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Transitioning towards sustainable heating: A mixed-methods study of heat pump acceptance among Flemish homeowners

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ABSTRACT

To meet EU climate goals, reducing fossil fuel use is crucial, and transitioning domestic energy consumption to sustainable sources like heat pumps offers a potential solution. However, uptake in Flanders remains low. This study explores predictors of heat pump adoption intention among Flemish homeowners using a mixed-methods approach. A quantitative survey based on an extended Theory of Planned Behaviour model (Study 1, $n = 692$, $M_{age} = 55.03$, $SD_{age} = 15.54$, male/female = 335/357) is complemented by semi-structured interviews with homeowners who do not own a heat pump (Study 2, $n = 16$, $M_{age} = 41$, $SD_{age} = 35$, male/female = 8/8). Study 1 indicates that perceived behavioural control and subjective norms positively influence heat pump adoption intention, with perceived behavioural control enhanced by product knowledge and technological innovativeness. Surprisingly, a positive attitude towards heat pumps is associated with a lower adoption intention. Study 2 reveals cost concerns, uncertainties about energy cost savings and property value increases as barriers to adoption intention, alongside a temporal disconnect between attitude and intention due to practical constraints. Our findings offer suggestions for communication strategies of policy makers such as addressing financial and practical barriers, mitigating practical constraints and enhancing public knowledge. Lastly, our survey results suggest the presence of yet unidentified moderating variables affecting the attitude-intention relationship, which could be determined in future research.

1. Introduction

Heating is the most carbon-intensive sector in the EU [1], making it crucial for reaching the European Green Deal goal of climate neutrality and increasing renewable energy use [2]. In Flanders, the Dutch speaking Northern region of Belgium, the aim is to reduce greenhouse gas emissions (GHGE) with 85 % by 2050 (compared to 2019), replacing fossil fuel (e.g. gas, coal, petroleum) and electric heating systems with sustainable alternatives [3–5]. Heat pumps, which convert energy from an external heat source (air or water) to heat spaces and/or water in dwellings [1], have the potential to reduce GHGE by at least 500 million tonnes by 2030 [6].

Since 2025, extensive energetic renovations and new buildings in Flanders are required to install at least a hybrid heat pump [7]. However, their adoption remains low. While the amount of heat pumps doubled in Belgium in 2021 (11 per 1000 households), this lags behind other European countries like France or Sweden (up to 39 per 1000 households) [8]. The EU's REPowerEU plan aims to double the amount of heat pumps every four years, targeting 60 million heat pumps by 2030 [9]. 72 % of Flemish people are homeowners, but only 17 % of single-family homes comply with an energy label A+, A or B [10,11], and 85 % of Flemish families use natural gas or oil for space heating [12],

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which is higher than the European average of 46 % [13]. Thus, understanding which factors influence Flemish households' decision to install a heat pump is essential. Since both ground source and air/water source heat pumps are used in Flanders [14], this study focuses on all types.

Prior research has been done on barriers and drivers that hinder or stimulate the adoption of renewable energy technologies in general, and heat pumps specifically. The main findings show that financial drivers such as reducing energy costs and value of the investment [15–19], and social influence [16,20–22] play a primary role, as well as environmental awareness [16,19,23] and interest in technologies [23,24]. Key barriers include financial barriers such as the high investment cost [1,16,25–27] and a lack of or uncertainty in financial policies [23,25,27], structural barriers such as installation conditions and the uncertain technical feasibility of heat pumps [15,23,26,27], and psychological barriers such as low awareness and understanding of heat pumps [1,15,16,21,25].

While some studies apply theoretical models such as attitude-behaviour-context theory [18,22,23] or agent-based modelling [20,28], most do not use a psychological framework to predict heat pump adoption intention [15,16,19,25,29]. Only two studies have applied the Theory of Planned Behaviour [26,30], and to our knowledge, none have done so in the context of Flanders.

This research aims at filling this gap by identifying predictors of Flemish homeowners' intention to install a heat pump using a sequential mixed-methods approach [31], with qualitative findings complementing quantitative data [32]. First, we conducted a quantitative study (Study 1) in which an extended version of the Theory of Planned Behaviour (TPB) [33] is tested because of its successful application in prior studies on renewable energy adoption [34–37]. Subsequently, we conducted qualitative semi-structured interviews (Study 2), providing a more comprehensive view.

2. Study 1: Quantitative survey

2.1. Theory of planned behaviour

In study 1, we use Ajzen's TPB [33] to understand what drives intention to install a heat pump. TPB proposes that the intention to perform a behaviour is predicted by three variables: attitude, subjective norms and perceived behavioural control (PBC). Attitude refers to the (un)favourable evaluation of a behaviour that someone can have. Subjective norms relate to the perceived social pressure to (not) perform a type of behaviour. Lastly, PBC refers to the perceived ease or difficulty of performing that behaviour [33].

We propose this behavioural model because of its potential to predict a variety of behaviours across different populations [38], its flexibility to extend it with other variables [38], its successful application in prior studies on renewable energy adoption [34–37] and curtailment behaviour [39], and its generally high explained variance [38,40]. TPB has been applied to research on the diffusion of renewable energy technologies such as photovoltaic (PV) panels, pellet wood stoves and bioenergy [34–37], though its use for heat pumps is limited. In one study, Hu et al. [26] used TPB, but did not account for attitude as a predictor for intention, instead replacing attitude by environmental concern and financial benefit, with only financial benefit being significantly positively associated with intention. A second study by Meles et al. [30] used the TPB constructs in a latent class analysis identifying that 60 % of the population has a positive, 22 % a neutral and 17 % a negative view towards heat pumps.

