B.M. Sopha, C. Klöckner, E.G. Hertwich, Adopters and non-adopters of wood pellet heating in Norwegian households, Biomass Bioenergy 35 (2011) 652–662, https://doi.org/10.1016/j.biombioe.2010.10.019.
[40] R. Baumhof, T. Decker, H. Röder, K. Menrad, An expectancy theory approach: what motivates and differentiates German house owners in the context of energy efficient refurbishment measures? Energy Building 152 (2017) 483–491, https://doi.org/10.1016/j.enbuild.2017.07.035.
[41] I. García-Maroto, F. Muñoz-Leiva, E. Higueras-Castillo, F. Liébana-Cabanillas, Characterisation of potential adopters of domestic biomass heating, Int. J. Green Energy 18 (2021) 219–230, https://doi.org/10.1080/15435075.2020.1854262.
[42] I. Ajzen, The theory of planned behavior, Organ. Behav. Hum. Decis. Process. 50 (1991) 179–211, https://doi.org/10.1016/0749-5978(91)90020-T.
[43] S. Sutton, Predicting and explaining intentions and behavior: how well are we doing? J. Appl. Soc. Psychol. 28 (1998) 1317–1338, https://doi.org/10.1111/j.1559-1816.1998.tb01679.x.
[44] C.J. Armitage, M. Conner, Efficacy of the theory of planned behaviour: a meta-analytic review, Brit. J. Soc. Psychol. 40 (2001) 471–499, https://doi.org/10.1348/014466601164939.
[45] M. de Wilde, The sustainable housing question: on the role of interpersonal, impersonal and professional trust in low-carbon retrofit decisions by homeowners, Energy Res. Soc. 51 (2019) 138–147, https://doi.org/10.1016/j.erss.2019.01.004.
[46] A. Freyre, S. Cozza, M. Rüetschi, M. Bürer, M. Sahakian, M.K. Patel, How to improve effectiveness of renewable space heating programs by better understanding homeowner-installer interactions, Energies 14 (2021) 4625, https://doi.org/10.3390/en14154625.
[47] A. Owen, G. Mitchell, A. Gouldson, Unseen influence: the role of low carbon retrofit advisers and installers in the adoption and use of domestic energy technology, Energy Policy 73 (2014) 169–179, https://doi.org/10.1016/j.enpol.2014.06.013.
[48] A. Owen, G. Mitchell, Outside influence: some effects of retrofit installers and advisors on energy behaviours in households, Indoor Built Environ. 24 (2015) 925–936, https://doi.org/10.1177/1420326X15600775.
[49] V. Rai, D.C. Reeves, R. Margolis, Overcoming barriers and uncertainties in the adoption of residential solar PV, Renew. Energy 89 (2016) 498–505, https://doi.org/10.1016/j.renene.2015.11.080.
[50] F. Wade, R. Hitchings, M. Shipworth, Understanding the missing middlemen of domestic heating: installers as a community of professional practice in the United Kingdom, Energy Res. Soc. Sci. 19 (2016) 39–47, https://doi.org/10.1016/j.erss.2016.05.007.
[51] F. Wade, M. Shipworth, R. Hitchings, How installers select and explain domestic heating controls, Build. Res. Inf. 45 (2017) 371–383, https://doi.org/10.1080/09613218.2016.1159484.
[52] K. Mahapatra, L. Gustavsson, Innovative approaches to domestic heating: Homeowners' perceptions and factors influencing their choice of heating system, Int. J. Consum. Stud. 32 (2007) 75–87, https://doi.org/10.1111/j.1470-6431.2007.00638.x.
[53] R. Ozaki, Adopting sustainable innovation: what makes consumers sign up to green electricity? Bus. Strateg. Environ. 20 (2011) 1–17, https://doi.org/10.1002/bse.650.
[54] S.M. Cruz, B. Manata, Measurement of environmental concern: a review and analysis, Front. Psychol. 11 (2020) 363, https://doi.org/10.3389/fpsyg.2020.00363.
[55] R. Dunlap, R. Jones, Environmental concern: conceptual and measurement issues, in: R. Dunlap, W. Michelson (Eds.), Handbook of Environmental Sociology, Greenwood Press, 2002, pp. 482–542.
[56] N. Fransson, T. Gärling, Environmental concern: conceptual definitions, measurement methods, and research findings, J. Environ. Psychol. 19 (1999) 369–382, https://doi.org/10.1006/jevp.1999.0141.
[57] M. Grębosz-Krawczyk, A. Zakrzewska-Bielawska, B. Glinka, A. Glińska-Neweś, Why do consumers choose photovoltaic panels? Identification of the factors influencing consumers' choice behavior regarding photovoltaic panel installations, Energies 14 (2021) 2674, https://doi.org/10.3390/en14092674.
[58] G.-W. Zheng, A.B. Siddik, M. Masukujjaman, S.S. Alam, A. Akter, Perceived environmental responsibilities and green buying behavior: the mediating effect of attitude, Sustain 13 (2020) 35, https://doi.org/10.3390/su13010035.