Considering the three predictors, we assume that this theoretical model will be appropriate to better understand the intention to adopt a heat pump. First, research shows the positive effect of attitude on intention to adopt renewable energy technologies [36,41]. For subjective norms, findings vary by region. In Asia, studies indicate that subjective norms have no or a negative effect on the intention to purchase renewable energy technologies [42,43], while in Europe, subjective norms and neighbour participation are positively associated with the intention to adopt a renewable energy technology [20,34,35,44–46]. Lastly, PBC is found to be a predictor of intention to adopt or pay for a renewable energy system [34,37,42,43].

Based on these studies, we propose the following hypotheses (see Fig. 1):

H1. A positive attitude towards installing a heat pump is positively associated with the intention to install a heat pump.

H2. Positive subjective norms towards installing a heat pump are positively associated with the intention to install a heat pump.

H3. PBC to install a heat pump is positively associated with the intention to install a heat pump.

2.2. Extending the TPB

Although TPB is a robust behavioural model, it has also been criticised for approaching decision-making as a rational process, overlooking other variables influencing complex human behaviour [47,48]. To address this, sustainability research often extends TPB, adding variables such as environmental concern or moral norms to improve explanatory power [49,50]. Based on prior renewable energy research, we selected eight factors: two financial and two ecological factors to predict attitude, one social factor to predict both subjective norms and PBC, and two knowledge factors and one technology factor to predict PBC. Fig. 1 shows the extended model and hypotheses, with the rationale for each factor explained below.

2.2.1. Predictors of attitude

Installing a heat pump can reduce a households' energy use and costs. When someone is aware of how much they spend on household heating [51] and they find it important to reduce energy costs [17,52], this might positively influence their attitude towards heat pumps. Someone's attitude might further be influenced by the prospect of an increase in property value, given that homes with higher EPCs command higher prices in Belgium in the past decade [53]. Research indicates that homeowners who are certain of a return on investment, have a higher intention to do an energy-related renovation [16,20,54]. Additionally, multiple studies show that respondents who are concerned about the environment, are more likely to undertake an energy renovation [55–57] and have a more positive attitude towards renewable energy [35]. Lastly, people with an ecological lifestyle (i.e. attempting to reduce the use of natural resources) are more prone to having a positive attitude towards or installing renewable energy systems [58–60].

Following the above, we hypothesise:

H4. Bill consciousness is positively associated with positive attitudes towards installing a heat pump.

H5. Expectation of property appreciation is positively associated with positive attitudes towards installing a heat pump.

H6. Environmental concern is positively associated with positive attitudes towards installing a heat pump.

H7. Ecological lifestyle is positively associated with positive attitudes towards installing a heat pump.

2.2.2. Predictors of subjective norms

If subjective norms are mostly injunctive norms (i.e. concerned with the perceived social pressures from people in someone's environment to perform a certain type of behaviour [61]), knowing heat pump owners could affect subjective norms, and subsequently someone's intention to install a heat pump. Indeed, research indicates that having neighbours with a renewable energy technology positively affects a person's intention to adopt that technology [34,62] Thus, we hypothesise:

H8. Heat pump ownership in the social network is positively

Fig. 1. Extended theory of planned behaviour model.

associated with positive subjective norms towards installing a heat pump.

2.2.3. Predictors of perceived behavioural control

Having knowledge about heat pumps in specific could make people feel more capable of installing one. Research shows that knowledge of green products is positively associated with PBC to buy them [63], and that renewable energy knowledge is positively associated with perceived ease of use of renewable energy technologies [42]. Additionally, since installing a heat pump is often part of a renovation project, renovation knowledge could influence adoption intention. Studies show that renovation knowledge is an important predictor for the uptake of renewable energy systems [51,52], and renovation knowledge has a positive effect on PBC to undertake an energy-efficiency renovation [54]. Moreover, someone's sense of capability can be influenced by their social environment, i.e. a social network offering trustworthy information sources [64]. Lastly, since heat pumps are a renewable energy technology, technological innovativeness can influence homeowners' decision. Research shows that technology awareness has a significant effect on the intention to install PV panels [65]. Technological innovativeness is also positively associated with PBC in research on renewable energy communities [44]. Following this, we hypothesise:

H9. Heat pump ownership in the social network is positively associated with PBC to install a heat pump.

H10. Product knowledge is positively associated with PBC to install a heat pump.

H11. Renovation knowledge is positively associated with PBC to install a heat pump.

H12. Technological innovativeness is positively associated with PBC to install a heat pump.

2.3. Methods

2.3.1. Sample description and procedure

An online survey was distributed in March 2023 among Dutch-speaking Flemish adults through a recruitment agency, using non-probability quota sampling, representative for age, gender and education. Participants, recruited from a panel of 15,000 consumers who signed up to participate in scientific studies, were assured anonymity and privacy, and the right to withdraw from the study. No personal details were collected. Eligibility criteria for the analysis included a) being +18 years, b) being a homeowner, and c) not owning a heat pump.

Our initial sample included 1746 participants. After excluding participants who did not accept the informed consent or failed the control question, 1045 remained. Of these, 692 participants (66.22 %) met the eligibility criteria, slightly below Flanders' 72 % homeownership rate [10], but exceeding the recommended minimum of 500 for SEM analysis [66]. Table 1 summarizes the socio-demographic information of the final sample. Most respondents completed upper secondary education and were employed full- or part-time. Most participants lived with a partner without children, and in a single-family detached house. Nearly half of our sample had recently renovated their home.

2.3.2. Ethics

The research adhered to the ethical guidelines set by the American Psychological Association. The study protocol received approval from the Ethics Committee of the Faculty of Political and Social Sciences at Ghent University (2020–35: NUDGE). Our research setup and hypotheses were registered in advance of the study's initiation and are available for review at: https://osf.io/u7y28/. Additionally, our data and model specifications are also publicly accessible.

2.3.3. Measures

2.3.3.1. Socio-demographics and dwelling composition. We first collected socio-demographic data, including participants' age, gender, and education level. Participants were asked to indicate their household type and household size by age group (children under 14, children/teenagers between 14 and 19, adults between 20 and 64, and adults over 65). Participants reported their primary occupation and household's average monthly net income, with options ranging from 'below 501 euros' to 'above 7000 euros', in 500 euros increments, and the choices 'no answer' or 'I don't know'.

Subsequently, we examined dwelling characteristics. Participants identified their housing status (own, rent, or live for free), house type and surface area (ranging from <20 m^2 to >400 m^2, with intermediate options). Participants indicated whether and when major energy-saving renovations occurred, their primary heating energy source (fuel oil, wood, pellets, district heating, heat pump, solar, gas, electricity, other), and renewable energy systems used (none, solar panels, solar water heating, heat pump(s), biomass heating system, other). Lastly, as not everyone knows the exact EPC score of their homes, participants estimated their EPC on a ratio scale (1 - 'very energy-efficient, low energy costs', 100 - 'not at all energy-efficient, high energy costs'). Table 1 provides an overview of all items.

Table 1
Demographic characteristics of our sample.

Characteristic		$n = 692$	Mean	SD
Age			55.03	15.54
Gender	Male	335 (48.41 %)		
	Female	357 (51.59 %)		
OECD transformed income			2522	1234.22
Education	Lower education	79 (11.42 %)		
	Upper secondary	332 (47.98 %)		
	Bachelor	183 (26.44 %)		
	Master+	98 (14.16 %)		
Occupation	Employed (full- or halftime)	331 (49.18 %)		
	Self-employed/freelance	20 (2.89 %)		
	Student/intern	5 (0.72 %)		
	Housewife/−man	20 (2.89 %)		
	Seeking work/temporary leave/unable to work	33 (4.77 %)		
	Retired	259 (37.43 %)		
Household	Single person	120 (17.34 %)		
	Single parent with 1 or more children	109 (15.75 %)		
	Couple without children	233 (33.67 %)		
	Couple with 1 or more children	201 (29.05 %)		
	Living with parents	28 (4.05 %)		
Home type	Single-family detached house	257 (37.14 %)		
	Single-family semi-detached house	172 (24.86 %)		
	Single-family terraced house	162 (23.41 %)		
	Apartment in a multi-family house	101 (14.59 %)		
Recent renovation	Yes (before 2018 or unknown date)	320 (46.25 %)		
	Recent (2018 or later)	174 (25.14 %)		
	No	198 (28.61 %)		

2.3.3.2. Theory of planned behaviour variables. Next, we gauged the TPB constructs, which were operationalised following Ajzen [33] and similar studies in the field [54,67]. They were subsequently adapted to fit the context of the present study. We used a five-point Likert scale (1 - totally disagree, 5 - totally agree) to measure agreement for all items, unless stated differently.

Table 2 provides an overview of all measured constructs. Since both ground source and air/water source heat pumps are used in Flanders [14], the term "heat pump" encompasses all types.

We measured *intention to install a heat pump* through four items, with an example item being: 'I am planning to have a heat pump installed'.

To assess *attitudes* towards installing a heat pump, we used a four-item five-point semantic differential scale, with item 1: '1 – bad, 5 – good', item 2: '1 – not beneficial, 5 – beneficial', item 3: '1 – a bad idea, 5 – a good idea' and item 4: '1 – detrimental, 5 – not detrimental'.

Subjective norms were measured using three items, with an example item being: 'Most people important in my life would approve of me getting a heat pump'.

To measure *perceived behavioural control*, we used two items, an example being: 'If I wanted to, I could have a heat pump installed'.

Table 2
Overview of all latent constructs and measured variables, with factor loadings, Cronbach's Alpha, Mean and SD. For all latent constructs, we use at least three-item constructs as recommended [73], except for PBC.