[59] M.C. Claudy, M. Peterson, A. O'Driscoll, Understanding the attitude-behavior gap for renewable energy systems using behavioral reasoning theory, J. Macromark. 33 (2013) (2013) 273–287, https://doi.org/10.1177/0276146713481605.
[60] M.N. Akroush, M.I. Zuriekat, H.I. Al Jabali, N.A. Asfour, Determinants of purchasing intentions of energy-efficient products, Int. J. Energy Sect. Manage. 13 (2019) 128–148, https://doi.org/10.1108/IJESM-05-2018-0009.
[61] S. Ebrahimigharehbaghi, Q.K. Qian, F.M. Meijer, H.J. Visscher, Unravelling Dutch homeowners' behaviour towards energy efficiency renovations: what drives and hinders their decision-making? Energy Policy 129 (2019) 546–561, https://doi.org/10.1016/j.enpol.2019.02.046.
[62] W.M.H. Broers, V. Vasseur, R. Kemp, N. Abujidi, Z.A.E.P. Vroon, Decided or divided? An empirical analysis of the decision-making process of Dutch homeowners for energy renovation measures, Energy Res. Soc. Sci. 58 (2019) 101284, https://doi.org/10.1016/j.erss.2019.101284.
[63] K. Gram-Hanssen, T.H. Christensen, P.E. Petersen, Air-to-air heat pumps in real-life use: are potential savings achieved or are they transformed into increased comfort? Energ. Buildings 53 (2012) 64–73, https://doi.org/10.1016/j.enbuild.2012.06.023.
[64] M. van Gerven, Wat de woningbezitter betaalt als we stoppen met aardgas [what the homeowner pays if we stop with natural gas], Eigen Huis (June 2018) 32–37.
[65] C. Aravena, A. Riquelme, E. Denny, Money, comfort or environment? Priorities and determinants of energy efficiency investments in Irish households, J. Consum. Policy 39 (2016) 159–186, https://doi.org/10.1007/s10603-016-9311-2.
[66] G. de Vries, M. Rietkerk, R. Kooger, The hassle factor as a psychological barrier to a green home, J. Consum. Policy 43 (2020) 345–352, https://doi.org/10.1007/s10603-019-09410-7.
[67] J. Palm, Household installation of solar panels: motives and barriers in a 10-year perspective, Energy Policy 113 (2018) 1–8, https://doi.org/10.1016/j.enpol.2017.10.047.
[68] K. Reindl, J. Palm, Installing PV: barriers and enablers experienced by non-residential property owners, Renew. Sust. Energ. Rev. 141 (2021) 110829, https://doi.org/10.1016/j.rser.2021.110829.
[69] D.M. Konisky, J. Milyo, L.E. Richardson, Environmental policy attitudes: issues, geographical scale, and political trust, Soc. Sci. Q. 89 (2008) 1066–1085, https://doi.org/10.1111/j.1540-6237.2008.00574.x.
[70] R. Proudlove, S. Finch, S. Thomas, Factors influencing intention to invest in a community owned renewable energy initiative in Queensland, Australia, Energy Policy 140 (2020) 111441, https://doi.org/10.1016/j.enpol.2020.111441.
[71] R. Yadav, G.S. Pathak, Young consumers' intention towards buying green products in a developing nation: extending the theory of planned behavior, J. Clean. Prod. 135 (2016) 732–739, https://doi.org/10.1016/j.jclepro.2016.06.120.
[72] E. Park, J.Y. Ohm, Factors influencing the public intention to use renewable energy technologies in South Korea: effects of the Fukushima nuclear accident, Energy Policy 65 (2014) 198–211, https://doi.org/10.1016/j.enpol.2013.10.037.
[73] K. Maichum, S. Parichatnon, K.-C. Peng, Application of the extended theory of planned behavior model to investigate purchase intention of green products among Thai consumers, Sustainability 8 (2016) 1077, https://doi.org/10.3390/su8101077.
[74] B. Wu, Z. Yang, The impact of moral identity on consumers' green consumption tendency: the role of perceived responsibility for environmental damage, J. Environ. Psychol. 59 (2018) 74–84, https://doi.org/10.1016/j.jenvp.2018.08.011.

[75] F.N.H. Montijn-Dorgelo, C.J.H. Midden, The role of negative associations and trust in risk perception of new hydrogen systems, J. Risk Res. 11 (2008) 659–671, https://doi.org/10.1080/13669870801967218.
[76] J. Hainmueller, D. Hangartner, T. Yamamoto, T., Validating vignette and conjoint survey experiments against real-world behavior, Proc. Natl. Acad. Sci. USA 112 (2015) 2395–2400, https://doi.org/10.1073/pnas.1416587112.
[77] Statistics Netherlands, Aardgas en Elektriciteit. [Natural Gas and Electricity.]. https://www.cbs.nl/nl-nl/dossier/energieprijzen/aardgas-en-elektriciteit, 2023 (accessed 17 September 2023).