		Factor loadings	Cronbach Alpha	Mean	SD
Intention to install a heat pump			0.93	2.62	0.97
BI_1	I am planning to have a heat pump installed	0.78			
BI_2	I want to make my house more sustainable by having a heat pump installed	0.80			
BI_3	There is a chance that I will install a heat pump in the future	0.95			
BI_4	It is possible that I will install a heat pump	0.95			
Attitude – For me, installing a heat pump is			0.93	3.11	1.47
ATT_1	Bad – good	0.90			
ATT_2	Not beneficial – beneficial	0.79			
ATT_3	A bad idea – a good idea	0.93			
ATT_4	Detrimental – not detrimental	0.86			
Subjective norms			0.89	3.66	0.81
SN_1	Most people important in my life would approve of me getting a heat pump	0.79			
SN_2	I think most people who are important in my life would have no problem with me buying a heat pump	0.90			
SN_4	I am confident that the individuals who matter most to me would have no issue with me investing in a heat pump	0.90			
Perceived behavioural control			0.86	3.13	1.13
PBC_1	I have the financial means to have a heat pump installed	0.77			
PBC_2	If I wanted to, I could have a heat pump installed	0.98			
Bill consciousness			0.80	4.13	0.63
FIN_CONCERN_1	I pay attention to energy-saving tips to reduce my electricity bills	0.68			
FIN_CONCERN_2	I keep track of my (monthly) electricity bills	0.75			
FIN_CONCERN_3	I am motivated to keep my (monthly) electricity costs under a reasonable amount	0.87			
Expectation of property appreciation			0.94	3.14	0.85
CoP_1	Investing in a heat pump will result in a profit due to the appreciation of my home's value	0.86			
CoP_2	Installing a heat pump will pay off in the long run as my home's value increases	0.95			
CoP_3	A heat pump is a wise investment, as it will lead to a financial gain through an increase in the value of my home	0.94			
Environmental concern			0.78	3.77	0.74
ENV_CONCERN_1	Humans are severely abusing the environment	0.77			
ENV_CONCERN_2	I would be willing to reduce my energy consumption to help protect the environment	0.69			
ENV_CONCERN_3	Major political change is necessary to protect the natural environment	0.76			
Ecological lifestyle			0.72	3.83	0.67
EL_1	The current civilization is destroying nature	0.74			
EL_2	I prefer energy-saving products	0.52			
EL_4	I worry about the human activity consequences on the climate change and act consistently	0.84			
Product knowledge			0.90	2.04	0.91
PK_1	I am very familiar with heat pumps	0.87			
PK_2	I often learn about heat pumps through articles or news	0.81			
PK_3	I know a lot about heat pumps	0.93			
PK_4	I actively look for information about heat pumps	0.70			
Renovation knowledge: How would you describe your knowledge about renovation. In other words, how much do you know about			0.94	2.30	0.89
RK_1	Products and materials to renovate	0.85			
RK_2	Renovation costs	0.87			
RK_3	Services offered by renovation contractors	0.86			
RK_4	Improving energy efficiency through renovation	0.91			

(*continued on next page*)

Table 2 (*continued*)

		Factor loadings	Cronbach Alpha	Mean	SD
RK_5	Financial support measures for renovations	0.81			
RK_6	How renovation affects the market value of homes	0.81			
Technological innovativeness			0.84	2.42	0.88
TI_1	Other people come to me for advice on new technologies	0.83			
TI_2	In general, I am among the first in my circle of friends to acquire new technology when it appears	0.82			
TI_3	I can usually figure out new high-tech products and services without help from others	0.65			
TI_4	I keep up with the latest technological developments in my areas of interest	0.70			

2.3.3.3. Extending the TPB. To measure the additional variables, we relied on validated scales, adapted to the context of installing a heat pump. If no validated scales were available, new items were created. For all questions, we used a five-point Likert scale (1 – totally disagree, 5 – totally agree), unless otherwise specified.

We measured *bill consciousness* using a validated three-item scale [68], with an example item being: 'I keep track of my (monthly) electricity bills'.

We measured *expectation of property appreciation* using a self-developed three-item scale. An example item is: 'Installing a heat pump will pay off in the long run as my home's value increases'.

We measured *environmental concern* using a three-item scale [69], with an example item being: 'Humans are severely abusing the environment'.

Ecological lifestyle was measured by combining items from [58] with items from [60], resulting in a four-item scale. An example item is: 'I prefer energy-saving products'.

Heat pump ownership in the environment was gauged with a yes/no statement: 'Someone close to me, including one of my neighbours, family members, friends or co-workers, already owns a heat pump'.

Product knowledge was measured using a four-item scale [70], with an example item being: 'I am very familiar with heat pumps'.

We measured participants' general r*enovation knowledge* using a six-item scale [52] asking them "how would you describe your knowledge of…" followed by six renovation aspects. Participants had to answer on a five-point Likert scale (1 – very little knowledge, 5 – a lot of knowledge). An example item is: 'Services offered by renovation contractors'.

Lastly, we assessed *technological innovativeness* using four items from the Technology Readiness Index (TRI) [71], with an example item being: 'Other people come to me for advice on new technologies'.

All items were translated into Dutch through a back-translation approach [72]. The initial translations from English to Dutch were translated back to English by an independent researcher, comparing for accuracy with the original item, until a satisfactory translation was reached.

2.3.4. Analytic strategy

For descriptive and preliminary analyses, we used Pearson's correlations, one-way ANOVAs and Welch *t*-tests. To test our behavioural model, we used Structural Equation Modelling (SEM), which integrates multiple dependent and independent variables in one model [74]. Following Anderson & Gerbing's approach [75], we removed items with factor loadings below 0.4, identifying whether our latent variables were reflected in our observed variables. We applied error covariance between items if similar phrasing was present and it was suggested based on the modification indices. We used Jeffreys's Amazing Statistics Program (JASP) for our analyses [76]. Given that our data was not normally distributed, we used maximum likelihood estimation with robust standard errors and a mean- and variance-adjusted test statistic, which compensates for non-normality and unequal variance [77].

Model fit was evaluated using the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the Tucker-Lewis Index (TLI). Following guidelines by Byrne [78], Schreiber et al. [79] and Bentler and Bonett [80], CFI values above 0.95 denote a good fit, and above 0.9 an acceptable fit. TLI values above 0.95 indicate a good fit. RMSEA values under 0.05 are considered a good fit, and values between 0.06 and 0.08 an acceptable fit. Given our sample size, we established our significance threshold at $p \leq 0.01$.

The necessary sample size for SEM depends on multiple elements such as the desired power and the number of indicators and pathways that are involved [81]. With a sample size of 692, our study exceeds the recommended minimum of 500 [66].

2.4. Results

2.4.1. Preliminary analysis

As shown in Table 2, the level of intention to install a heat pump was rather low, with an average score of 2.622 (on a five-point scale). Welch's *t*-test revealed no significant differences between men and women ($t(689) = -0.607$, $p = 0.544$) with regards to intention. Pearson's correlation showed that age was significantly negatively correlated with intention ($r = -0.304$, $p < 0.01$). A one-way ANOVA demonstrated that intention differed significantly between education levels ($F(3) = 11.697$, $p < 0.01$). Tukey post hoc tests revealed that participants with a lower education have a significantly lower intention to install a heat pump ($M = 2.149$, $SD = 0.979$) than people with a bachelor's ($M = 2.766$, $SD = 0.896$) or a master's degree or PhD ($M = 2.923$, $SD = 0.957$). One-way ANOVAs indicated no significant differences between house types ($F(3) = 2.120$, $p = 0.096$) and between recent renovation periods ($F(6) = 0.164$, $p = 0.986$) for intention. Lastly, a significant negative correlation between subjective EPC and intention was found ($r = -0.106$, $p < 0.01$), with persons reporting a higher EPC having a lower intention. We thus proceed with the inclusion of age, EPC and education level as co-variates in our SEM analysis, regressed on intent.

2.4.2. Measurement model

To assess whether our observed variables loaded significantly on our latent variables, we performed a confirmatory factor analysis. The initial model fit was satisfactory with RMSEA = 0.059, CFI = 0.912 and TLI = 0.901. After removing the observed variables with factor loadings below 0.4 (EL_3, PBC_3 and SN_3) and allowing correlated residuals between similarly phrased items (BI_3 and BI_4, TI_3 and TI_4, PK_1 and PK_3 and SN_2 and SN_4), our model fit increased with RMSEA = 0.045, CFI = 0.955 and TLI = 0.949. Our results showed that all constructs were significantly associated with intention to install a heat pump, except financial concern, as presented in Table 3. All factor loadings were satisfactory, the lowest factor loading being 0.520 for EL_4.

2.4.3. Pre-registered structural equation model

The model fit of our pre-registered model, provided in Fig. 2, was acceptable with RMSEA = 0.053, CFI = 0.918 and TLI = 0.910.

Table 3
Pearson correlation matrix of our latent constructs.

	1	2	3	4	5	6	7	8	9	10
Behavioural Intention (1)	1									
Attitude (2)	−0.45**	1								
Subjective norms (3)	0.43**	−0.54**	1							
Perceived behavioural control (4)	0.32**	−0.16**	0.22**	1						
Renovation knowledge (5)	0.12*	−0.03	0.04	0.17**	1					
Product knowledge (6)	0.36**	−0.07	0.14**	0.27**	0.56**	1				
Expectation of property appreciation (7)	0.45**	−0.57**	0.39**	0.14**	0.13**	0.19**	1			
Technological innovativeness (8)	0.24**	−0.07	0.16**	0.26**	0.44**	0.54**	0.14**	1		
Environmental concern (9)	0.22**	−0.29**	0.26**	0.15**	0.09	0.07	0.29**	0.13**	1	
Ecological lifestyle (10)	0.23**	−0.26**	0.24**	0.18**	0.11*	0.13**	0.31**	0.16**	0.80**	1
Financial concern (11)	0.08	−0.06	0.14**	0.01	0.21**	0.15**	0.15**	0.18**	0.35**	0.39**

* $p \leq 0.01$;
** $p \leq 0.001$.

Regarding the control variables, age ($\beta = -0.209$, $p < 0.001$) was significantly negatively associated with intention. EPC ($\beta = -0.003$, $p = 0.927$) failed to reach a statistically significant association with intention. Additionally, intention to install a heat pump was not significantly different between participants with an upper secondary degree ($\beta = 0.036$, $p = 0.530$), bachelor's degree ($\beta = 0.062$, $p = 0.269$), and master's degree ($\beta = 0.047$, $p = 0.335$), with lower education as a reference category.

Contrary to H1, in which we expected a positive association between attitude and intention, analysis revealed a significant negative association ($\beta = -0.405$, $p < 0.001$) between both constructs. Subjective norms were significantly positively associated with intention with the threshold of $p \leq 0.01$ ($\beta = 0.108$, $p = 0.013$), accepting H2. There was also a significant positive association between PBC and intention ($\beta = 0.280$, $p < 0.001$), confirming H3.

Regarding the extended constructs of TPB, we found that bill consciousness was not significantly associated with attitude ($\beta = 0.118$, $p = 0.015$), rejecting H4. Contrary to H5, our results showed a significant negative association ($\beta = -0.533$, $p < 0.001$) between expectation of property appreciation and attitude. Both environmental lifestyle and environmental concern failed to reach statistical significance, leading to the rejection of H6 ($\beta = 0.546$, $p = 0.212$) and H7 ($\beta = -0.736$, $p = 0.100$). H8 anticipated a positive association between heat pump ownership in someone's social network and subjective norms, but analysis revealed a significant negative association ($\beta = -0.094$, $p = 0.009$). We did not find a significant association between heat pump ownership in someone's social network and PBC, rejecting H9 ($\beta = -0.079$, $p = 0.039$). Consistent with H10, results showed a positive significant association between product knowledge and PBC ($\beta = 0.216$, $p = 0.001$). The association between renovation knowledge and PBC was not significant ($\beta = -0.059$, $p = 0.259$), rejecting H11. Lastly, we found support for H12, with technological innovativeness being significantly positively associated with PBC ($\beta = 0.182$, $p = 0.002$). Explained variance for intention is 31.5 %, and for attitude 35.4 %. We have low explained variance for subjective norms (0.9 %) and PBC (11.3 %).

2.4.4. Post-hoc analyses

We found negative associations between attitude and intention, expectations of property appreciation and attitude, and heat pump ownership in the environment and subjective norms, contrary to H1, H5 and H8 respectively. Therefore, we examined these results in more detail. It might be that positive attitudes towards heat pumps may not lead to a high intention to install one because of recent energy-efficiency renovations, financial constraints or dwelling type limitations.

To test these post-hoc hypotheses, we repeated our pre-registered analysis with the inclusion of three new variables: home type, recency of renovation and OECD transformed income. For OECD transformed income, we recoded the categorical variables by taking the mid-point for each category, following Ponnet et al. [82]. We took into account household size and age of household members [83], dividing the household salary by a weighted size of the household, assigning weights of 1 to the household head, 0.5 for members older than 14 and 0.3 for children younger than 14.

The resulting model indicated satisfactory fit with RMSEA = 0.049, CFI = 0.939 and TLI = 0.934. We found a slight reduction in the strength of association between attitude and intention ($\beta = -0.384$, $p < 0.001$). None of the newly included variables (house type, recency of renovation, OECD transformed income) were significantly associated with intention. Explained variance for intent (34.5 %), attitude (29.2 %), subjective norms (0.9 %) and PBC (10 %) were in line with the explained variance of the preregistered model.

3. Study 2: Semi-structured interviews

After analysing the survey results, we conducted semi-structured interviews with homeowners to explore the counterintuitive survey results. We pre-registered our research aims, questions and approach, and interviews were held in early December 2023 at a public library. Participants were sourced from library visitors and the author's network, ensuring none were part of study 1. Eligibility criteria included a) being 18+ years and b) being a homeowner. Before participating, interviewees signed an informed consent, guaranteeing confidentiality and anonymisation of all information. Each interview lasted 10–15 min, was recorded and accompanied by note-taking. In total, 16 people (8 men, 8 women) participated, aged 27 to 72 ($M_{age} = 41$, $SD_{age} = 35$). Fifteen participants lived in single-family homes, and one in an apartment. All participants, except one, did not have a heat pump installed.

The interview guide, informed by the survey results and the literature review, began with questions about home purchase timing and renovation history. Subsequently, participants rated their attitude towards heat pumps, using the four-item semantic differential scale used in the survey. This was followed by open-ended questions about motivations to (not) install a heat pump, focusing on perceived barriers such as installation costs or uncertainty of energy savings. Lastly, we assessed the influence of the social network in decision-making. Participants generally had a positive attitude towards heat pumps as a renewable energy technology, but various barriers prevented adoption, which we will address below.

One recurring barrier was installation costs. Most participants ($n = 11$) mentioned that installing a heat pump is a big investment competing with other renovation priorities. One participant mentioned: "we were doing a complete renovation, and we were looking for elements where we could save some money" (woman, 32). Subsequently, installing a heat pump is often pushed to the future, using the available budget for less expensive interventions.

Additionally, most participants ($n = 10$) found it hard to estimate whether the investment would pay off in terms of energy cost savings and increased property value. The efficiency of a heat pump depends on varying factors such as electricity and gas prices and the degree of insulation in the home. One participant mentioned that she was

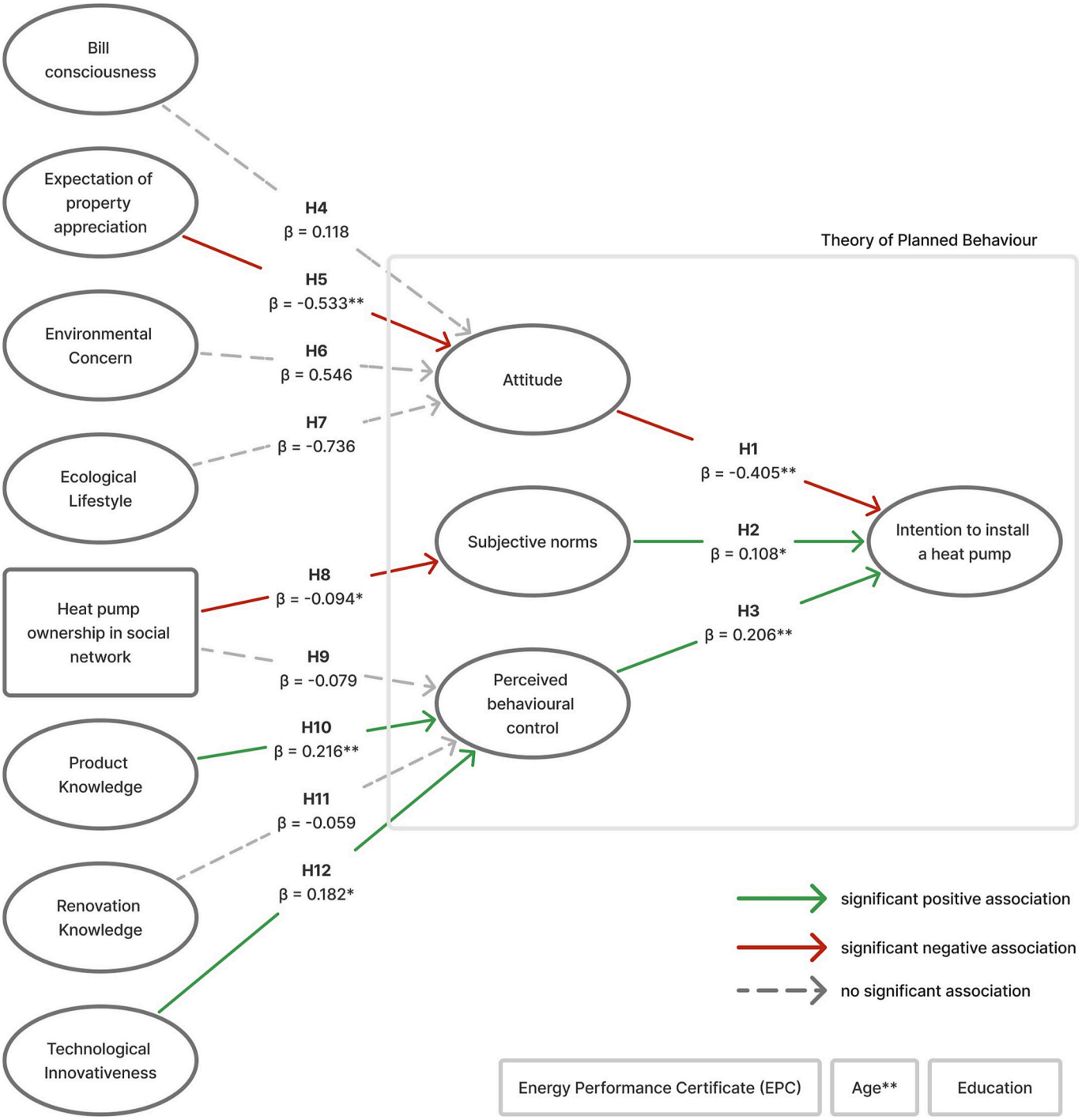

Fig. 2. Results from SEM analysis (RMSEA = 0.053, CFI = 0.918 and TLI = 0.91, $p \leq 0.01$ *, $p < 0.001$ **).

"uncertain whether it would be worth the investment" (woman, 30). Due to relatively low gas prices at the time of the interviews, some participants doubted they would save enough on their energy bills. One remarked, "right now it seems like a crazy investment because we (…) have a relatively low consumption" (woman, 30). Additionally, older participants ($n = 2$) mentioned that they would not live long enough to see a return on investment. One mentioned: "I don't have a family anymore, I don't heat my bedrooms (…) a heat pump does not pay itself back, it is just a serious cost" (woman, 72).

Structural limitations of the home also created significant challenges. For most participants ($n = 10$) a heat pump did not seem compatible with their dwellings. Specifically, participants living in smaller houses in an urban environment mentioned space constraints and heritage protection rules. A participant mentioned for example that "your house needs to be well insulated for a heat pump and I cannot insulate my front façade because it is part of the city view" (man, 40). Additionally, having neighbours with a heat pump influenced another participant to not install one, because of the noise disturbance: "Our neighbours have a heat pump on their roof, and it is not pleasant if we are sitting outside or the windows are open" (woman, 42).

Half of the participants ($n = 8$) believe that a heat pump installation requires additional interventions: "My house needs to be insulated better and I don't have double glazing yet", one participant mentioned (man, 65). Many participants wanted to tackle other renovations before

thinking about the installation of a heat pump, but as a participant added, the interventions were chosen with a heat pump in mind: "Our renovations now are really focusing on the insulation (…), and then it will be easier to install a heat pump" (man, 34).

Generally, participants had low knowledge of heat pumps, with one participant stating that he "wouldn't really know how it works" (man, 65). Five participants mentioned that they relied on an intermediary such as an architect to make the decision. These intermediaries often dissuaded them or dismissed heat pumps as an option. This could be linked to the lack of knowledge, as mentioned by another participant: "The architect decided it a bit for us, we trusted his experience that it was not the best option" (woman, 32).

Lastly, some participants ($n = 3$) indicated that it was just not the right time. Either their current energy system is still working fine, or heat pumps were not mature enough at the time of renovation. One participant mentioned: "My condensing boiler is already pretty frugal, so why should we switch to a heat pump?" (man, 27).

4. Discussion

This study aims to better understand the intention to install a heat pump using an extended TPB model. We investigated the association between on the one hand subjective norms, attitude and PBC, along with bill consciousness, expectation of property appreciation, environmental concern, ecological lifestyle, heat pump ownership, product knowledge, renovation knowledge and technological innovativeness, and on the other hand intention to install a heat pump. Our model explained 31.5 % of intention, which is slightly below the explained variance of similar work on pro-environmental behaviour (44.3 %) [84] and on the adoption intention of PV systems (between 29 % and 42 %) [64,85].

4.1. Findings and policy recommendations

Our findings confirmed the positive association between PBC and subjective norms and intention. However, the negative association between attitude and intention presents a theoretical challenge, as it is counterintuitive compared to previous research on renewable energy systems [35,45].

The interviews revealed that the installation cost of heat pumps significantly influences the decision-making process, outweighing the positive attitudes, a finding consistent with prior studies [16,26,27]. The survey results also indicated a negative association between expectation of property appreciation and attitude. People who are aware of the impact of a heat pump on their property value, have a more negative attitude. Interviewees suggested that this could be because it is difficult to estimate both the energy cost savings and the property value increase, as the economic advantage of a heat pump depends on the fluctuating costs of electricity and alternative heating sources [86,87]. Consequently, multiple interviewees regarded heat pumps as acceptable renewable energy technologies, but planned to install them at a later stage, indicating a temporal disconnect between attitude and purchase decision. Indeed, earlier studies highlighted perceived unpredictability of low-carbon technologies as a factor causing an intention-behaviour gap [88,89].

Furthermore, the interviews revealed that practical constraints and low awareness of the work necessary for preparing a home could temper positive attitudes, confirmed by previous studies [26,27]. Constraints such as space limitations, compatibility issues with existing home systems and anticipated installation challenges, led homeowners to prioritize less expensive preparatory interventions. Michelsen and Madlener [24] also found that homeowners prefer to maintain the status quo, fearing disruptions to their routines that come with switching to renewable energy.

Additionally, survey results indicated a relatively low mean attitude score and mean intention score, suggesting a neutral or moderately negative attitude and intention among most respondents. This suggests the potential influence of an unmeasured moderating variable on the association between attitude and intent, such as subsidy availability. During the study period, the Flemish government offered subsidies for heat pump installation under specific conditions (i.e. it being the sole heating source and meeting a minimum installation cost of 10,000 euros). Another possible moderating variable is PBC. Even with a positive attitude towards heat pumps, feelings of uncertainty and lack of control over the installation process might diminish the association between attitude and intention. Policy makers could leverage these insights in communication by using the barriers identified in the interviews as focal points in communication campaigns. For instance, campaigns could address the financial and practical barriers by providing clear and hands-on information on available subsidies and the home requirements for installing a heat pump. Additionally, mitigating practical constraints through - for example - support programs could further lower the threshold for potential adopters.

In addition, our survey results revealed a significant association between subjective norms and intention, consistent with other studies [21,26,42,90]. However, this association was weaker than that of PBC and attitude with intention. This indicates that the perceived approval of people within one's network is not a dominant predictor of adoption intention. One explanation could be that heat pumps are less visible than e.g. solar panels, making social influence less impactful. Moreover, the survey results indicated that knowing someone with a heat pump in your environment is negatively associated with subjective norms towards installing a heat pump. This could be related to issues such as noise disturbance, as mentioned by one interviewee. Thus, policy makers should leverage subjective norms strategically, promoting positive experiences from early adopters who can act as a group of pioneers, building public trust [20,21].

Lastly, the survey results revealed a significant positive association between PBC and adoption intention, consistent with other studies [42,90], and a positive association between product knowledge, technological innovativeness and PBC. Multiple interviewees mentioned the importance of knowledge, saying that the lack of knowledge on heat pumps dissuaded them from installing one. This is in line with prior studies showing that product knowledge facilitates the adoption of renewable energy sources [16,42] and a lack of knowledge hinders heat pump diffusion [21,24]. Moreover, because of this lack of knowledge, interviewees based their decision on the opinion of intermediaries such as architects. Therefore, policy makers could focus on highlighting the ease of installing heat pumps and enhancing public knowledge, both by distributing clear and accessible information as well as educating intermediaries such as architects, to become reliable information sources.

4.2. Limitations and conclusion

There are some limitations to consider when interpreting the results of this study. First, our survey sample is not fully representative of the Flemish population, making it hard to draw any conclusions on people's absolute intention to install a heat pump. Additionally, our interview sample for study 2 consisted almost exclusively of people living in an urban environment without a heat pump. To gain a more extensive understanding of motivations, future studies could include homeowners from different environments that own a heat pump.

Second, this study used a cross-sectional approach focusing on adoption intention as an outcome variable, making it difficult to draw conclusions concerning the causal pathways predicting the actual adoption rate of heat pumps. Additionally, we must consider the influence of confounding variables at the time of data collection, such as the fact that the gas and electricity prices at the time of the interviews did not favour heat pumps. To test the pathways in the decision-making process and to draw conclusions on actual adoption behaviour, a longitudinal study should be implemented.

While most constructs are three-item constructs, which are preferred to assure the validity of constructs [73], we applied a two-construct

measure for PBC. Moreover, in our post-hoc analysis, we only included OECD-adjusted household income. However, we did not take into account subjective social status and perceived financial comfort. Including these variables in future research might offer a more nuanced perspective on the perceived high costs of installing a heat pump, and impact the association between PBC and intention.

Lastly, the explained variance of TPB to predict intention to install a heat pump is slightly lower than comparable studies in this domain [64,84,85], meaning that TPB might be too limited to predict this type of high-impact sustainable behaviour. Future research could delve into identifying variables that moderate the relationship between attitude and intention, or could turn to other behavioural models to see how they might be complementary or more fitting to predict heat pump adoption intention.

Despite these limitations, this study provides key insights into the behavioural predictors of homeowners' intention to install a heat pump, using an extended TPB model. Results reveal that PBC and subjective norms positively affect adoption intention, with PBC being enhanced by product knowledge and technological innovativeness. Surprisingly, a positive attitude towards heat pumps is associated with a lower adoption intention. Interviews with homeowners revealed that cost concerns, uncertainty of energy cost savings and increases of property value, and practical constraints like limited space and additional renovations contribute to a temporal disconnect between attitude and purchase decision. Policy makers should focus on addressing financial and practical barriers, providing clear and accessible information on available subsidies and home preparation requirements, as well as leveraging subjective norms strategically and enhancing public knowledge, both with homeowners and intermediaries.

CRediT authorship contribution statement

Emma Martens: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Sofie Naeyaert:** Writing – review & editing. **Stephanie Van Hove:** Writing – review & editing. **Sabine Pelka:** Writing – review & editing. **Sabine Preuß:** Writing – review & editing. **Marta Gabriel:** Writing – review & editing. **Peter Conradie:** Writing – review & editing, Supervision, Methodology, Formal analysis, Data curation. **Koen Ponnet:** Writing – review & editing, Supervision, Methodology.

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.

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